MWDSI

MIDWEST DECISION SCIENCES INSTITUTE

2024 Midwest Decision Sciences Institute Conference

Hosted by Youngstown State University

April 12-13, 2024

Innovation and Adaptation:

Navigating Change in the Dynamic Business World

Conference Co-Chairs

Jeong Hoon Choi, Youngstown State University

Alina Marculetiu, Youngstown State University

Sebastian Brockhaus, Cleveland State University

Hongjiang Xu, Butler University

YOUNGSTOWN STATE UNIVERSITY

Williamson College of Business Administration

Table of Contents

Abstracts

The Effect of Supply Chain Disruptions on Business Post COVID19

Ceyhun Ozgur[1], Katia Fedor[1], Addy Kois[1], Ethan McFarland[2]

[1]Valparaiso University, Valparaiso, USA. [2]Valparaiso University, Valparaiso, USA

Abstract

There are many reasons for experiencing supply chain disruptions. The reasons could be miscommunication between the factory and the warehouse, miscommunication between the warehouse and the stores, or miscommunication between the stores and the customers. We investigated these possible disruptions throughout this paper with the help of a questionnaire. We further investigated the effect of various problems that may occur with the company stock which resulted in supply chain disruptions. There have been many papers written about the effect of the disruptions regarding these problems. With the goal of finding out the tactical approach from the company affects the value of the stock, we investigated this further. We looked at the relationship between amount of inventory and company stock price. In terms of inventory, this paper looks at how this shortage and overage effects the supply chain. We also looked at the accuracy of the forecasting method and its effect on the supply chain. Additionally, this paper examined the nature of the tactical standings of the company and the effects on supply chain disruptions and the position of the company stock. Based on the responses to the questionnaire, we found how the tactical elements affect the supply chain disruptions. We also showed the effect of the supply chain disruptions on the company stock.

A new era for RFID in supply chain management

Qiannong Gu[1], Pedro Reyes[2]

[1]Ball State University, Muncie, USA. [2]Baylor University, Baylor, USA

Abstract

The integration of RFID with other technologies like IoT (Internet of Things) and AI (Artificial Intelligence) has further expanded its applications, making it a key component in smart systems and automation across industries. Its use continues to grow as businesses seek to improve efficiency, accuracy, and security in their operations. This research reviews the recent use of RFID in the context of supply chain management. Despite its initial introduction to both professional and academic sectors about 20 years ago, the utilization of RFID in supply chains continues to grow. The merging of RFID system data with other advanced technologies has further enhanced its potential. A fresh examination of RFID's current state not only sheds light on the usual pattern of new technology adoption in the corporate sector but also opens avenues to investigate strategies for maximizing technology investment returns.

Escape ROOM?!? Try Escaping the Building…

Lori Koste

Grand Valley State University, Grand Rapids, MI, USA

Abstract

An Escape Room experience can be frantic, frustrating, exciting, confusing and exhilarating. Imagine invoking those emotions over a larger experience. Instead of a single room, now students must escape the entire School of Business. This paper discusses a cross-curriculum effort to incorporate the drama and fun of an escape room in a larger format. The concept of an Escape Room is applicable individually or on a group basis. Further, the approach is implemented in a learning management system (bb ultra) so can support assessment for competency-focused education.

Integrating Experiential Learning into Accounting Education: A Pedagogical Approach to Practical Tax Preparation

Robert Patterson[1], Kathleen Noce[2]

[1]Penn State Erie, Erie, USA. [2]Penn State University, Erie, USA

Abstract

In accounting education, bridging the gap between theoretical knowledge and practical application remains an ongoing challenge. This presentation introduces an innovative pedagogical strategy designed to enhance the learning experience of accounting students through applied projects centered on tax preparation. Utilizing fictitious scenarios that mirror real-life situations, the approach engages students in the comprehensive process of preparing annual taxes, thereby applying all they are learning in the course.

Grounded in the principles of Experiential Learning and Situational Learning Theory, this method emphasizes active participation, problem-solving, and critical thinking. Students navigate through complex, authentic tasks that simulate the responsibilities of accounting professionals, fostering not only a deeper understanding of tax laws and regulations but also enhancing their analytical and decision-making skills.

This presentation will detail the implementation of this approach within an accounting class, discussing the development of fictitious scenarios, the integration of theoretical concepts with practical application, and the pedagogical outcomes observed. It will also explore the alignment of this teaching method with current pedagogical theories, highlighting its potential to serve as a model for experiential learning in accounting education.

The objective of this presentation is to share insights on effective teaching strategies that prepare accounting students for the complexities of real-world tax preparation scenarios, thereby contributing to innovative education practices in the field of accounting. We aim to demonstrate how applied projects can not only enhance student engagement and learning outcomes but also equip future accounting professionals with the necessary skills to navigate the challenges of the profession.

Food Banks: Beyond Donations

Ryan Atkins

Duquesne University, Pittsburgh, USA

Abstract

Food banks serve a vital role in distributing food to individuals facing food insecurity. The focus on donations as the source of food in previous research paints food banks as passive recipients, whereas they may take on an active role in incentivizing donations. Similarly, at the distribution end, food banks may take an active role in drawing in and educating clients. Through multiple case studies, this research identifies innovative practices utilized by food banks, as well as outcomes such as superior nutritional options for clients, more effective matching of supply and demand, and minimization of food waste.

Applying ChatGPT to enhance the resume screening

Xiaoguang Tian

Purdue University Fort Wayne, Fort Wayne, USA

Abstract

Human Resources (HR) professionals encounter significant obstacles in leveraging resources to enhance business processes and outcomes with emerging analytical technologies. Drawing from recent research utilizing artificial intelligence (AI) and machine learning methodologies, this study focuses on optimizing the employee selection process. The research aims to offer HR professionals more precise insights into recommendation outcomes. Additionally, this paper introduces the novel use of ChatGPT in addressing critical unsupervised learning challenges within the business domain. By synthesizing empirical findings and practical applications, the study provides actionable insights for HR professionals navigating the complexities of modern workforce management.

Anglophone Supremacy in Global Accountancy and A Discussion on How International Candidates Can Become a Certified Public Accountant (CPA) from the United States

Recep Pekdemir, William Maas

University of Wisconsin La Crosse, La Crosse WI, USA

Abstract

This paper argues how anglophone, English-speaking countries overwhelmingly impact the global accounting profession and discusses the requirements for international candidates to become a Certified Public Accountant (CPA) in the United States. Without living abroad, many international accountants with a license or certification are nowadays Chartered Accountants (CA) of the United Kingdom or Certified Public Accountants of the United States and Territories. Thus, international candidates should know how to get one or both of those designations. In this context, this paper summarizes and documents the education requirements for international candidates who want to be licensed as a certified public accountant in the United States. National and international stakeholders, such as accounting students, accounting organizations, and regulators, may find this information useful.

Evaluating the Economic and environmental Impact of Combining Solar Panel Systems and Electric Vehicles in Household Settings.

Raghavan Srinivasan[1], Dr. Vinay Gonela[2]

[1]Ball State University, Muncie, USA. [2]Texas A&M University - Central Texas, Killeen, USA

Abstract

This research aims to analyze the economic implications of integrating solar panel systems and electric vehicles within household environments. Multiple household scenarios are constructed, taking into account electricity provision (with or without solar panel systems) and energy demands for vehicles (conventional and electric). Through a series of Monte Carlo simulation models, economic and environmental advantages of various setups are evaluated and compared. Findings suggest that while the combination of solar panels and electric vehicles yields substantial environmental benefits, it also incurs considerable costs. Moreover, it is revealed that while solar-generated electricity can supplement electric vehicle charging, it cannot serve as the sole energy source.

How to increase the socio-demographic diversity in schools considering transportation costs?

Bulent Erenay[1], Arsalan Paleshi[2]

[1]Northern Kentucky University, Highland Heights, USA. [2]York College of Pennsylvania, York, USA

Abstract

The disparity in the quality of education among schools is a major challenge for the authorities of education system and policy makers, even in the same school district. Generally, the schools that are located in low-income localities with higher percentage of racial minority groups have lower quality than the relatively high-income localities. In this study, we attempt to address this issue and develop a mathematical model that aims at minimizing the distance traveled by students from their homes to schools while making sure that at least a particular percentage of the students attending each school are from low-income families.

AI-enabled Social Transformation

Tewei Wang

University of Illinois Springfield, Springfield, USA

Abstract

Over the past two decades, we have observed the profound impact of information technology on both our business landscape and society. Venkastraman's seminal 1994 Sloan Management Review article outlined transformational levels that aptly foreshadowed the influence of IT on business. In this presentation, we undertake an analytical extension of this model to anticipate how artificial intelligence (AI) will shape future business paradigms. Much like the progression of IT-enabled transformation, AI is poised to evolve through stages facilitating task automation, culminating in a revolutionary phase of business process redesign. This transformative stage promises to reshape not only how we conduct business but also our fundamental behaviors as individuals. Ultimately, this societal shift will necessitate the redefinition of social structures, ethical beliefs, and behavioral norms.

User Assessment of Security Threats

Yi Guo[1], Young Ro[2]

[1]University of Michigan -- Dearborn, Dearborn, USA. [2]University of Michigan - Dearborn, Dearborn, USA

Abstract

Computer security breaches and attacks have become increasingly common occurrences. Understanding how end users assess and respond to these threats is a critical research question with significant implications for security practices and user education. When faced with security threats, end users typically evaluate them based on three key aspects: severity, vulnerability, and avoidability. These assessments guide their decisions on how to proceed. Preventative behaviors encompass actions such as installing and updating antivirus and anti-spyware software, keeping operating systems and critical software patched with the latest updates, and activating firewalls, among others. The nature of the threats significantly influences users' assessments. One factor is the severity of the threat in terms of potential damage, often measured by the potential financial loss. Another factor relates to the perceived proximity of the threat. Proximity is not solely geographical; an incident affecting a close friend can evoke a sense of immediacy regardless of physical distance. In this study, we aim to examine how the seriousness and perceived proximity of security threats impact end users' assessments and subsequent behaviors. We plan to conduct a controlled experiment using a series of security-related scenarios. These scenarios will manipulate two key attributes of security threats: their location or distance and their severity. Through a survey questionnaire, we will explore how these factors, along with individual characteristics, influence users' perceptions of vulnerability and avoidability and determine the types of preventative actions they would likely take.

Exploring the antecedents of paradoxical orientations of technology

Yi Guo[1], Xiaodong Deng[2]

[1]University of Michigan - Dearborn, Dearborn, USA. [2]Oakland University, Rochester, USA

Abstract

Paradoxical orientations of technology are the experiences with contradictory quality when users interact with a technology (Mick & Fournier, 1998; Jarvenpaa & Lang, 2005). Some observed paradoxical dimensions include control/chaos, freedom/enslavement, new/obsolete, competence/incompetence, and efficiency/inefficiency. The pervasive, ubiquitous, and intelligent nature of information technology may bring users updated experiences along the existing and new contradictory qualities. User experiences of paradoxical orientation will affect their intention to continued use and coping strategies.

The major focus of this study is to explore the factors that may influence an individual's paradoxical orientations of technology. Based on the traditional view of people, technology, and task, this study in particular first identifies antecedents along these three dimensions. For example, individual characteristics may include personal innovativeness and trust propensity. Characteristics of the technology in question may include its purpose (e.g., communication, productivity), interactivity, and intended skill set (general vs. specialized). Task at hand can be characterized by its complexity and cognitive demand (analytical vs. routine). Second, this study investigates the effects of these antecedents on paradoxical orientation. Finally, the study will provide insights on better design and use of technology for the benefits of individuals and society.

Impacts of cybersecurity on hospital efficiency and financial performance

Christopher Lee[1], Jeong Hoon Choi[2], Jung Young Lee[3], Sima Fortsch[4]

[1]Central Connecticut State University, New Britain, USA. [2]Youngstown State University, Youngstown, USA. [3]Northern Illinois University, DeKalb, USA. [4]Northern Kentucky University, Highland Heights, USA

Abstract

Hospitals have been suffering from cyber-attacks that put both patient privacy and safety at risk. However, the impacts of cybersecurity on hospitals' efficiency and financial outcomes are not well known, raising a question about the justification of the high investment costs. This study investigates the effects of cybersecurity on hospital efficiency and financial performance, focusing on the multi-factor authentication implementation status to mitigate unauthorized access. The study also examines the effect of hospital size as a moderator for the above relationships. We used ordinary least squares regression to test hypotheses with data from over a thousand hospitals in the United States. Data envelopment analysis models were used to generate hospital efficiency measures. Return on assets, return on equity, and operating margin were examined for financial performance. Both cybersecurity implementation and hospital size positively impact hospital efficiency and financial performance. There was a slight negative moderating effect of hospital size on the relationship between cyber security and hospital performance. Hospitals should consider cybersecurity a strategic investment for better efficiency and financial outcomes. This study also suggests that the expected benefits of multi-factor authentication implementation depend on the hospital's size.

Leveraging centrality in course-related Electronic Digital Social Networks for enhanced knowledge dissemination

Sharath Sasidharan

Bowling Green State University, Bowling Green, USA

Abstract

In modern educational environments, the effective dissemination of knowledge plays a critical role in fostering collaborative learning and academic success. Electronic digital social networks (EDSNs) can emerge as platforms for optimizing knowledge exchange and collaboration among students and educators. This study presents a novel approach to enhancing knowledge dissemination within the e-learning space by incorporating networking structures, specifically centrality metrics, into course-related EDSNs. Centrality metrics, including eigenvector centrality and betweenness centrality, have been widely recognized for their ability to identify key influencers, information hubs, and communication pathways within social networks. When extended to the e-learning space, centrality-based digital networking structures promote active participation, engagement, and interaction, leading to a vibrant and dynamic learning community. In addition, these structures enable students to customize their learning experiences, connect with like-minded peers, and explore mutual topics of interest, leading to peer-to-peer learning. This study underscores the transformative potential of integrating centrality metrics into course related EDSNs, revolutionizing knowledge dissemination in e-learning.

Harnessing innovation and centrality in design: Mitigating technostress in Enterprise System implementation

Sharath Sasidharan

Bowling Green State University, Bowling Green, USA

Abstract

Enterprise system implementation often entails significant challenges, particularly in managing technostress among users. This study proposes a novel approach to alleviate technostress during enterprise system implementation by engaging innovative and centrally networked users in the design process. Innovative users, characterized by their inclination for exploring new technologies and workflows, possess valuable insights that can inform the design of user-friendly interfaces and intuitive processes. By involving these users in the design process, organizations can leverage their creativity to develop solutions that mitigate technostress and enhance user acceptance. Furthermore, centrally networked users, identified through centrality metrics such as eigenvector centrality and betweenness centrality, serve as influential nodes within the organizational network. Engaging innovative and centrally networked users strategically in the design process enables organizations to leverage their network reach and influence to disseminate knowledge, foster peer support networks, and facilitate smoother transitions during enterprise system implementation. By embracing this innovative approach, organizations can navigate the complexities of enterprise system implementation with greater ease and success.

Optimizing performance outcomes: Leveraging centrality in project team formation

Sharath Sasidharan

Bowling Green State University, Bowling Green, USA

Abstract

Effective project team formation is paramount for achieving optimal performance outcomes in organizations. This abstract presents a novel approach to enhance performance outcomes by incorporating networking structures, particularly centrality metrics, into the process of creating project teams. Centrality metrics, including eigenvector centrality and betweenness centrality, have demonstrated effectiveness in identifying key influencers, communication channels, and collaboration pathways within organizational networks. By leveraging these metrics in the formation of project teams, organizations can maximize team performance and foster innovation and collaboration. The proposed framework ensures placement of centrally positioned individuals within project teams to facilitate efficient communication, knowledge sharing, and decision-making processes. Through a combination of quantitative analysis and qualitative assessment, organizations can evaluate the impact of centrality-based team formation on performance outcomes, including project success rates, team cohesion, and innovation levels. By leveraging insights from social network analysis and performance management, organizations can optimize the composition of project teams and maximize their potential for success.

Auditor Cybersecurity Focus and Client Cybersecurity Reporting

Yiyang Zhang[1], Stephanie Walton[2], Manlu Liu[3], Jing Tang[3], Xinlei Zhao[4]

[1]Youngstown State Unviersity, Youngstown, USA. [2]Louisiana State University, Baton Rouge, USA.
[3]Rochester Institute of Technology, Rochester, USA. [4]University of Toledo, Toledo, USA

Abstract

We examine the relationship between auditors' cybersecurity focus and their clients' cybersecurity reporting. Cybersecurity reporting is of increasing regulatory focus following SEC guidance on cybersecurity disclosures and the promulgation of a proposal focused on cybersecurity risk management and strategy. As cybersecurity activities can have substantial implications for financial reporting, auditors are poised to bridge the gap between proposed and existing technical guidance and their clients' reporting. We argue that auditors' cybersecurity focus reflects their strategy and expertise. We find that greater auditor cybersecurity focus is positively associated with the provision and quality of client cybersecurity disclosures. That is, clients utilizing an auditor with greater cybersecurity focus report additional cybersecurity disclosures and are less likely to receive a SEC cybersecurity comment letter. Our study provides a greater understanding of auditor involvement in cybersecurity reporting. Practically, we provide evidence that auditors can serve in a positive capacity fostering cybersecurity consideration.

AI-Driven Innovations in Faculty Curriculum Development

Kyle Chalupczynski

Penn State, Behrend, Erie, USA

Abstract

This paper details the application of Large Language Models (LLMs) by a faculty member to improve curriculum development, content creation, assessment, and feedback in educational settings. The author, leveraging experiences at Penn State Behrend, has developed and implemented a range of processes utilizing LLMs—from engineered prompts to chatbot integrations—aimed at enhancing teaching efficiency and student engagement. These innovations have facilitated the adaptation of course content to the evolving demands of the AI era, notably improving the delivery of personalized feedback and optimizing time spent on curriculum-related tasks. Sharing these practices has sparked broader innovation within the university, demonstrating the scalable impact of LLMs on educational quality. Feedback from students indicates a positive reception to these changes, highlighting the effectiveness of LLMs in enriching the learning experience.

Enhancing Business Curriculum with Large Language Models

Kyle Chalupczynski

Erie, Erie, USA

Abstract

The rapid advancement of artificial intelligence, particularly in the development of large language models (LLMs), presents both opportunities and challenges in the field of business education. This paper explores the importance of incorporating LLMs into the business curriculum, drawing on qualitative insights from the author's personal experiences with piloting various integration approaches. Through practical examples implemented in Management Information Systems (MIS) courses at Penn State Behrend, this study highlights innovative teaching methodologies that leverage LLMs in the classroom to enhance students' learning experiences. Despite the work-in-progress status of these findings, initial observations underscore the transformative potential of LLMs in fostering a dynamic learning environment. By integrating cutting-edge technology into educational settings, educators can equip students with the critical thinking and adaptability skills necessary to navigate the rapidly evolving business landscape. This paper calls for a broader discourse on the pedagogical implications of LLMs in business education, emphasizing the need for ongoing experimentation and dialogue within the academic community.

A Slack-based Data Envelopment Analysis (DEA) Model for Evaluation of Recycling Efficiency of Material Recovery Facilities (MRFs) in Reverse Supply Chains

Nima Alizadeh-Basban, Aditya Vedantam, Nallan Suresh

University at Buffalo, Buffalo, USA

Abstract

Material recovery facilities (MRFs) constitute an important element in reverse supply chains for recycling materials from both consumers and commercial enterprises, instead of diverting them to landfills and incineration. The recycling efficiency of MRFs is thus an important factor affecting the extent of recycling in reverse supply chains. There has been no study devoted to a systematic evaluation of the recycling efficiency of MRFs to date. This paper adopts a data envelopment analysis (DEA) approach to measuring MRF efficiency and develops, specifically a Slack-Based Measurement (SBM) model as the appropriate DEA model to evaluate MRF recycling efficiency. This models considers contamination in inputs as an undesired feature, along with uncertainty in inputs. In this paper, a robust optimization technique is employed to transform the SBM model into a robust formulation. The proposed model is validated using actual data of inputs and outputs from from eight diverse MRFs in New York State spanning the years 2018 to 2019. The effective use of SBM-DEA method in real MRF settings, along with implementation issues are also discussed.

A Qualitative Research Investigation of Reverse Supply Chains for Plastics Recycling

Azadeh Arjmanddavarani, Aditya Vedantam, Nallan Suresh

University at Buffalo, Buffalo, USA

Abstract

The importance of recycling plastics has been recognized world over, in the current drive towards a circular economy. In this study, we seek to understand, in fundamental terms, the structure and characteristics of the plastic recycling industry in the US, in order to develop ways and means to augment plastics recycling efficiency and improve economic incentives to increase the level of plastics recycled. Given the early stage of research in this area, it was determined that a case-study approach for investigation is appropriate at this stage. This study involves a systematic development o case study protocol, structured interviews and triangulation methods for understanding the efficacy of current recycling practices and unearthing better practices aimed at minimizing landfill and incineration. Several propositions derived from theoretical perspectives such as natural resource based view (NRBV) and institutional theory for adoption of recycling efforts, along with propositions derived from forward supply chains are tested systematically in cross-case and within-case analyses.

The Influence of Customer Base and Product Characteristics on Corporate Social Responsibility Performance

Sean Yim, Ben Lee

Penn State Behrend, Erie, USA

Abstract

This study addresses a gap in the literature on Corporate Social Responsibility (CSR) by examining the impact of a firm's customer base and product offering characteristics on its CSR performance. Despite a consensus that CSR is a viable strategy for achieving competitive advantage, with mixed findings in early literature, little is known about the role of a firm's customer bases and product offerings in shaping CSR outcomes. Utilizing a comprehensive dataset comprising over 8,000 firm-year observations, we investigate how a firm's Business-to-Business (B2B) customer base, customer concentration, service focus, and high-technology product offerings influence its CSR performance. The analysis reveals that a higher B2B ratio and customer concentration positively affect CSR performance, with the B2B ratio enhancing responsible environmental and social practices but diminishing corporate governance concerns. Conversely, customer concentration improves responsible business practices across various CSR pillars while reducing overall concerns. From a product-offering perspective, a service-offering focus elevates responsible environmental practices and positive corporate governance, whereas a high-tech focus intensifies concerns related to CSR performance. This research contributes to the CSR literature by elucidating the significance of customer base and product characteristics, opening new avenues for future investigation in this domain.

Co-optition in Sustainability Initiative

Jen-Yi Chen[1], Moonwon Chung[1], Chien-Hui Wang[2]

[1]Cleveland State University, Cleveland, USA. [2]Feng Chia University, Taichung, Taiwan

Abstract

Sustainability is important yet costly for most companies. This paper explores the dynamics of co-opetition, that is, cooperation among competitors, in sustainability initiatives. We study the strategic interaction of two competing brands' participation in the initiative by considering their market shares, consumer segments, and loyalties, as well as the change in profit margin and investment costs when participating. We characterize the circumstances where co-opetition may take place, which is mainly driven by the big brand. However, when one brand becomes too big, the possibility of co-opetition vanishes. A Prisoners' Dilemma, as well as two distinct multi-equilibrium outcomes, may arise, though some may be circumvented or intervened to attain the desired co-opetition outcome for the social good. The non-monotone nature of the profits in market factors implies that both the direct effect of the parameters and, more importantly, the indirect effect of the rival's strategy should be taken as a whole when contemplating one brand's best response to market changes. In our multi-brand extension, we find that one new type of multi-equilibrium outcome may occur but more importantly full cooperation among a large number of competitors is unlikely to happen.

Inventory and Financial Performance Analysis in the Medical Device Industry

Yong Taek Min[1], Sangdo Choi[2], Jeong Hoon Choi[3]

[1]Florida Gulf Coast University, Fort Meyers, USA. [2]o9 Solutions, Gainesville, USA. [3]Youngstown State University, Youngstown, USA

Abstract

The objective of this study is to explore the relationship between international trade and inventory management in the medical device manufacturing industry before the onset of the COVID-19 pandemic by examining the relationship between inventory and firm performance and develop a taxonomy of medical device manufacturing firms based on the earns-turns matrix. This research develops a new taxonomy of medical device manufacturing firms based on the earns-turns matrix. A large panel dataset of global medical device manufacturing firms was collected for the period 1990-2019. We classify the medical devices into conventional and advanced products. Although US medical device firms became more profitable and more technologically advanced, the number of US firms decreased, which indicate decreased domestic manufacturing surge capacity, especially for low cost but essential medical and surgical supplies and equipment. This study broadens the scope of supply chain management research by empirically investigating the relationship with international trade.

Beyond the Promise: Navigating Functional and Psychological Barriers in Interdisciplinary Program Development

Diane Parente, Greg Dillon, Matthew Swinarski, Carol Putman, Jeffrey Vaitekunas

Penn State Erie, Behrend College, Erie, USA

Abstract

Universities' promise of innovative interdisciplinary learning through integrated programs faces significant stakeholder resistance. This research leverages Innovation Resistance Theory to examine the diverse perspectives of students, parents, faculty, administration, and employers, unveiling the multifaceted nature of resistance. These barriers include employment concerns, program understanding, workload, resource allocation, and knowledge uncertainty. This research illuminates the complex interplay of functional and psychological barriers within Innovation Resistance Theory, offering crucial insights for the development of successful interdisciplinary programs.

How do policy-driven updates influence user engagement patterns over time?

Alejandro Hernandez De la Lanza, Maria Ibanez

Kellogg School of Management, Evanston, USA

Abstract

Mobile app developers are commonly believed to have complete discretion over the content they release through updates. However, mobile app marketplaces (i.e., Google Play, App Store) often require developers to release specific updates to ensure ecosystem compatibility. Failure to release them by specific deadlines can have consequences for developers: the app can be excluded from the platform. In this study, we rely on a natural experiment research design and application of the difference-in-differences methodology to examine the impact of such updates on user behavior in a freemium app over time. Our findings show that updating to a new mandated version alters user behavior. Although the number of different screens each user sees remains unchanged, users spend more time overall with the app. Furthermore, users initiate fewer sessions in the days immediately following the update while they watch more ads when using the app. By analyzing user behavior over time, we discover that the immediate impact of these updates leads to a temporary decrease in user interactions, which long-term benefits can offset. This finding can help developers implement timely updating strategies that minimize user base churn and allow for more efficient promotional campaigns.

Leveraging Artificial Intelligence for Rubric Development in Writing Assignments

Gary Smith

Penn State Erie, Erie, USA

Abstract

As the landscape of education evolves, there is a growing demand for efficient and adaptive assessment strategies. This presentation explores the integration of artificial intelligence (AI) techniques in the development of assignment rubrics for a college-level Management course. Writing meaningful and tight rubrics that both simplify the assessment for instructors and provides more meaningful feedback for the student is a “value add” in which AI can make an effective contribution.

In this session, we will share the on-going approach we are using in our Penn State Behrend Essentials of Management course to constantly improve and evolve our rubrics It is an iterative approach that leverages AI to provide input which we use each semester to continually refine how we evaluate student reflection essays and discussion boards.

Given time, we will ask for audience input on how they are utilizing AI to construct their rubrics and related output objectives.

Facilitating AI Integration in College Business Course Development: Teaching an Old Dog New Tricks

Gary Smith

Penn State Erie, Erie, USA

Abstract

The adage "You can't teach an old dog new tricks" is a proverbial expression that suggests it is difficult to change someone's habits, behaviors, or ways of thinking, especially if they are set in their ways or have been doing things a certain way for a long time.

College and University educators are now facing the “elephant in the room” known as AI (Artificial Intelligence). Through a guided discussion, this session provides an opportunity to share ideas as to how session attendees are integrating AI into both new and existing courses.

Spillover Effect of Bad News along the Socially Responsible Supply Chain: Evidence from Firm's Bankruptcy Shock

Rongyao Zhang, Huaiyu Peter Chen

Youngstown State University, Youngstown, USA

Abstract

This study explores whether and how corporate bankruptcy news shock affects the stock returns of its suppliers and major customers along the socially responsible supply chain. After controlling for the traditional asset pricing factors, we find an adverse effect and suggest that bad news will push firms' stock prices down. Bad news from major customers will also push the supplier's stock price down, implying that a spillover effect occurs on the supply chain. Our findings also show that the impact of a customer's bankruptcy news is contingent on the level of the supplier's ESG score, indicating that given the negative bankruptcy news shock of the same magnitude, there is a different reaction toward the same bankruptcy shock depending on the firms' ESG engagement, high ESG profile firms will react less compared to low ESG firms. These results resist several robustness checks and identify a new channel through which ESG activities contribute to firm value creation.

Examination of Daily Sport Fantasy Sports Participants' Gaming Behavior Using a Model of Goal-Directed Behavior

Brian Yim

Kent State University, Kent, USA

Abstract

This study examined the behavioral intentions of recreational and problem daily fantasy sports league participants with an extended model of goal-directed behavior (MGB; Perugini & Bagozzi, 2001). The primary goal was examining the latent moderation effect (intervention effect) of daily fantasy sports and responsible playing strategy (RPS) on behavioral intention. The current study used a quasi-experimental research design. Online survey participants (*N*=615) were randomly assigned to either control group (*n*=205) or to one of the two experimental groups (*n*=205 each) via Qualtrics. All groups were shown the webpage of a daily fantasy sports website but only the experimental groups' webpage contained RPS. Participants in the experimental group 1 were shown regular RPS (i.e., imposing online education for responsible gaming) interventions and the participants in the experimental group 2 were shown emotional RPS (i.e., displaying an image of a frustrated gamer). Ten variables were measured in the MGB which were: attitude, subjective norm, positive anticipated emotion, negative anticipated emotion , perceived behavioral control, illusion of control, RPS, desire, frequency of past behavior, and behavioral intentions. SmartPLS 4 was used to analyze the MGB models of all the groups and significant group level differences were found indicating a moderation effect of the RPS. Detailed findings will be shared at the presentation. Daily fantasy sport and sport gaming companies should develop effective RSP and communicate with their users to prevent addictive gaming behavior and to promote positive sport gaming habit.

Analysis of stock impact from bad news announcements in different stock markets

Jiangxia Liu[1], Sanjay Kumar[2]

[1]Valparaiso University, Valparaiso, USA. [2]Valparaiso University, Valparaiso, USA

Abstract

Classical finance theory assumes that the stock markets are efficient in incorporating value-relevant news. Shareholder wealth changes when a favorable or unfavorable event happens. Bad news impacts stock markets negatively. While focusing on the bad news events, we collect multinational data from China, India, Japan, and the US. The data is used to test for the differences in stock impact from news announcements. The selection of countries allows a rich comparison of countries at different levels of economic development and cultural orientation. The results indicate a wide difference in the results from the four countries. The markets in the US and India exhibit a larger negative impact, while Japanese companies are resilient to disruptions. Finally, we did not see a significant stock decline in companies in China. We argue that the impact difference can be partly explained based on the economic development levels, regulations, market cycle, and cultural orientation.

Operational Flexibility as a Strategic Countermeasure: Driving New Entrants to Exit

Ata Karbasi

Valparaiso University, Valparaiso, USA

Abstract

Incumbent firms have been found to react defensively to new market entrants, employing strategies to compete or deter new competitors. We study if, and under which circumstances, incumbents can use operational flexibility to deter entrants. Using a panel dataset from the U.S. airline industry, we find broad support for our hypotheses. We observe a shorter time to exit for entrants in markets with more competition and dynamism. The more operationally flexible incumbents are, the shorter the time to exit for entrants becomes. This becomes more likely in more competitive and dynamic markets.

Incorporating Sustainability Content into Accounting Curriculum

Jiangxia Liu

Valparaiso University, Valparaiso, USA

Abstract

Environmental and social sustainability are critical to meet the long-term needs of humans. Corporate Social Responsibility (CSR) is becoming prominent across the spectrum of companies and government bodies. Despite the relevance, classroom teaching is facing challenges and lagging in including topics related to sustainability in the curriculum. In this study, we focus on incorporating CSR into accounting classes. Various ideas and options are presented to embed coursework that helps teach CSR concepts. We use the accounting curriculum primarily; however, other business disciplines can also use our methods effectively.

Streamlining Patients' Opioid Prescription Dosage: An Explanatory Bayesian Model

Osman Aydas

Oakland University, Rochester, USA

Abstract

Nearly half a million people died between 1999 and 2019 from overdosing on both prescribed and illicit opioids. Thus, much research has been devoted to determining the factors affecting the dosages of opioid prescriptions. In this study, we build a probabilistic data-driven framework that develops Tree Augmented Naïve Bayes (TAN) models to predict patients' opioid prescription dosage categories and investigate the conditional interrelations among these predictors. As this framework is rooted in the CDC's prescription guidelines, it can be applied in clinical settings by focusing primarily on pre-discharge pain assessments. Following data acquisition and cleaning, we utilize Elastic Net (EN) and Genetic Algorithm (GA) to identify the most important predictors. Next, Synthetic Minority Oversampling Technique (SMOTE), and Random Under Sampling (RUS) are employed to overcome the data imbalance problem present in the dataset. A patient's gender, income level, smoking status, BMI, age, and length of stay at the hospital are identified as the most significant predictors for opioid prescription dosage. In addition, we construct a Bayesian Belief Network (BBN) model, which reveals that the effect of smoking status and gender in predicting opioid prescription dosage depends on the patient's income level. Finally, a web-based decision support tool that can help surgeons better assess and prescribe appropriate opioid dosages for patients is built.

Enhancing Mentorship in Business Education: Best Practices and Student Perspectives

Scott Stroupe

Penn State Univ., Erie, USA

Abstract

Mentorship, a time-honored practice, serves as a conduit for imparting essential professional skills and wisdom and shaping professional demeanor. Yet, mentorship is consistently underutilized in career readiness programs, particularly among first-generation students. This paper draws upon a comprehensive literature review and an innovative experiment that integrated mentorship into two business courses. Our findings reveal best practices for effective mentorship, emphasizing the unique traits and behaviors of effective mentors, productive relationship structures, and concrete developmental outcomes. Additionally, we present qualitative insights from a student survey, shedding light on their attitudes toward mentorship, motivations, and barriers. By bridging theory and practice, this study contributes to the ongoing discourse on mentorship efficacy and offers actionable recommendations for educators, practitioners, and policymakers. As we navigate the evolving landscape of business education, fostering meaningful mentorship experiences becomes paramount for nurturing the next generation of professionals.

Selection, Payment, and Information Assessment in Social Audits: A Behavioral Experiment

Gabriel Pensamiento, León Valdés

University of Pittsburgh, Pittsburgh, USA

Abstract

Companies often rely on third-party social audits to assess suppliers' social responsibility (SR) practices. However, empirical evidence suggests these audits can often be too lenient and poor practices go unreported, particularly if the auditor feels beholden to the supplier. We design and conduct an incentivized lab experiment to study how a supplier choosing and/or paying the auditor affects audit reports. We explore whether and how these levers affect auditors' assessment of noisy signals about the supplier's practices, and investigate the role of two behavioral phenomena: motivated reasoning and reciprocity. We find that auditors who are paid and chosen by the supplier are more lenient, with the effect more pronounced when the information observed suggests poor SR practices. We do not find evidence of auditors being more likely to believe the supplier has good practices when chosen by it. Conversely, reciprocity towards the supplier plays an important role behind our results. Finally, auditors who are merely paid by the supplier are not more lenient, offering good news for practitioners. Our results can help guide companies' auditing and procurement policies. First, they show that removing a supplier's ability to choose its own auditor is critical to increase detection of poor SR practices, particularly when the risk of them is high. Second, removing the suppliers' ability to choose their auditor—while still paying them—might be enough to reduce leniency. Finally, our findings shed light on some of the behavioral drivers behind auditors decisions, which can guide interventions to mitigate audit leniency.

A Sustainability Inventory Project With Societal Impact

Carol Putman

Penn State Behrend, Erie, USA

Abstract

Learning about sustainability in the college classroom is important to enhancing student skill development for their business careers. The seventeen UN Sustainability Development Goals (SDGs) are a business priority and challenge. Manufacturing and service industries seek to hire innovative graduates with ESG/SDG skills to help achieve new strategic goals and mandates. One career-ready application catered to this need involves project work with a real-world partnership. This paper presents a project experience related to SDGs 2 (zero hunger) and 11 (sustainable cities and communities), where students have an opportunity to apply a variety of business skills toward data-driven food inventory solutions while having a positive impact on the community. Efforts to integrate these skills into business curriculum are necessary as a step forward in sustainability for positive impact at the local and global level.

AI Echo: A framework for generative AI bias mitigation

Jason Davidson[1], Ankur Gupta[1], Jerry Schnepp[2]

[1]Butler University, Indianapolis, USA. [2]Judson University, Elgin, USA

Abstract

OpenAI and their product ChatGPT have elevated generative artificial intelligence (AI) from a concept romanticized by science fiction enthusiasts to a household name. “In the past 20 years, no internet-based application has had a faster ramp up,” with ChatGPT reaching 100 million users in two months (Hu, 2023). This rapid user adoption highlights the potential opportunities and competitive advantages that can be gained by early adopters. Users are harnessing the power of ChatGPT to enhance both creativity and productivity. Generative AI tools like Dall.E2 can be used to create new digital art through prompt engineering without the need for traditional artistic acumen. With nearly limitless opportunities for societal impact, these innovations come with challenges in data quality and security.

Like all technology, generative AI is not infallible. The quality of the data generated can range from near flawless, to not factual, or highly biased. This is such a common occurrence that these missteps have been named hallucinations. While hallucinations are a well documented challenge with data quality in generative AI, as Dr. Joy Buolamwini of the algorithmic justice league states, the underlying bias in data generation may prove to be its biggest challenge. This research aims to address implicit bias in generative AI models. We will introduce a novel approach of injecting selected bias to counter balance existing bias in training data. The goal being a framework for ethical AI development with the consideration of bias from concept to creation.

A Systematic review of the literature of Maturity Models in the context of Big Data

Godwin Izibili

Emporia State University, Emporia, USA

Abstract

The advent of big data has revolutionized the way organizations collect, process, and utilize data. With the increasing volume, velocity, variety, and availability of data, organizations recognize the need to develop mature and dynamic capabilities to effectively manage and exploit this asset. This systematic review aims to explore the application of maturity models in the context of big data to assess organizational readiness and capability in handling data challenges.

Drawing on management and information systems literature, we define “Maturity" as the state of being complete and models as "normative theories," "best practice guides," or "certification mechanisms" because they provide a framework for assessing and improving organizational practices. Organizations can enhance their ability to extract hidden knowledge and make informed decisions by adopting discipline and consistency in best practices.

Through a comprehensive review of ten studies, we aim to see what has been researched about applying maturity models in the context of big data, identify gaps in the literature, and maturity models addressing the complexities of volume, velocity, and variety. Additionally, we seek to understand the essential human factors that influence the effective use of big data in organizations.

Using the PRISMA method and scholarly databases, we will analyze existing literature to summarize findings, identify gaps, and propose future research areas. This research aims to contribute to both scholarly and practical understanding of how organizations can leverage maturity models to harness the full potential of big data for improved decision-making and performance.

Keywords: big data analytics, organizational performance, maturity models

Challenges and Opportunities in Teaching Sustainable Development Goals (SDGs) in Higher Education

Scott Stroupe

Penn State Univ., Erie, USA

Abstract

Since introducing the Sustainable Development Goals (SDGs) in 2016, higher education institutions have grappled with effectively teaching these global objectives. The sheer number of goals complicates memorization, and their broad scope challenges students' understanding of their interconnectedness. This presents a dilemma for first-year seminar professors tasked with introducing SDGs within an already crowded curriculum, especially when a university's practices may not consistently align with SDG principles. I will present my research that draws upon a comprehensive literature review of pedagogical strategies related to SDGs and the qualitative results of an innovative group activity that prompts students to assess how the university is addressing (or not addressing) these goals. It will shed light on student awareness of the SDGs and their ability to connect SDGs to their immediate environment. It will also suggest some best practices for addressing this complex but essential topic with first-year students to foster informed and engaged global citizens committed to advancing the SDGs.

Data Quality and cybersecurity in cloud based GPT- Using cloud based GPT in business

Hongjiang Xu, Jason Davidson

Butler University, Indianapolis, USA

Abstract

The field of Artificial Intelligence (AI) has developed rapidly in recent years. One of the most well-known AI platforms is OpenAI's generative AI package, ChatGPT. ChatGPT is a cloud-based solution that features both text and image generation in its most recent iteration. The benefits of early adopters to generative AI packages like ChatGPT are near endless, however, there are issues related to data quality and cybersecurity that need attention. When businesses begin using any cloud based solution, they need to understand the benefits as well as the potential threats in particular, data quality (DQ) and cybersecurity issues. These challenges are potentially exacerbated when using generative AI.

Like other areas of data analytics and software engineering, bias can cause problems in performance. When users interact with GPT models to answer questions or find solutions, the results are a snapshot based on the corpus of the data at the time of training. The answers provided by GPT need to be evaluated very carefully, as it might carry some serious data quality issues. If the users rely on the answers without careful evaluation, it could lead to negative consequences. If a business uses a Cloud based GPT, it cannot replace subject matter experts because of its fundamental issues as how it generates information.

Generative AI models using deep neural networks to learn the pattern and generate similar new content. However, if the content AI was based or had data quality issues, the new content would inherit the same issues. And the new content then feed back into the pool of contents that is going to be used to generate answers for the new users. This becomes a cycles of bad quality contents reinforce other bad quality contents. Overtimes, it would be even more difficult to evaluate the quality of the information from the GPT. Businesses using cloud based GPT have to be aware of these potential data quality issues, otherwise, using GPT in business might become a security threat.

Utilizing the Analytical Hierarchy Process and Machine Learning techniques for revenue maximization through strategic ticketing.

Tausif Utchhash, Kirill Samaray

The University of Akron, Akron, USA

Abstract

This study identifies the important factors influencing the National Basketball Association (NBA)'s revenue from ticket sales during home games, employing a comprehensive approach that integrates expert opinions, advanced analytics, and machine learning. Utilizing the Analytical Hierarchy Process (AHP) model, the research initially gathers insights from industry experts to evaluate the impact of various factors on revenue. These factors include average player points per game (PPG), television rating, number of all-star players, average team ranking, day of the week, and social media coverage. Expert-derived weights for each parameter are aggregated into a unified confidence matrix, establishing a solid foundation for further analysis.

The project harnesses Machine Learning (ML) techniques, notably the Random Forest Classifier, Neural Networks, and Ensemble Learning, leveraging the expert-weighted parameters to train models on historical data for predicting future ticket sales revenue. This predictive modeling serves to refine ticket pricing and marketing strategies, enhancing revenue generation.

Additionally, the study incorporates JMP software to formulate a tier-based system for game categorization based on expected profitability. This innovative approach facilitates the strategic application of differentiated ticketing strategies, aligning with each game's revenue potential.

This research offers a novel methodology for optimizing NBA ticket sales strategies, merging expert opinion with machine learning and JMP software analytics. It not only sheds light on the dynamics of sports entertainment economics but also equips stakeholders with actionable insights for revenue maximization through strategic ticketing.

Navigating Barriers in Sustainable Supply Chains: Impacts on Collaboration and Triple Bottom Line Performance

Alina Marculetiu[1], Cigdem Ataseven[2]

[1]Youngstown State University, Youngstown, USA. [2]Cleveland State University, Cleveland, USA

Abstract

Our study examines the effect of sustainability barriers on Supply Chain Sustainability Collaboration (SCSC) and their consequential impact on Triple Bottom Line (TBL) performance. Specifically, it addresses how internal and external barriers shape the efficacy of SCSC, explores the interaction between these barriers, and assesses their indirect effects on economic, social, and environmental outcomes. This research uses survey data and structural equation modeling to highlight the nuanced dynamics between organizational hurdles and sustainable practices in the US. This research fills a significant gap in the existing literature by offering a comprehensive analysis of the interplay between diverse barriers and sustainable supply chain collaboration practices, contributing to a deeper understanding of the mechanisms driving successful sustainability integration in global supply chains.

The Digital Divide: A Post-COVID Analysis

Rhoda Joseph, Elizabeth McQuillen

Wayne State University, Detroit, USA

Abstract

The digital divide is not a new concept. Studies on the digital divide began in the mid-1990s referring to individuals and communities that did not have access to information and communications technologies (ICTs). An early seminal work on the digital divide suggested that bridging the divide was the most urgent task at hand (Van Dijk, 2006). A more recent study identified different approaches to examine the digital divide including an approach through decolonization lens that encompasses multiple components including communities, cultural norms, and human dignity (Bon, Saa-Dittoh & Akkermans, 2024). The digital divide has been extensively researched and the one common denominator is that the divide persists and arguably has increased, which some studies now call the "digital chasm" (Charumbira et. al, 2024; Pandey & Mishra, 2024).

During the Covid-19 pandemic, there was a significant shift from in-person to web-based activities in the United States, and around the world. In this study we are motivated by two research questions: how has the post-covid 19 exacerbated the digital divide in the delivery of educational and healthcare services; and secondly, who will be most impacted by this shift. Our study will begin with a review of the existing literature collected from the period 2022-2024 focused on educational and healthcare outcomes. Phase two of the study will focus on collecting primary data. Lastly, we will examine results and evaluate impact to both practitioners and researchers. This study extends the existing literature on the digital divide arguable, now referred to as the digital chasm.

Exploring the client-side security of the firms adopting cloud-based solutions

Xiaodong Deng[1], Hongjiang Xu[2]

[1]Oakland University, Rochester, USA. [2]Butler University, Indianapolis, USA

Abstract

Cybersecurity has received increasing attentions from the firms who have moved their businesses over to the cloud and enjoy the benefits of derived flexibility and productivity from web-based solutions or services including infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). These firms also need to choose the cloud hosting option, such as public cloud, private cloud, or hybrid cloud, that is most suitable for their business needs. Different cloud-based solutions are associated with their own cybersecurity risks and responsibilities, just like the traditional on-premise information systems are associated with a similar set of security risks and responsibilities. While different cloud computing solutions may shift different responsibilities of managing the related information technology (IT) resources and services securely from the focal firms to the service providers, the focal firms cannot delegate their security responsibilities to the service providers.

This study explores security responsibilities of the firms or clients who have adopted a cloud-based service. Client-side security refers to the security responsibilities of a firm using the cloud service (Bidgoli 2024). In particular, this study uses the security responsibilities of the on-premise solution as a base and summarizes the responsibilities for three typical cloud-based services (i.e., IaaS, PaaS, and SaaS). Some major concerns include data security and privacy, connectivity, reliability, and interoperability. The implications of the responsibilities will be discussed in terms of their impacts on the firms' security strategy and policy, in-house supportive expertise, employees' training programs, and possible residue security risks.

Let Them Know How Good You Are: The Influence of Implicit Theories on Donation Intention

Doori Song

Youngstown State University, Youngstown, USA

Abstract

Charitable giving is a cornerstone in sustaining the diverse work of nonprofit organizations. While the sector depends on the altruism of donors, understanding the psychological underpinnings of their giving intentions is crucial. This study posits that such intentions are significantly influenced by donors' implicit theories-ingrained beliefs about the malleability of personal traits. Prior research has primarily delineated two such theories: incremental and entity theories. Incremental theorists consider personal qualities as dynamic and improvable through efforts, thereby seeking self-enhancement through direct actions. Conversely, entity theorists perceive personal traits as static, leading them to seek opportunity to affirm their self-image to themselves and others through signaling.

The novel contribution of this research lies in its hypothesis that entity theorists are more likely to demonstrate a heightened intention to donate when their contributions are publicly acknowledged, aligning with their signaling motivation. In contrast, incremental theorists' willingness to donate is hypothesized to be less affected by public recognition, as their motivation is not inherently linked to signaling. This delineation offers a fresh lens to view donor behavior, bridging a gap in existing marketing and philanthropic research by intertwining implicit theories with charitable giving.

From an academic standpoint, this study enriches the dialogue on donor motivation by introducing a theoretical framework that correlates the visibility of donation with the intention to give. Practically, it informs nonprofit marketing strategies by suggesting that tailoring donor recognition to align with underlying psychological profiles may enhance fundraising efficacy.

The Psychology of Luxury: How Implicit Theories Shape Attitudes Toward High-End Brands.

Doori Song

Youngstown State University, Youngstown, USA

Abstract

In the flourishing landscape of the United States' luxury brand market, which contributes to exhibit robust growth and innovation, consumer attitudes towards high-end products reveals deep psychological underpinnings This study delves into the intricate relationship between individuals' implicit theories – incremental and entity theories- and their predilections for intrinsic versus extrinsic cues when forming attitudes toward luxury brands and products. Individuals with an incremental theory, who believe personal attributes can evolve over time, are hypothesized to gravitate towards intrinsic cues, such as product quality, reflecting a pursuit of self-enhancement and a genuine appreciation for the artisanal value of luxury items. Conversely, those aligned with an entity theory, viewing personal traits as fixed, are posited to favor extrinsic cues, including brand logos and price, as these elements serve as potent symbols of social status and identity, thereby facilitating the signaling of one's social standing to others.

This research contributes to the nuanced understanding of luxury brand consumption, highlighting how deeply entrenched psychological beliefs can shape consumer behavior in the luxury market. By elucidating the link between consumers' theories of personality and their luxury brand preference, the findings offer valuable insights for marketers aiming to tailor their strategies to the psychological profiles of their target audience, ultimately enhancing brand positioning and consumer engagement in the competitive luxury sector. This study not only expands the theoretical landscape of consumer behavior but also provides practical implications for brand managers and advertisers seeking to connect with consumers on a more profound psychological level.

Examining The Effects Of Mobility On Entrepreneurial Training, Microenterprise Profits And Household Incomes

Ramesh Dangol, Patrick Bateman

Youngstown State University, Youngstown, USA

Abstract

National governments and international development institutions (e.g. World Bank) are embracing entrepreneurship as a solution to increase female labor participation. They are investing in entrepreneurship training programs with the belief that they will help women develop business capabilities, which in turn foster new business ownership and increase household income. Although the argument that entrepreneurship training can foster business startups and improve profitability is theoretically sound, prior studies have not established an unequivocal relationship between them. We argue that spatial mobility is a factor that impacts the relationship between training programs and business profitability. spatial mobility is required to access the factor market, where entrepreneurs purchase inputs to make finished goods and the product market where they sell finished goods. However, not all women can move within and across equally and, consequently, some can access both markets more easily than others. Therefore, we hypothesize that this variation in spatial mobility can impact the extent to which women can exploit their entrepreneurial capabilities. In other words, women with higher levels of spatial mobility can access both markets more easily compared to their counterparts and exploit their entrepreneurial capabilities to the fullest. In other words, spatial mobility can moderate the effects of entrepreneurial capabilities on business outcomes. We contribute to the women's entrepreneurship literature by highlighting an external factor that can enhance the effect of entrepreneurship training programs on firm performance.

Using Power BI for Data Management and Analysis of the Campus Cupboard Program

Heather Barhorst, Ajay Vaidya

University of Akron, Akron, USA

Abstract

The Campus Cupboard program through the ZipAssist office at the University of Akron provides students in periodic need with access to basic necessities of daily living. All UA students have access to food and hygiene products through the on-campus pantry, two large-scale food distributions, and six grab-n-go location across campus in addition to the Clothing Collab, Roo-Store, Menstrual, and Campus Community Garden programs. ZipAssist, the student advocacy and support office, started the Campus Cupboard program in 2019 after reviewing The Hope Center's national data on food insecurity and basic needs for college student populations and identifying similar needs for UA students.

The creation of a Power BI Dashboard for the Campus Cupboard serves as both a data housing and automation tool. Data analysis identifies useful insights to monitor changes in need and capacity to inform process changes and promote efficiency for direct service staff. Utilizing data visualization tools so non-technical audiences can view the program's patterns and trends for timely, cross-department communication with campus stakeholders including the Development team for communication with donors and the Board of Trustees reports, presentations, and grant writing.

This presentation will be a live demonstration of the Power BI Campus Cupboard Dashboard and an explanation of how the data informs different components and stakeholders. The goal is to inform the audience on what is possible with Power BI and how you can bring this to your campus or organization.

Pipelines for Soccer Research Using an Supply Chain Agent Sourcing Lens

Asoke Dey[1], Yohann Mauger[2], Seungbum Lee[1]

[1]The University of Akron, Akron, USA. [2]Northern Kentucky University, Cincinnati, USA

Abstract

The overriding goal of this study is to understand the recruitment process of student athletes, specifically in the case of intercollegiate soccer programs in the U.S. This study is particularly interested in the use of an agency, and how the usage of the agency influences and shapes both local and international recruitment. Building on the supply chain theories in agent sourcing and published work in talent management and recruitment, the study develops a research agenda in the talent sourcing domain. To achieve the goal of this study, in-depth semi-structured interviews were conducted with 14 coaches who have been utilizing agencies for a talent sourcing strategy. Our research findings are consistent with previous research and will guide future research in the areas of sports management, talent sourcing, and international talent migration.

Do Two Minds Think Alike? Efficiency Benefits from Common ERP Vendor Usein a Supply Chain

Yiyang Zhang[1], Russell Barber[2], Robert Pinsker[3], Stephanie Walton[4]

[1]Youngstown State University, Youngstown, USA. [2]University of Colorado Denver, Denver, USA. [3]Florida Atlantic University, Boca Raton, USA. [4]Louisiana State University, Baton Rouge, USA

Abstract

Utilizing a common enterprise resource planning (ERP) vendor could improve supplier and customer performance by increasing supply chain information technology (IT) alignment, agility, and efficiency. However, supply chains could be hesitant to utilize a common ERP vendor for fear of intellectual capital loss, increased costs, and IT incapability with existing IT architecture. Relational view theory argues that information sharing and process integration advantages are achieved when supply chain partners share assets, knowledge, and capabilities through relation-specific investments, complementary resources, and knowledge sharing processes. We find evidence that common ERP vendor (CERPV) use is associated with greater supplier and customer efficiency, performance, and partnership strength. Our study directly examines the impact of CERPV use within a supply chain, adding to the limited accounting information systems' evidence on the role of inter-organizational ERP system investments on efficiency.

Papers

A PRELIMINARY LOOK AT THE UTILITY OF R VIS-A-VIS EXCEL IN TEACHING AN INTRODUCTORY ANALYTICS COURSE

Esmail Mohebbi

College of business, University of West Florida, Pensacola, FL 32504, USA emohebbi@uwf.edu

ABSTRACT

The wide variety of software tools available for data analysis drives business and data analytic course instructors to choose one or a subset of tools from the available options as the primary means of instructional practices and hands-on teaching and learning. Excel (including its powerful family of add-ins), Power BI, Tableau, R, Python, and SQL are among the tools that are most commonly incorporated into data analytics courses at various levels to meet the curricular needs of business students. We share some preliminary takeaways from using Excel and R in an introductory undergraduate course in business analytics while focusing on the utility and effectiveness of the tools in achieving the targeted students' learning outcomes.

Keywords: Analytics; Business Statistics; Instructional Tools; Teaching and Learning

INTRODUCTION

The practical utility and popularity of data analytics as a highly coveted skillset set in today's job market has led to the creation of new or metamorphosis of traditional business statistics courses in or toward data analytics in business schools' curricula to produce workforce-ready marketable graduates. Accordingly, incorporating the correct software tools to facilitate the instillation of data wrangling and analytical skills in business students in various majors has occupied a critical position in such course designs and curriculum planning efforts. The proper software selection is even more critical in fundamental analytics courses embedded in the core business curriculum, which is mandatory for all business majors with diverse academic backgrounds and varying strengths and weaknesses in quantitative skills and computational aptitude (Al-Haddad et al., 2019; Rotondo, 2020).

Microsoft Excel is undoubtedly among the most common software tools used to analyze data and produce summary measures, tables, and illustrations for reporting purposes in the business world. To that end, familiarity with Excel, albeit in various degrees of fluency, is one of the essential qualifications that organizations seek in candidates that they consider for employment in a broad spectrum of positions ranging from entry-level clerical positions to highly expert data analysts and business specialists. Also, Excel is the “go-to” tool for many mod-level managers who rely on their analytical skills to analyze data and run “what-if” scenarios to draw insights, verify reported

findings, compare alternatives, and formulate decisions. Furthermore, from a functionality standpoint, the availability of user-friendly Excel-based "add-ins" such as Analytic Solver and Palisade, as well as the integrability of Microsoft Power Pivot, Power Query, and BI tools along with DAX in the Excel environment, has elevated and strengthened the standing of Excel as a viable and practical platform for data wrangling and analytical platform among the non-data-scientific business professionals. (See, He, 2011; Convery & Swaney, 2012; Singh et al., 2104; Barreto, 2015; Peng, 2015; Dyer & Rogers, 2015; Gordon, 2016; Jacobs et al., 2016; Willis, 2016;

Frownfelter-Lohrke, 2017; Halliday, 2019; Hunter et al., 2020; Sankaran et al., 2021; and Libby et al., 2022, among others, for more recently reported cases in economics, accounting, finance, MIS, business and data analytics, operations, supply chain, and strategic management.)

While Excel, accompanied by its various forms of ad-ins and related software suites, serves as the standard or primary platform for teaching data and business analytics (particularly at an introductory level) in most business curricula, the availability of powerful alternatives such as Tableau, R, Python, and SQL provides the instructors with options when choosing the data analysis software tool(s) to support their course content and instructional practices. In particular, the open-source (free) feature of R, coupled with its highly capable and broad spectrum of statistical computing, data mining, visualization, and machine learning functions, has earned this programming language the reputation as a viable alternative for teaching analytics in business schools. On that note, the continuous enhancement of existing features and the introduction of new features enabled by the open-source community contribute to the sustainability of R as an attractive instructional tool for the instructors of analytics courses from the introductory to advanced levels. Furthermore, the availability of RStudio has made using R more convenient and efficient, especially for novice or skilled users, who often constitute a large portion of students in introductory statistics and analytics courses in business schools. Accordingly, using RStudio to illustrate statistical computations in introductory textbooks has become increasingly common over the past decade.

Discussions about the merits of R versus other software suites in the academic education literature weigh the difficulty of learning R as a programming language for students against its impressive analytical power, higher productivity, sustainability, affordability, and skills' marketability (e.g., Muenchen, 2014; Markham, 2016). To that end, a recent study by Sankaran et al. (2022) found that students expressed an avidity to overcome the stricter challenge of learning R compared to working with Excel in return for what they perceived as the intrinsic benefits of R in their future careers.

This ongoing research study aims to investigate the merits of R vis-a-vis Excel as the data-wrangling tool to facilitate and attain the targeted students' learning outcomes in an introductory undergraduate course in business analytics. In particular, the study focuses on students' performance-based results gathered over multiple coursework components to assess students' actual learning when R is used as an alternative to Excel to conduct comparable analytical tasks. It is envisioned that the findings of this study will contribute toward facilitating a more effective course design and cultivating more fruitful learning environments for students.

EXPERIMENTAL SETTING

An introductory business analytics mandatory course taught at the junior level as part of the business core curriculum in an AACSB-accredited business school serves as the experimental environment for this study. The prerequisite for this course is an introductory MIS course, which covers Excel, among other topics, at the introductory to intermediate level. Accordingly, students entering the analytics course are expected to possess working knowledge and hands-on experience with Excel; however, almost all students have yet to become familiar with R beyond name

recognition. Furthermore, most students lack the foundational knowledge and skills in any programming language.

Given these circumstances, Excel, by default, is regarded as the preferred and primary instructional tool for conducting data analysis in examples, exercises, assignments, and exams. However, the functional limitation of Excel coupled with the licensing fees of Analytic Solver - the popular Excel add-in for addressing such limitations - requires students to use R when working on specific portions of the course content that could not be completed in standard Excel.

The need for the inevitable - albeit delayed - introduction of students to R into the course content has prompted the instructor to experiment with encouraging students to use R in earlier stages of the course to conduct the practice work and homework assignments they would otherwise complete in Excel due to their prior familiarity with Excel and the ensuing perception of experiencing a higher efficiency when working in that environment. Accordingly, hands-on illustrations of selected examples by the instructor are provided using Excel and RStudio concurrently earlier in the semester to alleviate the fear of coding and help students overcome the challenge of learning a new (if not their first) programming language.

The assessment data for conducting a comparative analysis between the utility of R and Excel in achieving the targeted learning outcomes are gathered based on student's performance on comparable assignments. The analytical results, combined with students' feedback on their experiences with R, are used to draw inferences about the viability of using R as the primary data analysis tool in an undergraduate business analytics course by evaluating its effectiveness, induced performance efficiency, attractiveness, and acceptance among students.

PRELIMINARY FINDINGS

Having devised a set of preliminary hypotheses, the collection, preparation, and refinement of assessment data to support this study is currently underway so that the first set of experimental results can be shared at the conference. Meanwhile, the preliminary observations depict a mixed picture of how undergraduate business majors might view R. More specifically, while most students seem to acknowledge that learning how to use R could potentially enhance their marketability in the job and broaden their career path options, the portion of students who view the acquisition of programming skills in R or Python as a "must-have" trait is considerably lower in comparison with Excel. Naturally, the challenge of learning R - which is often viewed as somewhat arcane and cryptic by students with no programming experience - seems to contribute to this perception. Furthermore, anecdotal comments from students point to a noticeable dispersion in their views and enthusiasm toward learning R based on their majors. It should be emphasized that any conclusions based on these preliminary observations would be considered entirely premature as formal data analysis is pending.

REFERENCES

1. Al-Haddad, S., Thorne, B., Ahmed, V., & Sause, W. (2019). Teaching information technology alongside business analytics: Case study. *Journal of Education Business*, 94 (2), 92-100.
2. Barreto, H., Why Excel? (2015). *The Journal of Economic Education*, 46 (3), 300-309.
3. Convery, S. P., & Swaney, A.M. (2012). Analyzing business issues—with Excel: The case of Superior Log Cabins, Inc. *Issues in Accounting Education*, 27 (1), 141-156.
4. Dyer, J. N, & Rogers, C. (2015). Adapting the Access Northwind database to support a Database Course. *Journal of Information Systems Education*, 26 (2), 85-101.
5. Frownfelter- Lohrke, C. (2017). Teaching good Excel design and skills: A three spreadsheet assignment project. *Journal of Accounting Education*, 39, 68-83.
6. Gordon, S. P. (2016). Functional Excel. *Mathematics and Computer Education*, 50 (2), 86-93.
7. Halliday, S.D. (2019). Data literacy in economic development. *The Journal of Economic Education*, 50 (3), 284-298.
8. He, X.J. (2011). Enhancing Excel skills in teaching undergraduates in business. *Communications of the International Information Management Association* (IIMA), 11 (4), 13-30.
9. Hunter, K., Alberti, C.T., Boss, S.R., & Thibodeau, J.C. (2020). IntelliClean: A teaching case designed to integrate data cleaning and spreadsheet skills into the audit curriculum. *Journal of Empirical Emerging Technologies in Accounting*, 17 (2), 17-24.
10. Jacobs, A., Robinson, D.F., & DePaolo, C.A. (2016). Using Excel to make strategic managerial decisions. *Journal of Information Systems Education*, 27 (2), 93-98.
11. Libby, T., Schwebke, J.M., & Goldwater, P.M. (2022). Using data analytics to evaluate the drivers of revenue: An introductory case study Using Microsoft Power Pivot and Power BI. *Issues in Accounting Education*, 37 (4),97-105.
12. Peng, Z. (2015). The Applications of online technologies and Excel spreadsheets in teaching undergraduate introductory business finance course. *Business Education Innovation Journal*, 7 (1), 22-32.
13. Rotondo, G. (2020). Closing the technology skills gap in accounting education: Making Excel certification a student responsibility. *Business Education Innovation Journal*, 12 (1), 30-37.
14. Sankaran, S., Sankaran, K. & Bui, T. (2023) Student satisfaction with R vs. Excel in Data Mining and Business Analytics: A Herzberg's motivation-hygiene theory perspective. *Decision Sciences Journal of Innovative Education*, 21, 68–82.
15. Singh, A., Mangalaraj, G., & Taneja, A. (2014). Addressing business needs: A creative module for teaching data macros in an accounting information systems course. *Journal of Accounting Education*, 32,61-75.

16. Willis, V.F. (2016). A model for teaching technology: Using Excel in an accounting information systems course. *Journal of Accounting Education*, 36, 87-

Developing a Competitive Advantage in EV Supply Chain Systems: A Conceptual Framework for National Benchmarking Studies

Narges Mashhadi Nejad, Paul Hong

University of Toledo, Toledo, USA

Abstract

In the face of escalating environmental concerns and rapid technological advancements, this research presents a timely exploration into developing competitive advantages within national Electric Vehicle (EV) supply chain systems. With the EV industry at the threshold of reshaping global transportation and energy consumption, understanding and optimizing the complex web of activities from raw material extraction to vehicle delivery is crucial for national economic and environmental strategies. This study introduces a novel conceptual framework for benchmarking national capabilities in the EV supply chain, incorporating mixed-methods research grounded in supply chain management, competitive strategy, and sustainability. By examining key factors for competitive advantage and conducting case studies with descriptive statistics on selected countries, this research aims to provide strategic insights for policymakers, industry stakeholders, and researchers. It underscores the importance of technological innovation, regulatory environments, and market dynamics in achieving a competitive edge in the global EV market. Ultimately, this study contributes to advancing the global shift towards sustainable transportation by offering a systematic approach for enhancing national competencies in the EV supply chain.

Keywords: Competitive Advantage; Electric Vehicle (EV); Supply Chain Benchmarking Sustainability; Technological Innovation; National Strategy

Introduction

In recent years, the electric vehicle (EV) industry has emerged as a cornerstone of the global transition towards sustainable transportation. The EV industry is characterized by rapid technological advancements and a growing awareness of environmental concerns. The EV industry represents more than just an alternative to traditional auto manufacturing, but a fundamental change in the way people live and travel (Brand et al., 2019; Su & Urban, 2021). It is important to note that the shift from internal combustion engines to electric power trains represents profound changes in energy consumption, urban planning, and, fundamentally, the supply chains that support this industry. Understanding the intricacies of the EV supply chain at the national level is of paramount importance due to the strategic importance of the EV industry for economic and environmental policy (Chizaryfard et al., 2023; Günther et al., 2015).

The supply chain for electric vehicles is a complex web of interdependent activities, ranging from the extraction of raw materials to the delivery of finished vehicles to consumers (Braz & de Mello, 2022; Kalaitzi et al., 2019). Unlike conventional vehicles, EVs rely heavily on specific raw materials like lithium and cobalt, intricate electronics, and advanced battery technology, each of which presents unique supply chain challenges and opportunities. Therefore, a country's capability to efficiently manage and innovate within this supply chain can be a significant determinant of its competitive advantage in the global market (Günther et al., 2015).

This research delves into the rapidly evolving landscape of Electric Vehicle (EV) supply chain systems, spotlighting the critical need for countries to develop competitive advantages in this domain. In an era marked by escalating environmental concerns and the swift technological advancements in EV production, this study emerges as a timely and necessary exploration. It is propelled by the compelling motivation to understand how national frameworks can adapt to and thrive within the global shift towards sustainable transportation. By dissecting the multifaceted components of the EV supply chain, from raw material extraction to final assembly, this research aims to unveil strategic insights that nations can leverage to bolster their standings in the global EV market.

The study sets out with a twofold aim: firstly, to identify the key factors that contribute to a competitive advantage in the EV supply chain at a national level, and secondly, to assess how different countries benchmark against these factors. To address these aims, two research questions are posited: What are the critical components of the EV supply chain that nations need to optimize for competitive advantage? And how do selected countries compare in their current EV supply chain capabilities and infrastructures?

Employing a mixed-methods approach, this research is grounded in a robust theoretical foundation that draws from the disciplines of supply chain management, competitive strategy, and sustainability. The conceptual framework developed for this study outlines a comprehensive set of benchmarking parameters, including technological innovation, regulatory environments, resource availability, and market dynamics. Propositions are set forth based on the theoretical underpinnings, and a series of case studies involving selected countries are conducted. These case studies are enriched with descriptive statistics to provide a nuanced understanding of each country's positioning in the EV supply chain landscape.

The potential contributions of this research are manifold. Firstly, it offers a novel conceptual framework for national benchmarking in the EV supply chain, providing policymakers, industry stakeholders, and academic researchers with a systematic approach to evaluate and enhance competitive advantage in this critical sector. Secondly, by presenting an empirical analysis of case studies coupled with descriptive statistics, the study sheds light on the diverse strategies and practices employed by leading nations in the EV market. This not only highlights the path for emerging players to catch up but also propels the discourse on sustainable transportation forward. In sum, this research serves as a foundational piece for future studies and strategic planning, aiming to accelerate the global transition to electric mobility through informed and strategic enhancements in national EV supply chains.

Theoretical Foundation

The theoretical foundation encompasses the established theories and conceptual models that inform the study's direction, shaping its research questions, methodology, and the subsequent interpretation of findings. It provides the context necessary for comprehending the studied phenomena and ensures the investigation is aligned with relevant theories to present and interpret the analysis results for practical implementation in real world contexts (Dania et al., 2019; Nagariya et al., 2022). In the context of EV Supply Chain Systems. Theories such as dynamic capabilities, business model innovation, and benchmarking methodology supply interpretive frameworks to analyze how certain factors influence competitive advantage and how benchmarking can be leveraged (Bachmann & Jodlbauer, 2023; Sjödin et al., 2023).

Dynamic Capabilities Theory

The concept of dynamic capabilities is central to how firms can strategically navigate the complex and rapidly evolving electric vehicle (EV) market. As Teece et al. (1997) laid out, dynamic capabilities enable firms to adeptly manage resources, aligning their supply chains with the fluctuating demands of the EV industry. These capabilities are particularly pertinent for EV supply chains where the integration, reconfiguration, and release of resources must be timely and innovative to match technological advancements and market shifts (Teece et al., 1997). Teece (2007) further underscored the significance of these capabilities for fostering innovation and growth within the EV sector, highlighting the necessity for firms to evolve their resource base continually to maintain competitive advantage in this fast-paced market (Teece, 2007). Eisenhardt and Martin (2000) and Zollo and Winter (2002) demonstrated that through deliberate learning mechanisms and specific processes like product development and strategic alliances, firms could utilize dynamic capabilities to effectively respond to new industry trends such as sustainable practices and advanced battery technologies (Eisenhardt & Martin, 2000; Zollo & Winter, 2002). Teece's subsequent work reaffirmed that by cultivating these capabilities, EV firms could not only react to industry dynamics but also actively shape the supply chain ecosystem to their benefit, securing a competitive position that sustains over time (Teece, 2014, 2018). This approach is integral to the success of firms within the EV supply chain, where the ability to adapt and innovate is crucial for long-term viability and leadership in the market.

Business Model Innovation:

Business model innovation theory examines the mechanisms through which firms can radically redefine their business logic to create, deliver, and capture value in new and unique ways. In the rapidly advancing EV supply chain systems, this innovation is critical as it addresses how firms can restructure their operations to leverage emerging opportunities and technologies, thus securing a competitive advantage (Evans et al., 2017; Foss & Saebi, 2018). As Costa et al. (2022) and Hall & Roerich (2016) highlight, adapting business models within the EV industry allows nations and firms to strategically navigate global market shifts, ensuring sustainable sourcing of raw materials, effective integration of advanced technologies, and responsiveness to regulatory changes (Costa et al., 2022; Hall & Roelich,

2016). Moreover, the adoption of sustainable business models as discussed by Jagan et al. (2023), demonstrates the importance of integrating environmental and social governance practices into the core strategy of manufacturing firms, which is increasingly relevant in the EV industry (Jagani et al., 2023). Empirical applications by Amit and Zott (2001), Chesbrough (2010) illustrate how business model innovation can lead to new sources of value creation and growth, reinforcing the argument that in the context of EV supply chain systems, such innovations are not merely beneficial but necessary for maintaining competitiveness (Amit & Zott, 2001; Chesbrough, 2010; Foss & Saebi, 2018; Massa et al., 2017)

Benchmarking Theory

Benchmarking theory is centered on the concept of measuring an organization's processes, performance, and products against the best industry standards or practices. Benchmarking becomes a strategic tool for nations to assess the efficiency and effectiveness of their EV supply chain systems. By comparing national systems against leading global standards, countries can pinpoint critical areas for improvement and opportunities for innovation within their supply chains. This comparative analysis is vital because it allows for the adoption of best practices and the integration of advanced processes that contribute to the development of a robust and competitive EV industry (Hoang et al., 2023).

Benchmarking is particularly important in the EV sector due to the industry's rapid evolution and the complex network of suppliers, manufacturers, and technology involved. The ability to measure up to and exceed international benchmarks can result in improved supply chain resilience, cost efficiencies, and technological advancements. The foundational work by Robert C. Camp and the practical applications developed through Xerox's "Leadership Through Quality" initiative have been instrumental in advancing benchmarking theory (Camp, 1993). Subsequent empirical research, such as Ammons and Dale J. Roenigk 's (2015) study on public performance, Cantagallo et al.'s (2016) strategic application of benchmarking, and Anand and Kodali's (2008) manufacturing performance assessment, further demonstrate the utility of benchmarking across different sectors (Ammons & Roenigk, 2015; Anand & Kodali, 2008; Battagello et al., 2016). These contributions are crucial for nations looking to enhance their competitive stance in the EV market by identifying gaps, setting performance targets, and implementing best practices to optimize their supply chain systems for sustained international success.

Conceptual Framework

A conceptual framework is pivotal as it offers a structured approach for research, guiding the identification and analysis of key variables and their interrelations within national benchmarking studies (Yeravdekar & Behl, 2017). It enables the integration of insights across multiple disciplines to assess and enhance countries' positions in the global EV market through strategic benchmarking, highlighting performance indicators and areas for improvement. Furthermore, this framework facilitates effective

communication among stakeholders, supports strategic planning and policy formulation, and encourages adaptability and innovation by forecasting emerging trends. Thus, it plays a crucial role in helping nations achieve and sustain a competitive edge in the evolving electric vehicle supply chain landscape (Reinhardt et al., 2020).

Figure 1 presents a conceptual framework that outlines the key phases in the development of the electric vehicle (EV) ecosystem, beginning with the influence of global market dynamics and industrial policy priorities on EV ecosystem formation. It emphasizes two core components of formation: EV Production Infrastructure Orientation, focusing on the establishment and alignment of manufacturing capabilities, and EV Market Adoption Prioritization, which involves strategies to encourage consumer uptake of EVs. Following formation, the framework transitions into the EV Ecosystem Implementation phase, which includes the practical integration of production infrastructure and the consideration of consumer market choices, reflecting the response to the formation strategies.

This framework provides a comprehensive view of the progression from market and policy influences on the tangible growth and transformation of the EV industry. It serves as a roadmap for stakeholders to understand how initial market trends and policies can shape the strategic development of an industry that is crucial to the future of sustainable transportation. Moreover, it delineates the evolution of the EV ecosystem, emphasizing the importance of growth and transformation in achieving long-term industry sustainability and success. This framework is essential for policymakers, industry leaders, and researchers as it provides a structured approach to analyze the effectiveness of different strategies and their outcomes, ensuring that the EV industry's trajectory aligns with broader environmental goals and market viability.

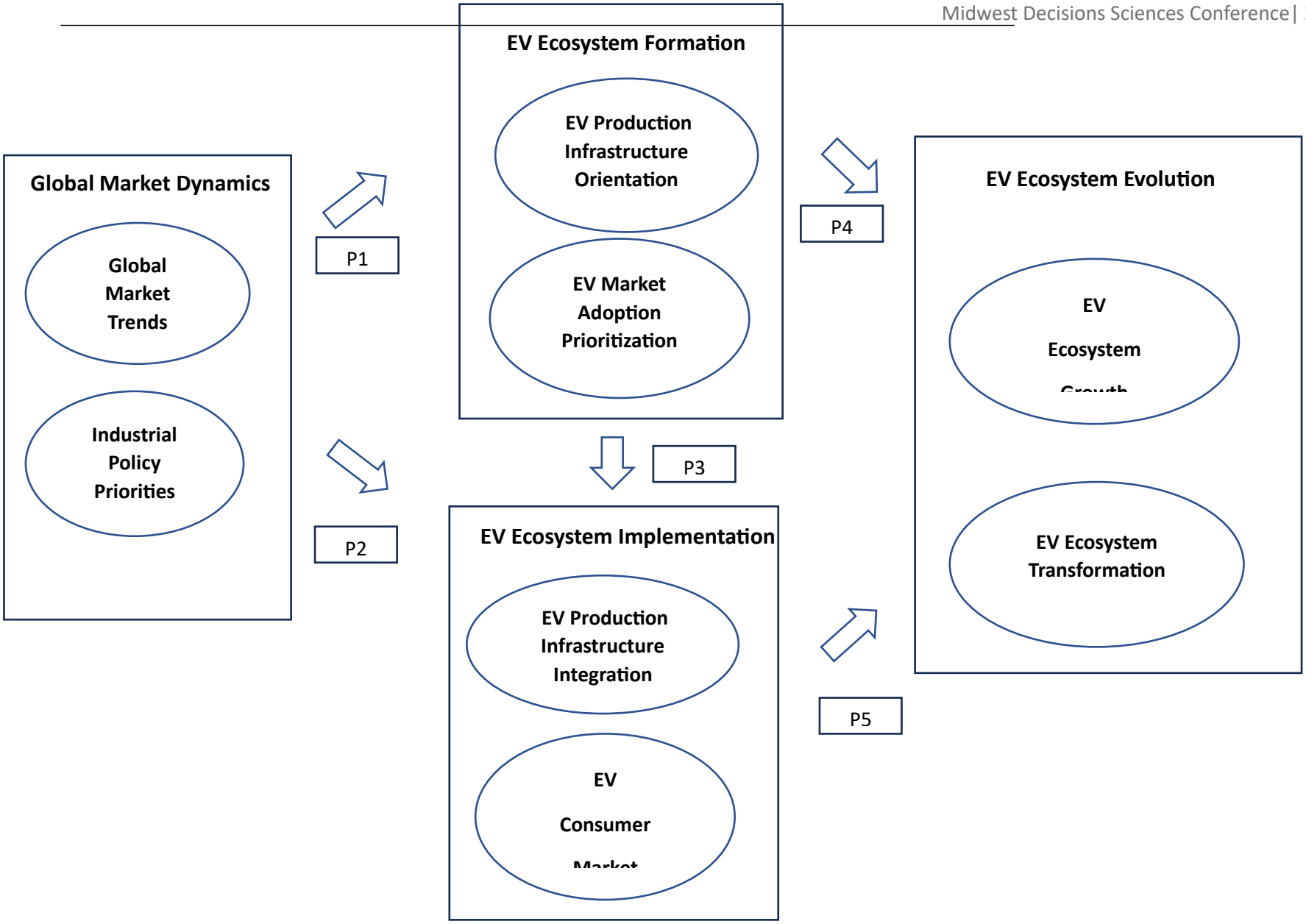

Global Market Dynamics
Global Market Trends
Industrial Policy Priorities
P1
P2
EV Ecosystem Formation
EV Production Infrastructure Orientation
EV Market Adoption Prioritization
P3
EV Ecosystem Implementation
EV Production Infrastructure Integration
EV Consumer Market
P4
P5
EV Ecosystem Evolution
EV Ecosystem Growth
EV Ecosystem Transformation

Figure 1. Conceptual Framework: Market Dynamics, Ecosystem Formation, Implementation and Evolution

Table 1 in the research serves as a comprehensive framework categorizing the pivotal factors and key indicators for developing competitive advantages within the Electric Vehicle (EV) supply chain systems. The table is systematically split into two sections, with the first part addressing broad trends and initiatives like Global Market Trends, Industry Policy Initiatives, EV Infrastructure Orientation, and EV Market Prioritization. These encompass the current movements in the market, the role of government in supporting the EV industry, the development of essential production and support systems, and the strategies to boost consumer adoption of EVs. The second part of the table dives into EV Production Infrastructure Integration, EV Consumer Market Choices, EV Ecosystem Growth, and EV Ecosystem Transformation, focusing on the integration of EV manufacturing processes, consumer demands, market expansion, and ecosystem evolution which together drive the value creation and business model innovation within the EV sector.

Table 1 provides a practical perspective on the elements that form a robust and competitive EV ecosystem, enabling an in-depth assessment of a country's strengths and areas for improvement in its EV supply chain. It also functions as a vital benchmarking framework, allowing nations to measure their supply chain systems against international standards and pinpoint potential areas for strategic enhancement. This benchmarking capability not only directs policymakers and industry leaders toward data-driven decisions but also underpins the strategic insights necessary for elevating national capabilities in the EV supply chain. Hence, Table 1 stands as an integral part of the research, laying the empirical and conceptual groundwork for analyzing, assessing, and boosting competitive edges within national EV supply chain systems.

Table 1. EV Ecosystem: Constructs and Key Indicators

Key Factors and Definition	Key Indicators and Definition
Global Market Trends refer to the prevailing movements and directions in the worldwide market that impact the electric vehicle industry, including shifts in consumer behavior, technological advancements, and economic factors that drive the supply and demand for EVs on a global scale in shaping the competitive landscape and fostering innovation within the EV sector (Bierau et al., 2016; Gereffi et al., 2010; Gonzalez-Loureiro et al., 2015; Handfield et al., 2013)	▪ **International EV Adoption Growth** captures the percentage of new car sales represented by electric vehicles in various countries, reflecting the global shift in consumer preferences towards more sustainable transportation options. It serves as a key indicator of how quickly different regions are embracing electric mobility and the effectiveness of policies aimed at promoting EV usage (Gielen et al., 2019; Jackson et al., 2018; Wang et al., 2019). ▪ **Technological Innovation Advancements** measures the extent of technological progress within the electric vehicle industry, including battery performance, charging technology, and vehicle efficiency improvements. It assesses the pace of innovation and its role in reducing costs, improving range, and enhancing the overall appeal of EVs to consumers worldwide, thereby influencing global market trends (Coccia, 2017; Gorjian et al., 2021; Lee et al., 2018).
Industry Policy Initiatives are the series of strategic actions and regulatory measures implemented by governments to support and enhance the electric vehicle industry, such as the creation of EV-friendly legislation, R&D funding, and infrastructure grants, which are designed to foster an environment conducive to EV growth and innovation. (Gereffi & Lee, 2016; Hsu et al., 2013; Kester et al., 2018; Zhang et al., 2014)	▪ **Government Subsidies and Tax Incentives for EVs** quantify the financial incentives provided by governments to encourage the purchase and use of electric vehicles. It includes direct subsidies to reduce the purchase price of EVs, tax credits, rebates for consumers, and other fiscal measures aimed at making EVs more financially attractive to both consumers and manufacturers. By measuring the extent and generosity of these incentives, one can assess how policy initiatives are being used to stimulate demand and support the EV market (Gong et al., 2020; Shao et al., 2017; Yan, 2018; X. Zhang et al., 2018). ▪ **Investment in EV Charging Infrastructure** measures the level of investment, both public and private, in developing and expanding the electric vehicle charging network. It includes the number of charging stations, the geographic coverage of charging infrastructure, and the availability of fast-charging options. This variable is crucial for evaluating how policy initiatives are addressing one of the key barriers to EV adoption—charging convenience and accessibility—and facilitating the integration of electric vehicles into the transportation system (Fang et al., 2020; Madina et al., 2016; L. Zhang et al., 2018).
EV Infrastructure Orientation encompasses the strategic alignment and development of the foundational elements necessary for electric vehicle production and support, such as investments in charging station networks, energy grid updates, and the establishment of battery manufacturing capabilities to facilitate	▪ **Charging Station Network Density** quantifies the distribution and availability of EV charging stations within a defined geographic area, measuring the number of charging points per square kilometer or per capita. It reflects the strategic efforts to create a robust and accessible charging infrastructure, which is essential for supporting the current and future needs of EV users. A higher density indicates a stronger orientation towards accommodating EVs, facilitating their adoption by reducing range anxiety and improving convenience (Andrenacci et al., 2016; Giménez-Gaydou et al., 2016; Wang & Deng, 2019). ▪ **Battery Manufacturing Capacity** measures the total production capability of battery manufacturing facilities dedicated to electric vehicles within a region or country, often expressed in gigawatt-hours (GWh) per year. It reflects

the growth of the EV sector. (Dong et al., 2014; Madina et al., 2016; Morrissey et al., 2016).	the strategic investment in establishing a local or national supply chain for EV batteries, which is crucial for reducing dependency on imports, securing the supply of critical components, and supporting the overall growth of the EV sector. An increase in battery manufacturing capacity signifies a forward-looking orientation towards strengthening the foundational elements of the EV infrastructure (Jajja et al., 2021; Mauler et al., 2021; Niri et al., 2021).
EV Market Prioritization reflects the deliberate focus and incentivization by stakeholders, including policymakers and industry leaders, to accelerate consumer adoption of electric vehicles through subsidies, educational initiatives, and marketing strategies aimed at positioning EVs as a preferable alternative to traditional vehicles (Bakker et al., 2014; van der Koogh et al., 2023; X. Zhang et al., 2018).	▪ **EV Purchase Incentives** captures the range and magnitude of financial incentives provided to consumers for purchasing electric vehicles, such as tax credits, rebates, and subsidies. It directly measures the efforts made by governments or industry bodies to lower the cost barrier for consumers, making EVs more financially attractive compared to traditional internal combustion engine vehicles. The effectiveness of these incentives in boosting EV sales can serve as a key indicator of market prioritization and the commitment to accelerating EV adoption (S.-C. Ma et al., 2019; Wang et al., 2021; Wee et al., 2018). ▪ **Public Awareness and Educational Campaigns** assesses the extent and impact of informational and educational campaigns designed to raise public awareness about the benefits of electric vehicles, including environmental advantages, lower operating costs, and government incentives. It might include metrics such as campaign reach, frequency, and changes in public perception or knowledge levels regarding EVs. This variable reflects strategic efforts to change consumer attitudes and preferences towards electric vehicles, further indicating a prioritized market development approach by highlighting the long-term advantages of EV adoption (Austmann & Vigne, 2021; Bailey et al., 2015; Okada et al., 2019; Zhang et al., 2011).

Table 1. EV Ecosystem: Constructs and Key Indicators

Key Factors and Definition	Key Indicators and Definition
EV Production Infrastructure Integration encapsulates the assimilation of EV manufacturing processes and technologies within the existing automotive production landscape, characterized by the adoption of specialized machinery, the establishment of dedicated EV assembly lines, and the alignment with renewable energy sources for a greener manufacturing footprint (Gu et al., 2017; Holland et al., 2021; Zhang, 2014).	▪ **Industry Market Size** measures the total value of the semiconductor industry within a country, encompassing the country's overall revenue from semiconductor sales. It would also include the country's share in global semiconductor manufacturing, which reflects its position and influence in the international market (Beneito et al., 2015; Scherer, 1965; Xin et al., 2015). ▪ **Investment Intensity** captures the amount of investment dedicated to research and development (R&D) in the semiconductor sector. It would also take into account the level of capital investment in semiconductor fabrication plants (fabs) and the presence and activities of major industry players within the country. This variable is crucial for understanding the potential for innovation and advancement in the industry(Li et al., 2023; Raitano & Vona, 2017; Zhang & Yi, 2024).
EV Consumer Market Choices encompass the range of options and preferences expressed by consumers in the electric vehicle market, including the selection of EV models based on performance, price, design, and available charging infrastructure, reflecting the market's response to consumer demand and driving forces behind EV sales trends (Huang et al., 2021; Liao et al., 2019; Mandys, 2021).	▪ **EV Model Preference** measures consumers' preferences among different EV models, categorizing choices based on factors like performance, price, design, and environmental impact. It reflects the diverse criteria consumers use to decide which EV suits their needs and desires, offering insight into how specific attributes drive market demand (Axsen et al., 2015; Liao et al., 2017; Shin et al., 2015). ▪ **Charging Infrastructure Satisfaction** assesses consumer satisfaction with the availability and convenience of EV charging infrastructure, including public and home charging options. It gauges the extent to which charging infrastructure meets consumer needs and influences their decision to purchase an EV, serving as a critical determinant of EV adoption rates (Globisch et al., 2019; Hardman et al., 2018; Liu et al., 2018).
EV Ecosystem Growth refers to the expansion of the electric vehicle industry in terms of market size, production volumes, and geographic reach, such as the increase in EV sales globally and the spread of EV adoption across different regions highlighting a comprehensive evolution of the ecosystem supporting electric mobility (Alarcón et al., 2023; Rong et al., 2017).	▪ **Supply Chain Robustness** assesses the strength and stability of the supply chain, particularly the consistent availability of essential raw materials and components needed for semiconductor manufacturing. It can be measured by metrics such as the diversification of raw material sources, the number of suppliers for critical components, and the inventory turnover ratio(Durach et al., 2015; Govindan & Fattahi, 2017; Simchi-Levi et al., 2018). ▪ **Supply Chain Agility** evaluates the ability of the supply chain to quickly adapt to disruptions, changes in demand, or other unforeseen events. It can be quantified by the speed of recovery from supply chain disruptions, the flexibility of logistics and distribution networks to reroute or modify operations, and the effectiveness of established backup systems and contingency plans (Eckstein et al., 2015; Gligor et al., 2015; Patel & Sambasivan, 2022).
EV Ecosystem Transformation denotes the qualitative changes and advancements within the electric vehicle industry that enhance its	▪ **Regulatory Alignment and Compliance** measures the degree to which a country's semiconductor industry aligns with international technology standards and regulations. It can include assessments of how national regulations

value chain, including the integration of new technologies, the transition to sustainable energy sources, and the evolution of business models to support a more robust EV infrastructure (Dehkordi et al., 2024; Lu et al., 2014; Rong et al., 2017).	match up with global best practices, the ease of compliance for semiconductor firms, and the country's participation in international regulatory bodies (Gray & Silbey, 2014; Hashmi et al., 2016; Outa & Waweru, 2016). ▪ **Government Support and Trade Dynamics** evaluates the extent and impact of government support for the semiconductor industry, which can include financial subsidies, tax incentives, and investment in industry-related research. It also measures the influence of trade agreements and export-import controls on the industry, reflecting how trade policies facilitate or hinder the industry's growth and competitiveness in global markets (Doh & Kim, 2014; Rasiah et al., 2016; Sydow & Müller-Seitz, 2020).

Proposition Development

Proposition development is crucial in the study of as it provides a structured approach to formulating and testing specific hypotheses about how various factors influence competitiveness in the EV industry. By clearly defining propositions, researchers can direct their investigation towards key aspects of the EV supply chain, ensuring a focused and hypothesis-driven analysis. This process not only facilitates the efficient allocation of research resources but also aids in building or testing theories related to competitive advantage. Moreover, the insights gained from testing these propositions can offer valuable strategic guidance to policymakers and industry stakeholders, driving informed decision-making and highlighting areas for innovation and improvement within the EV supply chain. Thus, proposition development serves as a foundational step in exploring and enhancing the competitive dynamics of the EV market (Adnan et al., 2017; Brodie et al., 2011).

Global Market Dynamics and EV Ecosystem Formation

Global market dynamics, including trends and policy directives, are instrumental in shaping the foundational stage of the EV ecosystem, which is concerned with establishing production infrastructure and fostering market readiness for EV adoption. As international market trends increasingly favor eco-friendly and technologically advanced vehicles, and as governments enact policies to bolster this shift, a deliberate focus is placed on creating a robust EV production infrastructure and promoting the adoption of EVs among consumers (Gupta et al., 2020; Jaiswal & Zane, 2022; Kim et al., 2021; Tarigan, 2019). These global forces are vital for nurturing fertile ground that supports the burgeoning EV industry and stimulates its growth.

Hence, the intensity and direction of global market forces and policy initiatives are directly correlated with the establishment and effectiveness of the EV ecosystem formation, influencing variables such as the capacity and readiness of production infrastructure and the prioritization of EVs within the market.

Thus, it is posited,

P1: The more pronounced and targeted the Global Market Dynamics, specifically through Global Market Trends and Industrial Policy Priorities, the more pronouncedly will the EV Ecosystem Formation be realized, as seen in the strategic development of EV Production Infrastructure Orientation and the heightened emphasis on EV Market Adoption Prioritization.

Global Market Dynamics and EV Ecosystem Implementation

The dynamics within the global market, encompassing shifts in market trends and the strategic direction of industrial policies, profoundly impact the implementation phase of the EV ecosystem. This phase is characterized by tangible actions such as the integration of EV production infrastructures, such as the development of specialized machinery and battery manufacturing capabilities (Gu et al., 2017; Yang et al., 2022), and the alignment of consumer

market choices with the evolving landscape of electric vehicles (Liao et al., 2017; Shin et al., 2015).

As consumer behavior increasingly favors sustainable transportation options and governments provide incentives and regulatory support, the infrastructure necessary to produce and support EVs is more likely to be developed and integrated into the existing automotive landscape (Mandys, 2021). Additionally, these global dynamics steer consumer preferences and choices in the EV market, influencing the demand for and accessibility to a wide range of EV models and the supporting charging infrastructure. Therefore, it is posited,

P2: The stronger the Global Market Dynamics, reflected in comprehensive Global Market Trends and deliberate Industrial Policy Priorities, the more significantly the EV Ecosystem Implementation is advanced, evidenced by the robust integration of EV Production Infrastructure and the broadening of EV Consumer Market Choices.

EV Ecosystem Formation and EV Ecosystem Implementation

The formation of the EV ecosystem, guided by the strategic orientation towards EV production infrastructure and the prioritization of EV market adoption, critically shapes its implementation, which includes the practical integration of EV production facilities and the accommodation of consumer preferences in the EV market (Y. Ma et al., 2019). The strategic choices made during the ecosystem's formation—like investing in manufacturing capabilities specific to EVs and creating a favorable market environment through policy and incentives—lay the groundwork for how the EV market takes shape (Shao et al., 2019; Zhang et al., 2014; Zhou et al., 2019). These foundational decisions dictate the ease with which production infrastructure can be incorporated into the automotive sector and influence the extent to which consumer choices can be aligned with available EV options (Q. Zhang et al., 2018). Hence, the depth and direction of the ecosystem's formation directly translate into the effectiveness and reach of its implementation, impacting variables such as the variety and uptake of EV models and the development of a comprehensive charging network.

Thus, it is posited,

P3: The more deliberate and focused the EV Ecosystem Formation, particularly in terms of EV Production Infrastructure Orientation and EV Market Adoption Prioritization, the more effectively the EV Ecosystem Implementation occurs, as seen in the comprehensive integration of production infrastructure and the alignment of EV offerings with consumer market choices.

4.4. **EV Ecosystem Formation** and **EV Ecosystem Evolution**

The initial establishment of the EV ecosystem, characterized by the orientation towards developing EV production infrastructure and strategies for market adoption, is instrumental in

dictating the trajectory of its evolution, which includes the ecosystem's growth and transformative changes (Agbesi et al., 2023).

The decisions and directions taken during the ecosystem's formation set a definitive path for future development. The emphasis on constructing EV-specific production capabilities and creating market conditions conducive to EV adoption not only fuels the initial uptake of EVs but also paves the way for the ecosystem to expand, innovate, and transform (Chhikara et al., 2021; Khatua et al., 2023; Kumar et al., 2021; Shi et al., 2023). These foundational measures are pivotal in steering the direction of the ecosystem's evolution, determining how it adapts to new challenges and opportunities over time, and how it scales in response to technological advancements and market forces. Consequently, the clarity and robustness of the ecosystem's formation are directly linked to the dynamism and resilience of its evolution, affecting aspects such as the diversification of the EV market, the maturation of technology, and the sustainability of the industry's growth.

Therefore, it is posited,

P4: The more strategic and targeted the EV Ecosystem Formation, specifically in terms of EV Production Infrastructure Orientation and EV Market Adoption Prioritization, the more profound and dynamic the EV Ecosystem Evolution will be, as evidenced by the expansion of the EV market and the progressive transformation of the ecosystem itself.

4.5. **EV Ecosystem Implementation** and **EV Ecosystem Evolution**

The implementation phase of the EV ecosystem, which entails the concrete development of EV production infrastructure and the shaping of consumer market choices, serves as a critical precursor to and a determinant of the ecosystem's subsequent evolution (Das et al., 2020). This evolution is characterized by the growth and transformation of the EV sector.

The meticulous integration of EV production facilities into the existing automotive framework, along with efforts to sync consumer preferences with the availability of EV options, lays the foundation for the ecosystem's future trajectory (Erdinc et al., 2015; Singh et al., 2020). As these elements become more entrenched and consumer options expand, the EV ecosystem is primed for growth and is likely to undergo significant transformations. This stage of implementation, therefore, not only influences the immediate accessibility and adoption of EVs but also seeds the potential for the ecosystem's continuous development, scalability, and adaptability to future advancements and market dynamics (Secinaro et al., 2020). As such, the effectiveness of implementation efforts is inherently tied to the vigor and flexibility of the ecosystem's evolution, impacting factors such as market diversity, technological progression, and the overall robustness of the EV industry. Therefore, it is posited,

P5: The more comprehensive and thorough the EV Ecosystem Implementation, particularly through the integration of EV Production Infrastructure and the cultivation of EV Consumer Market Choices, the more significant and far-reaching the EV Ecosystem Evolution will be, as evidenced by sustained growth and the transformative development within the EV sector.

Design Benchmarking Studies of Ten Countries

The design process of benchmarking studies for the EV market necessitates formulating precise hypotheses and a robust research framework (Collis & Hussey, 2009). Effective action plans involve systematic data gathering—both quantitative metrics and qualitative insights—tailored to the strategic selection criteria that target countries leading in EV adoption and policy engagement. The anticipated outcomes will categorize these countries by their EV ecosystem efficacy, revealing industry best practices and challenges, and delivering strategic intelligence to stakeholders.

5.1. Design Process of Benchmarking studies

The design process of benchmarking studies, especially in the context of the EV industry, involves a systematic and iterative approach to establish a comparative analysis framework (Figure 1). Initially, the process begins with the selection of relevant benchmarks, drawing on the constructs and key indicators (Table 1). These benchmarks are chosen to capture the multi-dimensional aspects of the EV ecosystem, such as infrastructure readiness, market dynamics, policy environment, and technological innovation. Researchers then operationalize these benchmarks into measurable variables, ensuring they are applicable across different national contexts and can yield insights into the competitive dynamics of the sector. This step is followed by the development of propositions, as seen in the research model, which are hypothesis-driven statements that predict relationships between these variables. These propositions are informed by the conceptual framework illustrated in Figure 1, which maps the interactions between global market dynamics, EV ecosystem formation, implementation, and evolution (Delbridge et al., 1995).

Once the framework is set, researchers collect data from the selected countries, utilizing both primary and secondary sources to ensure depth and accuracy. This data collection is guided by the predefined variables and is meticulously designed to allow for comparability (Alsharari & Aljohani, 2023). The subsequent analysis entails evaluating the data against the propositions, employing statistical tools and qualitative assessments to uncover patterns, disparities, and underlying causes of different performance levels across the nations studied. This analysis not only identifies the strengths and weaknesses within each country's EV ecosystem but also provides insights into how different factors interrelate and influence one another. The goal of the benchmarking study design is to create actionable intelligence that can be used by stakeholders to inform strategy, policy, and operational decisions, driving the EV industry towards more sustainable and competitive practices (Warnecke et al., 2019). The findings from these studies offer valuable guidance on where to allocate resources, which policies to

enact, and what strategic initiatives to prioritize to bolster the growth and evolution of the EV ecosystem.

5.2. Effective Action Plans for Benchmarking Studies

For effective benchmarking studies of the electric vehicle (EV) sector across various nations, a detailed and systematic strategy is paramount (Cohen et al., 2015). We have initially established specific, pertinent criteria and indicators for assessment, leveraging factors such as EV Production Infrastructure Integration and EV Ecosystem Transformation, as delineated in Table 1. This encompasses the acquisition of both quantitative and qualitative data, including but not limited to market size, research and development expenditures, supply chain resilience, and policy frameworks. It is also critical to incorporate qualitative elements—such as the level of government backing, consumer predilections, and the range of available EV models—to fully encapsulate the multifaceted nature of the EV ecosystem. Ensuring that data is up-to-date, valid, and uniform across all countries is crucial, as is considering distinctive local factors—like specific policy environments, economic statuses, and cultural perceptions of EVs—that could steer the development and efficacy of the EV ecosystem.

Following data collection, we plan to engage in relevant analysis, employing diverse statistical methodologies to discern trends, connections, and cause-and-effect dynamics within the data. Techniques like multidimensional scaling method, selective regression analysis examine the relationship between governmental incentives—a component of Global Market Dynamics—and EV adoption rates. The objective is to pinpoint exemplary practices and effective strategies conducive to a thriving EV ecosystem and to identify shared obstacles or deficiencies. This stage should also scrutinize the interaction among various factors—for example, the influence of EV Production Infrastructure Integration on the growth and metamorphosis of the EV ecosystem. The insights derived should be transformed into practical guidance to assist decision-makers in enhancing the EV sector's competitive edge. Ultimately, the benchmarking study should culminate in a comprehensive report that not only compares and contrasts the countries based on the established criteria but also delves into the subtleties behind the rankings, thus enriching the understanding of each nation's standing in the global EV domain.

5.3. Selection Criteria of Ten Countries for Benchmarking Studies

The selection criteria for the ten countries in the benchmarking studies are strategically chosen to ensure that each participant is a key player in the global EV market. This requires the presence of a robust EV market, indicated by an adequate number of EV sales and registrations, which serves as a proxy for consumer adoption and market maturity. Additionally, active government participation through industrial policy initiatives is essential; these countries should exhibit clear, strategic frameworks and support mechanisms that foster the EV market, such as subsidies, tax incentives, or investment in infrastructure. The formulation of the EV ecosystem in these countries should demonstrate a proactive approach in establishing production facilities, encouraging R&D, and integrating supply chains. The implementation of these strategies should be observable through the deployment of EVs and the establishment of a supportive infrastructure. Finally, outcome measures must be tangible, showcasing

growth in the EV sector, advancements in technology, and a positive environmental impact, indicating a successful evolution of the EV ecosystem.

The second aspect of the selection criteria hinges on the availability and quality of data. For a comprehensive benchmarking study, it is critical to have access to relevant descriptive data that encompasses market size, growth rates, and infrastructure availability. Financial data from key firms within the EV industry, including sales revenue, R&D spending, and market capitalization, will provide insight into the economic health and investment climate of the EV ecosystem. Additionally, visible EV ecosystem industries should be identifiable, with a clear presence of manufacturers, service providers, and supply chain participants. Media reports from reputable sources will also be instrumental in providing qualitative insights into market trends, consumer attitudes, and the perceived effectiveness of government policies. This data will form the backbone of the benchmarking study, allowing for a robust comparison across the selected countries' EV ecosystems.

For national benchmarking studies in the Electric Vehicle (EV) ecosystem, when establishing selection criteria for a benchmarking study in the EV ecosystem, it is essential to consider a diverse range of factors that capture the full spectrum of global EV leadership and potential. This includes advanced economies that are current EV ecosystem leaders, distinguished by their substantial investments in R&D, advanced manufacturing capabilities, and considerable market size with high EV adoption rates. These nations showcase the pinnacle of what is achievable in the EV sector, with robust infrastructure and market conditions that support the sustained growth and evolution of electric mobility. The criteria must, therefore, prioritize countries that demonstrate a strong commitment to the development of EV technology through both public and private sector investments, and that have the manufacturing prowess and market conditions conducive to fostering a thriving EV environment.

In parallel, the criteria must also identify emerging economies that exhibit significant potential for EV ecosystem development. This potential is characterized by large population sizes that signal burgeoning market opportunities, explicit government policy priorities favoring the EV industry, and active pollution control measures that necessitate a shift to cleaner transportation methods. Additionally, the international strategic alliances and collaborative arrangements that these countries forge are critical, as they indicate a willingness to engage in global technology exchanges, investment opportunities, and supply chain integrations essential for the advancement of their EV sectors. The selected countries for the study should be representative of both these established and emerging facets, offering insights into the current state of EV advancements and the dynamic growth prospects shaped by strategic demographic, policy, and partnership initiatives on the global stage. According to these criteria, the following countries are chosen for our study.

- China: As the largest automotive market in the world, China has made significant investments in EV technology and infrastructure. It offers substantial government subsidies and has a rapidly growing network of charging stations.
- United States: With numerous incentives for EV buyers and increasing investment in charging infrastructure, the U.S. has a robust and innovative EV market, home to leading EV companies like Tesla.
- Norway: Known for having the highest per capita number of all-electric cars, Norway's

aggressive incentives for EVs and a strong commitment to environmental sustainability make it a leader in the EV space.

- Germany: As the birthplace of the automobile, Germany has a strong automotive industry and is investing heavily in electrification, with a goal to become a leading market for EVs.
- Japan: With a history of innovation in the automotive sector, Japan has been a pioneer in hybrid technology and is now pushing towards fully electric vehicles with substantial investments in technology and infrastructure.
- South Korea: With companies like Hyundai and LG Chem leading in battery technology and vehicle production, South Korea is a significant player in the EV market.
- France: France is notable for its early adoption of EVs, supportive government policies, and a strong network of charging points.
- Brazil: Brazil's potential as an EV market is bolstered by its substantial bioenergy sector, which could provide a unique synergy with electric mobility, particularly in the development of flex-fuel electric vehicles (hybrids that can use ethanol). Additionally, Brazil has a strong manufacturing base and government support for local automotive production, which could pivot to EVs in the future.
- Netherlands: The Netherlands has one of the densest charging networks globally and strong policy support for EV adoption, making it an important market for EVs.
- United Kingdom: The UK government has set ambitious targets for EV adoption and is supporting this transition with investments in infrastructure and incentives.
- Sweden: Sweden's dedication to sustainability has led to supportive policies for EVs, including tax breaks and incentives, positioning it as a leader in the adoption of clean vehicles.
- India has recently seen a push towards electric mobility, spurred by government initiatives like the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme and plans to build charging infrastructure. India's vast market potential, coupled with government incentives to both manufacturers and consumers, makes it an intriguing case for study, especially considering its challenges related to infrastructure and technology adaptation.
- Mexico, with its strong automotive manufacturing industry, is an important player in the North American market. The country's proximity to the U.S. and its extensive auto parts manufacturing makes it a key candidate for EV production. While consumer adoption is still nascent, the potential for growth and the country's strategic position as a manufacturing hub could offer valuable insights into how EV ecosystems can develop in regions with established automotive industries.
- Israel has a burgeoning high-tech sector and is rapidly becoming a hotbed for automotive innovation, particularly in the EV and autonomous driving spaces. With companies like Store Dot, which is developing fast-charging battery technology, Israel is a prime example of how advanced technology can spur EV adoption. The country's strong push for innovation, coupled with government incentives for electric cars, makes it an interesting case for studying the impact of cutting-edge technology on national EV ecosystems.
- Canada presents a case of a large, resource-rich country with significant regional variation in EV adoption. Some provinces like Quebec and British Columbia have introduced substantial incentives for EV purchases and are investing in charging infrastructure. Canada's abundant clean electricity resources, its commitment to reducing greenhouse gas emissions, and its automotive manufacturing expertise position it as a strategic player in North America's EV market.
- Italy has a rich automotive history and is known for its luxury and performance car industry. The country has been slower in the adoption of EVs compared to other European nations, but recent incentives and the growth of the charging infrastructure network are changing the landscape. Italy's focus on design and engineering excellence could potentially lead to significant

contributions to the aesthetic and performance aspects of EVs.

- Saudi Arabia represents a unique case in the transition to electric vehicles. As one of the world's largest oil producers, the country has a vested interest in the global energy market. However, Saudi Arabia is also looking towards the future with its Vision 2030 initiative, which includes plans to diversify its economy and invest in renewable energy and sustainable practices. The country has started taking steps towards developing its EV market, which makes it a compelling study in how an oil-rich nation approaches the shift to electric mobility and how it balances its traditional energy sector with new, sustainable technologies.
- South Africa, as the most industrialized country in Africa, has an established automotive industry and is beginning to explore the EV sector. The country faces unique challenges such as a reliance on coal for electricity and a need for substantial infrastructure investment. However, with the government's automotive production and development plan, there is potential for South Africa to become a leader in electric mobility on the continent, particularly if it can harness its renewable energy resources for EV charging.
- Nigeria, with one of the largest economies in Africa, has seen rapid urbanization and growth in its consumer base. The country's automotive market is still developing, and the introduction of EVs faces hurdles like inconsistent power supply and the need for infrastructure development. However, Nigeria's burgeoning tech sector and its potential for economic growth make it an important country to watch in the adoption of electric vehicles, especially considering its role as a significant oil producer.

These countries represent a diverse cross-section of the global EV ecosystem, each with unique strengths and approaches to the adoption of electric vehicles. China's market scale and government backing, the U.S.'s technological innovation, Norway's policy-driven market penetration, and Germany's automotive heritage are key differentiators. Japan and South Korea's technological expertise, particularly in battery manufacturing, places them at the forefront of EV development. The European countries of France, the Netherlands, the UK, and Sweden demonstrate strong policy environments and societal willingness to adopt EVs, with comprehensive charging networks and various incentives for consumers. This mix of market maturity, policy frameworks, and consumer adoption rates makes these countries ideal for benchmarking studies to understand the global EV landscape and draw valuable lessons for other nations aiming to enhance their EV ecosystems.

5.4. Methods of Benchmarking Studies

Our benchmarking methodology for evaluating the global electric vehicle (EV) ecosystem draws inspiration from the foundational work of Guzman et al. (2020), and Hong et al. (2012, 2023), employing national benchmarking methods to create a comprehensive analysis (Guzman et al., 2020; P. Hong, H.-W. Chen, et al., 2023; Hong et al., 2012). By selecting over twenty countries, we aim to cover a broad spectrum of EV ecosystem maturity, ensuring sufficient variability to analyze the various stages of EV adoption, the effectiveness of regulatory frameworks, market readiness, and the development of infrastructure. This approach allows us to collect data across a wide array of indicators, including EV policies, market size, infrastructure readiness, R&D capabilities, and more, laying the groundwork for a nuanced comparison of EV ecosystems at different stages of maturity.

The methodology involves a detailed process, starting with extensive data collection to develop performance metrics that include the number of EVs sold, market share, charging infrastructure,

government incentives, and R&D investment levels. These metrics serve as the basis for a comparative analysis to distinguish between leading and lagging countries in terms of their EV ecosystem development. Additionally, the analysis will consider contextual factors such as each country's energy mix, GDP per capita, geographic size, and urbanization rates, as well as the role of international strategic alliances and collaborations in shaping the EV landscape. This methodological framework, informed by the analytical insights provided by Goh and See (2021), Guzman et al. (2020), and recent studies by Hong et al. (2023), emphasizes the importance of collaborative learning and the integration of best practices across different sectors (Goh & See, 2021; Guzman et al., 2020; P. C. Hong et al., 2023).

By synthesizing the methodologies and insights from related benchmarking studies, including those on water utility benchmarking by Goh and See (2021), global health system strengthening by Guzman et al. (2020), and the digital and social governance insights from Hong et al. (2023), our study will offer a multidimensional perspective on the EV ecosystem. This benchmarking effort aims to map out the global EV landscape, identifying best practices, pinpointing strategic gaps, and highlighting areas ripe for growth. Ultimately, the study's main contribution is to provide a strategic blueprint for countries, policymakers, and industry stakeholders, guiding them through the complexities of transitioning towards a sustainable electric mobility future, thereby enriching the global discourse on EV adoption and integration (Francisco et al., 2020; P. Hong, N. Y. Ahn, et al., 2023; Kim et al., 2022; Zhang et al., 2021).

5.5. Expected Benchmarking Outcomes

Upon following a rigorous benchmarking design process and implementing effective actions, the expected outcomes of benchmarking ten countries in the EV sector would likely yield a rich data set delineating the strengths and weaknesses of each country's EV ecosystem. These outcomes would include a ranked profile of each country based on predefined criteria such as infrastructure development, policy effectiveness, market growth, and innovation capacity. The analysis would reveal which countries are leading in terms of EV adoption, production capabilities, and market development, as well as those lagging due to inadequate infrastructure or policy support. Furthermore, benchmarking would uncover best practices in fostering a vibrant EV market—such as effective subsidy schemes, tax incentives, or investment in charging infrastructure—that have proven successful in the leading countries. It would also identify common challenges that impede EV ecosystem development, such as supply chain constraints or consumer resistance, offering insights into potential areas for international cooperation or policy exchange.

The benchmarking outcomes would not only benchmark the current state of EV ecosystems but also provide predictive insights regarding future growth trajectories and innovation pathways. The findings could project which countries might experience burgeoning EV markets due to emerging policies or investments and which might face stagnation without strategic changes. By comparing diverse approaches to EV ecosystem development, the outcomes would also facilitate the transfer of knowledge across borders, enabling countries to learn from each other's experiences and adopt strategies suited to their specific context. This comparative analysis would be instrumental in guiding stakeholders—policymakers, industry leaders, investors, and researchers—to tailor their strategies to promote a more sustainable and competitive EV market globally.

Understanding these benchmarking outcomes is an important contribution as it provides a comprehensive, evidence-based assessment of where each country stands in the global race to transition to electric mobility. It informs stakeholders on how to prioritize resources and efforts to improve their national EV ecosystems, fosters international collaboration by highlighting successful policies and practices, and stimulates competition among countries, driving further innovation and investment in the sector. This benchmarking process not only serves as a snapshot of the current landscape but also acts as a catalyst for change, propelling the global EV industry toward a more sustainable and technologically advanced future. Such studies are essential for building a collaborative and forward-thinking approach to tackle the challenges of sustainable transportation and climate change.

6. Conclusion

The dynamic evolution of the Electric Vehicle (EV) ecosystem is a central theme of our study, emphasizing the need for countries to not only establish but also continuously refine their strategies in this rapidly changing industry. As technological innovation propels the market forward and consumer demands shift, maintaining competitiveness requires a commitment to ongoing improvement, adaptive policymaking, and active market engagement. This research underscores the diversity of the EV market across different nations, shaped by unique policy frameworks, consumer preferences, and levels of infrastructure readiness. It highlights the importance of customizing benchmarking studies to reflect these national differences, ensuring that strategic plans are both relevant to specific contexts and aligned with global best practices.

Our conclusions advocate for a multidimensional approach to enhancing a country's EV ecosystem, encompassing technological agility, policy evolution, infrastructure scalability, consumer engagement, market integration, and global collaboration. By fostering innovation, adjusting policies to support market growth, scaling infrastructure to meet increasing demand, engaging consumers effectively, integrating the EV market with broader economic sectors, and participating in international cooperation, countries can navigate the complexities of the EV landscape successfully. The benchmarking framework and strategic recommendations presented in this study are intended as ongoing tools for assessment and adaptation, guiding nations toward not just competitiveness but leadership in the shift towards electric mobility. This approach is crucial for realizing the broader objectives of sustainable development and environmental stewardship, addressing global climate challenges through the advancement of the EV market.

References

Adnan, N., Nordin, S. M., Rahman, I., Vasant, P. M., & Noor, A. (2017). A comprehensive review on theoretical framework-based electric vehicle consumer adoption research. *International Journal of Energy Research*, *41*(3), 317-335.

Agbesi, P. K., Ruffino, R., & Hakovirta, M. (2023). The development of sustainable electric vehicle business ecosystems. *SN Business & Economics*, *3*(8), 143.

Alarcón, F. E., Mac Cawley, A., & Sauma, E. (2023). Electric mobility toward sustainable cities and road-freight logistics: A systematic review and future research directions. *Journal of Cleaner Production*, 138959.

Alsharari, N. M., & Aljohani, M. S. (2023). The benchmarking implementation and management control process as influenced by interplay of environmental and cultural factors: institutional and contingency perspectives. *Benchmarking: An International Journal*.

Amit, R., & Zott, C. (2001). Value creation in e-business. *Strategic management journal*, *22*(6-7), 493-520.

Ammons, D. N., & Roenigk, D. J. (2015). Benchmarking and interorganizational learning in local government. *Journal of Public Administration Research and Theory*, *25*(1), 309-335.

Anand, G., & Kodali, R. (2008). Benchmarking the benchmarking models. *Benchmarking: An International Journal*, *15*(3), 257-291.

Andrenacci, N., Ragona, R., & Valenti, G. (2016). A demand-side approach to the optimal deployment of electric vehicle charging stations in metropolitan areas. *Applied Energy*, *182*, 39-46.

Austmann, L. M., & Vigne, S. A. (2021). Does environmental awareness fuel the electric vehicle market? A Twitter keyword analysis. *Energy Economics*, *101*, 105337.

Axsen, J., Bailey, J., & Castro, M. A. (2015). Preference and lifestyle heterogeneity among potential plug-in electric vehicle buyers. *Energy Economics*, *50*, 190-201.

Bachmann, N., & Jodlbauer, H. (2023). Iterative business model innovation: A conceptual process model and tools for incumbents. *Journal of Business Research*, *168*, 114177.

Bailey, J., Miele, A., & Axsen, J. (2015). Is awareness of public charging associated with consumer interest in plug-in electric vehicles? *Transportation Research Part D: Transport and Environment*, *36*, 1-9.

Bakker, S., Maat, K., & Van Wee, B. (2014). Stakeholders interests, expectations, and strategies regarding the development and implementation of electric vehicles: The case of the Netherlands. *Transportation Research Part A: Policy and Practice*, *66*, 52-64.

Battagello, F. M., Cricelli, L., & Grimaldi, M. (2016). Benchmarking strategic resources and business performance via an open framework. *International journal of productivity and performance management*, *65*(3), 324-350.

Beneito, P., Coscollá-Girona, P., Rochina-Barrachina, M. E., & Sanchis, A. (2015). Competitive pressure and innovation at the firm level. *The Journal of industrial economics*, *63*(3), 422-457.

Bierau, F., Perlo, P., Müller, B., Gomez, A. A., Coosemans, T., & Meyer, G. (2016). Opportunities for European SMEs in global electric vehicle supply chains in Europe and beyond. Advanced Microsystems for Automotive Applications 2015: Smart Systems for Green and Automated Driving,

Brand, C., Anable, J., & Morton, C. (2019). Lifestyle, efficiency and limits: modelling transport energy and emissions using a socio-technical approach. *Energy Efficiency*, *12*, 187-207.

Braz, A. C., & de Mello, A. M. (2022). Circular economy supply network management: A complex adaptive system. *International journal of production economics*, *243*, 108317.

Brodie, R. J., Hollebeek, L. D., Jurić, B., & Ilić, A. (2011). Customer engagement: Conceptual domain, fundamental propositions, and implications for research. *Journal of service research*, *14*(3), 252-271.

Camp, R. C. (1993). A bible for benchmarking, by Xerox. *Financial Executive*, *9*(4), 23-28.

Chesbrough, H. (2010). Business model innovation: opportunities and barriers. *Long Range Planning*, *43*(2-3), 354-363.

Chhikara, R., Garg, R., Chhabra, S., Karnatak, U., & Agrawal, G. (2021). Factors affecting adoption of electric vehicles in India: An exploratory study. *Transportation Research Part D: Transport and Environment*, *100*, 103084.

Chizaryfard, A., Lapko, Y., & Trucco, P. (2023). Strategic closed-loop supply chain configuration in the transition towards the circular economy of EV batteries: an evolutionary analytical framework. *The International Journal of Logistics Management*, *34*(7), 142-176.

Coccia, M. (2017). Sources of technological innovation: Radical and incremental innovation problem-driven to support competitive advantage of firms. *Technology Analysis & Strategic Management*, *29*(9), 1048-1061.

Cohen, S., Eimicke, W., & Miller, A. (2015). *Sustainability policy: hastening the transition to a cleaner economy*. Wiley Online Library.

Collis, J., & Hussey, R. (2009). *Business research: A practical guide for undergraduate and postgraduate students*. Palgrave macmillan.

Costa, E., Wells, P., Wang, L., & Costa, G. (2022). The electric vehicle and renewable energy: Changes in boundary conditions that enhance business model innovations. *Journal of Cleaner Production*, *333*, 130034.

Dania, W. A. P., Xing, K., & Amer, Y. (2019). Collaboration quality assessment for sustainable supply chains: benchmarking. *Benchmarking: An International Journal*, *26*(5), 1469-1498.

Das, H. S., Rahman, M. M., Li, S., & Tan, C. (2020). Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. *Renewable and Sustainable Energy Reviews*, *120*, 109618.

Dehkordi, R., Ahokangas, P., Evers, N., & Sorvisto, M. (2024). Business model design for Electric Commercial Vehicles (ECVs): An ecosystemic perspective. *Energy Policy*, *186*, 113971.

Delbridge, R., Lowe, J., & Oliver, N. (1995). The process of benchmarking: a study from the automotive industry. *International Journal of Operations & Production Management*, *15*(4), 50-62.

Doh, S., & Kim, B. (2014). Government support for SME innovations in the regional industries: The case of government financial support program in South Korea. *Research Policy*, *43*(9), 1557-1569.

Dong, J., Liu, C., & Lin, Z. (2014). Charging infrastructure planning for promoting battery electric vehicles: An activity-based approach using multiday travel data. *Transportation Research Part C: Emerging Technologies*, *38*, 44-55.

Durach, C. F., Wieland, A., & Machuca, J. A. (2015). Antecedents and dimensions of supply chain robustness: a systematic literature review. *International Journal of Physical Distribution & Logistics Management*, *45*(1/2), 118-137.

Eckstein, D., Goellner, M., Blome, C., & Henke, M. (2015). The performance impact of supply chain agility and supply chain adaptability: the moderating effect of product complexity. *International Journal of Production Research*, *53*(10), 3028-3046.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: what are they? *Strategic management journal*, *21*(10-11), 1105-1121.

Erdinc, O., Paterakis, N. G., Pappi, I. N., Bakirtzis, A. G., & Catalão, J. P. (2015). A new perspective for sizing of distributed generation and energy storage for smart households under demand response. *Applied Energy*, *143*, 26-37.

Evans, S., Vladimirova, D., Holgado, M., Van Fossen, K., Yang, M., Silva, E. A., & Barlow, C. Y. (2017). Business model innovation for sustainability: Towards a unified perspective for creation of sustainable business models. *Business Strategy and the Environment*, *26*(5), 597-608.

Fang, Y., Wei, W., Mei, S., Chen, L., Zhang, X., & Huang, S. (2020). Promoting electric vehicle charging infrastructure considering policy incentives and user preferences: An evolutionary game model in a small-world network. *Journal of Cleaner Production*, *258*, 120753.

Foss, N. J., & Saebi, T. (2018). Business models and business model innovation: Between wicked and paradigmatic problems. *Long Range Planning*, *51*(1), 9-21.

Francisco, A., Mohammadi, N., & Taylor, J. E. (2020). Smart city digital twin–enabled energy management: Toward real-time urban building energy benchmarking. *Journal of Management in Engineering*, *36*(2), 04019045.

Gereffi, G., Frederick, S., & Gereffi, G. (2010). The global apparel value chain, trade and the crisis: challenges and opportunities for developing countries.

Gereffi, G., & Lee, J. (2016). Economic and social upgrading in global value chains and industrial clusters: Why governance matters. *Journal of business ethics*, *133*(1), 25-38.

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy strategy reviews*, *24*, 38-50.

Giménez-Gaydou, D. A., Ribeiro, A. S., Gutiérrez, J., & Antunes, A. P. (2016). Optimal location of battery electric vehicle charging stations in urban areas: A new approach. *International Journal of Sustainable Transportation*, *10*(5), 393-405.

Gligor, D. M., Esmark, C. L., & Holcomb, M. C. (2015). Performance outcomes of supply chain agility: when should you be agile? *Journal of operations management*, *33*, 71-82.

Globisch, J., Plötz, P., Dütschke, E., & Wietschel, M. (2019). Consumer preferences for public charging infrastructure for electric vehicles. *Transport Policy*, *81*, 54-63.

Goh, K. H., & See, K. F. (2021). Twenty years of water utility benchmarking: A bibliometric analysis of emerging interest in water research and collaboration. *Journal of Cleaner Production*, *284*, 124711.

Gong, S., Ardeshiri, A., & Rashidi, T. H. (2020). Impact of government incentives on the market penetration of electric vehicles in Australia. *Transportation Research Part D: Transport and Environment*, *83*, 102353.

Gonzalez-Loureiro, M., Dabic, M., & Kiessling, T. (2015). Supply chain management as the key to a firm's strategy in the global marketplace: Trends and research agenda. *International Journal of Physical Distribution & Logistics Management*, *45*(1/2), 159-181.

Gorjian, S., Sharon, H., Ebadi, H., Kant, K., Scavo, F. B., & Tina, G. M. (2021). Recent technical advancements, economics and environmental impacts of floating photovoltaic solar energy conversion systems. *Journal of Cleaner Production*, *278*, 124285.

Govindan, K., & Fattahi, M. (2017). Investigating risk and robustness measures for supply chain network design under demand uncertainty: A case study of glass supply chain. *International journal of production economics*, *183*, 680-699.

Gray, G. C., & Silbey, S. S. (2014). Governing inside the organization: Interpreting regulation and compliance. *American Journal of Sociology*, *120*(1), 96-145.

Gu, H., Liu, Z., & Qing, Q. (2017). Optimal electric vehicle production strategy under subsidy and battery recycling. *Energy Policy*, *109*, 579-589.

Günther, H.-O., Kannegiesser, M., & Autenrieb, N. (2015). The role of electric vehicles for supply chain sustainability in the automotive industry. *Journal of Cleaner Production*, *90*, 220-233.

Gupta, R., Mejia, C., Gianchandani, Y., & Kajikawa, Y. (2020). Analysis on formation of emerging business ecosystems from deals activities of global electric vehicles hub firms. *Energy Policy*, *145*, 111532.

Guzman, J., O'Connell, E., Kikule, K., & Hafner, T. (2020). The WHO Global Benchmarking Tool: a game changer for strengthening national regulatory capacity. *BMJ global health*, *5*(8).

Hall, S., & Roelich, K. (2016). Business model innovation in electricity supply markets: The role of complex value in the United Kingdom. *Energy Policy*, *92*, 286-298.

Handfield, R. B., Straube, F., Pfohl, H.-C., & Wieland, A. (2013). Trends and strategies in logistics and supply chain management: embracing global logistics complexity to drive market advantage.

Hardman, S., Jenn, A., Tal, G., Axsen, J., Beard, G., Daina, N., Figenbaum, E., Jakobsson, N., Jochem, P., & Kinnear, N. (2018). A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transportation Research Part D: Transport and Environment*, *62*, 508-523.

Hashmi, M., Governatori, G., & Wynn, M. T. (2016). Normative requirements for regulatory compliance: An abstract formal framework. *Information Systems Frontiers*, *18*, 429-455.

Hoang, V., Nguyen, K.-D., & Nguyen, H.-L. (2023). Framework and determinants of benchmarking: a theoretical analysis and case study in Vietnam. *International Journal of Emerging Markets*, *18*(10), 4651-4668.

Holland, S. P., Mansur, E. T., & Yates, A. J. (2021). The electric vehicle transition and the economics of banning gasoline vehicles. *American Economic Journal: Economic Policy*, *13*(3), 316-344.

Hong, P., Ahn, N. Y., & Jung, E. (2023). Linkage role of ICT and Big Data in COVID-19: a case of Korea's digital and social communication practices. *Journal of Information, Communication and Ethics in Society*, *21*(2), 161-180.

Hong, P., Chen, H.-W., Ahrens, F., Park, Y. S., & Cho, Y. S. (2023). Challenges and Opportunities of Altasia: A National Benchmarking Assessment. *Sustainability*, *15*(19), 14507.

Hong, P., Hong, S. W., Jungbae Roh, J., & Park, K. (2012). Evolving benchmarking practices: a review for research perspectives. *Benchmarking: An International Journal*, *19*(4/5), 444-462.

Hong, P. C., Jung, E., Ahn, N. Y., & Hyun, Y. (2023). Safety governance during COVID-19 pandemic and beyond: a benchmarking inquiry of multiple countries. *Digital Policy, Regulation and Governance*, *25*(6), 568-587.

Hsu, C. C., Choon Tan, K., Hanim Mohamad Zailani, S., & Jayaraman, V. (2013). Supply chain drivers that foster the development of green initiatives in an emerging economy. *International Journal of Operations & Production Management*, *33*(6), 656-688.

Huang, Y., Qian, L., Soopramanien, D., & Tyfield, D. (2021). Buy, lease, or share? Consumer preferences for innovative business models in the market for electric vehicles. *Technological Forecasting and Social Change*, *166*, 120639.

Jackson, R. B., Le Quéré, C., Andrew, R., Canadell, J. G., Korsbakken, J. I., Liu, Z., Peters, G. P., & Zheng, B. (2018). Global energy growth is outpacing decarbonization. *Environmental Research Letters*, *13*(12), 120401.

Jagani, S., Deng, X., Hong, P. C., & Mashhadi Nejad, N. (2023). Adopting sustainability business models for value creation and delivery: an empirical investigation of manufacturing firms. *Journal of Manufacturing Technology Management*, *ahead-of-print*. https://doi.org/https://doi.org/10.1108/JMTM-03-2023-0099

Jaiswal, M., & Zane, L. J. (2022). Drivers of sustainable new technology diffusion in national markets: The case of electric vehicles. *Thunderbird International Business Review*, *64*(1), 25-38.

Jajja, M. S. S., Hassan, S. Z., Asif, M., & Searcy, C. (2021). Manufacturing value chain for battery electric vehicles in Pakistan: An assessment of capabilities and transition pathways. *Journal of Cleaner Production*, *328*, 129512.

Kalaitzi, D., Matopoulos, A., & Clegg, B. (2019). Managing resource dependencies in electric vehicle supply chains: a multi-tier case study. *Supply Chain Management-an International Journal*, *24*(2), 256-270. https://doi.org/10.1108/scm-03-2018-0116

Kester, J., Noel, L., de Rubens, G. Z., & Sovacool, B. K. (2018). Policy mechanisms to accelerate electric vehicle adoption: a qualitative review from the Nordic region. *Renewable and Sustainable Energy Reviews*, *94*, 719-731.

Khatua, A., Kumar, R. R., & De, S. K. (2023). Institutional enablers of electric vehicle market: Evidence from 30 countries. *Transportation Research Part A: Policy and Practice*, *170*, 103612.

Kim, K., Lee, J., & Kim, J. (2021). Can liquefied petroleum gas vehicles join the fleet of alternative fuel vehicles? Implications of transportation policy based on market forecast and environmental impact. *Energy Policy*, *154*, 112311.

Kim, S.-C., Hong, P., Lee, T., Lee, A., & Park, S.-H. (2022). Determining strategic priorities for smart city development: Case studies of south Korean and international smart cities. *Sustainability*, *14*(16), 10001.

Kumar, R. R., Chakraborty, A., & Mandal, P. (2021). Promoting electric vehicle adoption: Who should invest in charging infrastructure? *Transportation Research Part E: Logistics and Transportation Review*, *149*, 102295.

Lee, M., Yun, J. J., Pyka, A., Won, D., Kodama, F., Schiuma, G., Park, H., Jeon, J., Park, K., & Jung, K. (2018). How to respond to the fourth industrial revolution, or the second information technology revolution? Dynamic new combinations between technology, market, and society through open innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, *4*(3), 21.

Li, C., Ba, S., Ma, K., Xu, Y., Huang, W., & Huang, N. (2023). ESG rating events, financial investment behavior and corporate innovation. *Economic Analysis and Policy*, *77*, 372-387.

Liao, F., Molin, E., Timmermans, H., & van Wee, B. (2019). Consumer preferences for business models in electric vehicle adoption. *Transport Policy*, *73*, 12-24.

Liao, F., Molin, E., & van Wee, B. (2017). Consumer preferences for electric vehicles: a literature review. *Transport Reviews*, *37*(3), 252-275.

Liu, J.-p., Zhang, T.-x., Zhu, J., & Ma, T.-n. (2018). Allocation optimization of electric vehicle charging station (EVCS) considering with charging satisfaction and distributed renewables integration. *Energy*, *164*, 560-574.

Lu, C., Rong, K., You, J., & Shi, Y. (2014). Business ecosystem and stakeholders' role transformation: Evidence from Chinese emerging electric vehicle industry. *Expert Systems with Applications*, *41*(10), 4579-4595.

Ma, S.-C., Xu, J.-H., & Fan, Y. (2019). Willingness to pay and preferences for alternative incentives to EV purchase subsidies: An empirical study in China. *Energy Economics*, *81*, 197-215.

Ma, Y., Rong, K., Luo, Y., Wang, Y., Mangalagiu, D., & Thornton, T. F. (2019). Value Co-creation for sustainable consumption and production in the sharing economy in China. *Journal of Cleaner Production*, *208*, 1148-1158.

Madina, C., Zamora, I., & Zabala, E. (2016). Methodology for assessing electric vehicle charging infrastructure business models. *Energy Policy*, *89*, 284-293.

Mandys, F. (2021). Electric vehicles and consumer choices. *Renewable and Sustainable Energy Reviews*, *142*, 110874.

Massa, L., Tucci, C. L., & Afuah, A. (2017). A critical assessment of business model research. *Academy of management annals*, *11*(1), 73-104.

Mauler, L., Duffner, F., & Leker, J. (2021). Economies of scale in battery cell manufacturing: The impact of material and process innovations. *Applied Energy*, *286*, 116499.

Morrissey, P., Weldon, P., & O'Mahony, M. (2016). Future standard and fast charging infrastructure planning: An analysis of electric vehicle charging behaviour. *Energy Policy*, *89*, 257-270.

Nagariya, R., Kumar, D., & Kumar, I. (2022). Sustainable service supply chain management: from a systematic literature review to a conceptual framework for performance evaluation of service only supply chain. *Benchmarking: An International Journal*, *29*(4), 1332-1361.

Niri, M. F., Liu, K., Apachitei, G., Ramirez, L. R., Lain, M., Widanage, D., & Marco, J. (2021). Machine learning for optimised and clean Li-ion battery manufacturing: Revealing the dependency between electrode and cell characteristics. *Journal of Cleaner Production*, *324*, 129272.

Okada, T., Tamaki, T., & Managi, S. (2019). Effect of environmental awareness on purchase intention and satisfaction pertaining to electric vehicles in Japan. *Transportation Research Part D: Transport and Environment*, *67*, 503-513.

Outa, E. R., & Waweru, N. M. (2016). Corporate governance guidelines compliance and firm financial performance: Kenya listed companies. *Managerial Auditing Journal*, *31*(8/9), 891-914.

Patel, B. S., & Sambasivan, M. (2022). A systematic review of the literature on supply chain agility. *Management Research Review*, *45*(2), 236-260.

Raitano, M., & Vona, F. (2017). Competition, firm size and returns to skills: Evidence from currency shocks and market liberalisations. *The World Economy*, *40*(12), 2676-2703.

Rasiah, R., Shahrivar, R. B., & Yap, X.-S. (2016). Institutional support, innovation capabilities and exports: Evidence from the semiconductor industry in Taiwan. *Technological Forecasting and Social Change*, *109*, 69-75.

Reinhardt, R., Christodoulou, I., García, B. A., & Gasso-Domingo, S. (2020). Sustainable business model archetypes for the electric vehicle battery second use industry: Towards a conceptual framework. *Journal of Cleaner Production*, *254*, 119994.

Rong, K., Shi, Y., Shang, T., Chen, Y., & Hao, H. (2017). Organizing business ecosystems in emerging electric vehicle industry: Structure, mechanism, and integrated configuration. *Energy Policy*, *107*, 234-247.

Scherer, F. M. (1965). Firm size, market structure, opportunity, and the output of patented inventions. *The American economic review*, *55*(5), 1097-1125.

Secinaro, S., Brescia, V., Calandra, D., & Biancone, P. (2020). Employing bibliometric analysis to identify suitable business models for electric cars. *Journal of Cleaner Production*, *264*, 121503.

Shao, J., Yang, H., & Zhang, A. (2019). Adoption of Electric Vehicles: Manufacturers' Incentive and Government Policy. *Journal of Transport Economics and Policy (JTEP)*, *53*(2), 175-198.

Shao, L., Yang, J., & Zhang, M. (2017). Subsidy scheme or price discount scheme? Mass adoption of electric vehicles under different market structures. *European Journal of Operational Research*, *262*(3), 1181-1195.

Shi, L., Chen, G., & Wang, S. (2023). Dynamic analysis of the investment decision of electric vehicle charging facilities and the promotion effect measurement for electric vehicles. *European Journal of Transport and Infrastructure Research*, *23*(2), 1-23.

Shin, J., Bhat, C. R., You, D., Garikapati, V. M., & Pendyala, R. M. (2015). Consumer preferences and willingness to pay for advanced vehicle technology options and fuel types. *Transportation Research Part C: Emerging Technologies*, *60*, 511-524.

Simchi-Levi, D., Wang, H., & Wei, Y. (2018). Increasing supply chain robustness through process flexibility and inventory. *Production and Operations Management*, *27*(8), 1476-1491.

Singh, V., Singh, V., & Vaibhav, S. (2020). A review and simple meta-analysis of factors influencing adoption of electric vehicles. *Transportation Research Part D: Transport and Environment*, *86*, 102436.

Sjödin, D., Parida, V., & Kohtamäki, M. (2023). Artificial intelligence enabling circular business model innovation in digital servitization: Conceptualizing dynamic capabilities, AI capacities, business models and effects. *Technological Forecasting and Social Change*, *197*, 122903.

Su, C., & Urban, F. (2021). Circular economy for clean energy transitions: A new opportunity under the COVID-19 pandemic. *Applied Energy*, *289*, 116666.

Sydow, J., & Müller-Seitz, G. (2020). Open innovation at the interorganizational network level–Stretching practices to face technological discontinuities in the semiconductor industry. *Technological Forecasting and Social Change*, *155*, 119398.

Tarigan, A. K. (2019). Expectations, attitudes, and preferences regarding support and purchase of eco-friendly fuel vehicles. *Journal of Cleaner Production*, *227*, 10-19.

Teece, D. J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic management journal*, *28*(13), 1319-1350.

Teece, D. J. (2014). A dynamic capabilities-based entrepreneurial theory of the multinational enterprise. *Journal of international business studies*, *45*, 8-37.

Teece, D. J. (2018). Business models and dynamic capabilities. *Long Range Planning*, *51*(1), 40-49.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic management journal*, *18*(7), 509-533.

van der Koogh, M., Chappin, E., Heller, R., & Lukszo, Z. (2023). Stakeholder prioritizations for electric vehicle charging across time periods. *Transport Policy*, *142*, 173-189.

Wang, N., Tang, L., & Pan, H. (2019). A global comparison and assessment of incentive policy on electric vehicle promotion. *Sustainable Cities and Society*, *44*, 597-603.

Wang, T., & Deng, S. (2019). Supply chain leading models of building charging stations: Leaders, subsidy policies, and cost sharing. *International Journal of Sustainable Transportation*, *13*(3), 155-169.

Wang, X.-W., Cao, Y.-M., & Zhang, N. (2021). The influences of incentive policy perceptions and consumer social attributes on battery electric vehicle purchase intentions. *Energy Policy*, *151*, 112163.

Warnecke, D., Wittstock, R., & Teuteberg, F. (2019). Benchmarking of European smart cities–a maturity model and web-based self-assessment tool. *Sustainability Accounting, Management and Policy Journal*, *10*(4), 654-684.

Wee, S., Coffman, M., & La Croix, S. (2018). Do electric vehicle incentives matter? Evidence from the 50 US states. *Research Policy*, *47*(9), 1601-1610.

Xin, Y., Gu, X., & Li, T. (2015). Industry competition structure, market power, and stock price crash risk. *China Accounting and Finance Review*, *17*, 1-46.

Yan, S. (2018). The economic and environmental impacts of tax incentives for battery electric vehicles in Europe. *Energy Policy*, *123*, 53-63.

Yang, Z., Huang, H., & Lin, F. (2022). Sustainable electric vehicle batteries for a sustainable world: Perspectives on battery cathodes, environment, supply chain, manufacturing, life cycle, and policy. *Advanced Energy Materials*, *12*(26), 2200383.

Yeravdekar, S., & Behl, A. (2017). Benchmarking model for management education in India: a total interpretive structural modeling approach. *Benchmarking: An International Journal*, *24*(3), 666-693.

Zhang, L., Zhao, Z., Xin, H., Chai, J., & Wang, G. (2018). Charge pricing model for electric vehicle charging infrastructure public-private partnership projects in China: A system dynamics analysis. *Journal of Cleaner Production*, *199*, 321-333.

Zhang, Q., Li, H., Zhu, L., Campana, P. E., Lu, H., Wallin, F., & Sun, Q. (2018). Factors influencing the economics of public charging infrastructures for EV–A review. *Renewable and Sustainable Energy Reviews*, *94*, 500-509.

Zhang, X. (2014). Reference-dependent electric vehicle production strategy considering subsidies and consumer trade-offs. *Energy Policy*, *67*, 422-430.

Zhang, X., Bai, X., & Shang, J. (2018). Is subsidized electric vehicles adoption sustainable: Consumers' perceptions and motivation toward incentive policies, environmental benefits, and risks. *Journal of Cleaner Production*, *192*, 71-79.

Zhang, X., Xie, J., Rao, R., & Liang, Y. (2014). Policy incentives for the adoption of electric vehicles across countries. *Sustainability*, *6*(11), 8056-8078.

Zhang, X., & Yi, G. (2024). Start-Ups and Innovation Ecosystem in China. *Science, Technology and Society*, 09717218231215379.

Zhang, X., Zou, T., Lassaletta, L., Mueller, N. D., Tubiello, F. N., Lisk, M. D., Lu, C., Conant, R. T., Dorich, C. D., & Gerber, J. (2021). Quantification of global and national nitrogen budgets for crop production. *Nature Food*, *2*(7), 529-540.

Zhang, Y., Yu, Y., & Zou, B. (2011). Analyzing public awareness and acceptance of alternative fuel vehicles in China: The case of EV. *Energy Policy*, *39*(11), 7015-7024.

Zhou, X., Zhao, R., Cheng, L., & Min, X. (2019). Impact of policy incentives on electric vehicles development: a system dynamics-based evolutionary game theoretical analysis. *Clean Technologies and Environmental Policy*, *21*, 1039-1053.

Zollo, M., & Winter, S. G. (2002). Deliberate learning and the evolution of dynamic capabilities. *Organization Science*, *13*(3), 339-351.

Strategic Pricing and Marketing in SaaS Startups: Enhancing Investment Prospects

Xiangling Hu[1], Ping Su[2]

[1]Grand Valley State University, Grand Rapids, USA. [2]Hofstra University, New York, USA

Abstract

The cornerstone of startup success lies in its capacity to procure sufficient funding for launching operations. Startups, by their nature, urgently seek both customers and revenue, sparking a debate among investors and analysts on whether a growth strategy should prioritize user acquisition or profit generation. Common belief posits that business triumph hinges on profitability, subsequently attracting a substantial customer base. Among various business models, Software as a Service (SaaS) stands out for its widespread acceptance among startups due to its scalable and subscription-based nature. This study constructs a theoretical model to analyze how SaaS startups can optimize their pricing and marketing strategies to maximize funding opportunities. It posits that a startup's funding potential is intricately linked to a balanced mix of profitability and an expanding customer base, a hypothesis derived from examining both operational and marketing expenditures. By examining operational and marketing expenditures, this model seeks to identify optimal strategies for pricing, marketing efforts, and timing for funding acquisition.

1 Introduction

At the early stages of internet and mobile startups, many companies are still in the process of "burning money" and have yet to generate substantial revenues or profits. Analysts and investors often place a significant emphasis on customer size, such as active user count, as a critical criterion in investment valuations during this stage, as these companies may not yet have a way to generate meaningful revenue or profits (Jokinen, 2015). As a result, internet or mobile startups may focus on expanding their customer base by underpricing their products and services to attract customers without the need to worry about generating revenue early on. Market demand indices, such as Monthly Unique Visitors (the sum of all visits to a website over the course of a month), are often listed as the top criteria in e-commerce valuations for internet service businesses (CFI Team, 2022). For example, in its seed round, an investor proposed $500,000 for 10.2% of Facebook with the condition that Facebook reach 1.5 million users by the end of 2004. It took Facebook six years to become profitable, and Twitter even took twice as long to reach profitability. In 2013, Snapchat had only $0.5 million in revenue and a negative $350 million in profit, yet its valuation was $14.8 billion, with 86 million annual active users (i.e., daily active users in Q2 of each year) (MANSOOR IQBAL, 2022). Twitch, a popular website for watching people play games, was acquired by Amazon for $1.1 billion in August 2014. Despite having 55 million monthly visits, Twitch had

an aggressive net sale of $12 million and an operating loss of $3 million by the end of Q3 2014. In early 2012, Facebook paid around $30 per active user for Instagram. In early 2014, Facebook agreed to pay nearly $80 per user for WhatsApp.

Software as a Service (SaaS) has become a popular business model in the technology industry, offering a subscription-based service for customers to access software over the internet. SaaS has gained significant traction in recent years, with the global SaaS market projected to reach $157 billion by 2022. Notable examples of business-to-business SaaS include Amazon.com, which offers storage and computing power in the cloud, and Ebay.com, which offers a global trading platform. In this paper, we specifically study software as a service (SaaS) startup within the internet and mobile industry. We analyze how a SaaS company maximizes market demand under capital constraints. We assume that the company has initially secured K dollars of investment. The market demand is a logistic increasing function of time t and is negatively impacted by the selling price p_t, but positively impacted by the marketing effort m_t. The firm uses this capital to grow its business and maximize its demand before either its capital is exhausted or at period T, whichever comes first, to negotiate with venture capitalists who evaluate the startups mainly based on the latest period's market demand for another round of funding.

For many SaaS companies, such as gaming websites, new websites, apps in Google Play and Apple's App Store, they do not normally reject demand. SaaS allows for scalability, as businesses can easily adjust their subscription plans to accommodate their changing needs. This has led to a wide range of industries adopting SaaS, including healthcare, education, and finance. The maximum service capacity can easily be expanded according to the realized demand. This is different from manufactured product sales, in which products may run out of stock when demand exceeds the order quantity, or there may be leftover inventory when demand is less than the order quantity. SaaS companies provide the service to anyone who buys it on their websites or in mobile stores. The marginal physical cost for providing digital services is almost zero, and the cost for coping with increasing demand is normally to expand the supporting team when sales appear to reach maximum capacity. Therefore, it is reasonable to assume that for these companies, demand is always fulfilled while the variable cost for each new customer is spent on customer support.

In Operations Management, we typically assume that the firm is a profit maximizer. A start-up's survival to thrive relies on its success in attracting sufficient external funding. Therefore, its objective is not purely profit maximization. The start-ups work hard to understand the investors' decision-making processes and maximize their investment opportunities. There exists a lot of studies on VCs' criteria of evaluations (Köhn, 2018). In this paper, we assume that a SaaS company's funding is a weighted sum of the firm's profitability and its client base. We build a stylized model in which the startup with an initial capital incurs marketing expenses each period. Marketing effort is spent on maintaining current clientele and attracting new customers. The startup maximizes its investment opportunity by jointly making pricing and marketing effort investment decisions and selecting the best timing to seek funding. Notably, real-world examples such as Slack's freemium model and Zoom's user-friendly pricing strategies illustrate the practical applications of our theoretical model.

2 Literature Review

Startup funding is a crucial aspect of the entrepreneurial process, as it enables new firms to acquire the resources necessary for growth and expansion. However, the process of obtaining funding can be challenging, particularly for startups that lack a track record of financial performance. To address this challenge, research has focused on identifying key valuing signals that reflect a firm's economic performance.

Ferrati and Muffatto (2021) conducted a study that examined the use of valuing signals in the context of startup funding. They found that financial performance metrics, such as revenue growth and profitability, are commonly used by investors to assess the potential of a startup. Additionally, they found that non-financial performance metrics, such as customer satisfaction and market share, can also serve as valuable indicators of a startup's economic performance.

Signaling theory is a concept that explains how firms use certain characteristics or actions to communicate information about their quality to potential investors, customers, and other stakeholders. This literature review will focus on the use of signaling theory to communicate firm quality in the context of various signals such as human capital, intellectual capital, social capital, firm age and size, strategic partnerships, the entrepreneur's willingness, business models, and commitment. Recent studies further underscore the evolving nature of these signals, especially in the digital and SaaS domains.

Connelly et al. (2011) proposed that human capital is a significant signaling mechanism that firms use to communicate their quality to potential investors. This theory is supported by research such as Baum and Silverman (2004) and Becker-Blease and Sohl (2015) which found that human capital, such as education, experience, and skills, can serve as an indicator of a firm's potential for success. Similarly, researchers have proposed that intellectual capital can also serve as a signaling mechanism for firm quality. Ahlers et al. (2015) found that intellectual capital, such as patents, trademarks, and copyrights, can communicate a firm's innovative capabilities and potential for future growth.

Social capital has also been proposed as a signaling mechanism for firm quality. Vismara (2016) found that firms with strong networks and reputation can signal to potential investors and customers that they are trustworthy and have a good reputation in the market. Other researchers have proposed that firm age and size, strategic partnerships, the entrepreneur's willingness, business models, and commitment can also serve as signals of firm quality. Baum et al. (2000) found that older and larger firms can signal stability and experience, while Plummer et al. (2016) found that strategic partnerships can signal a firm's capability to collaborate and access resources. Leland and Pyle (1977) proposed that the entrepreneur's willingness to invest personal resources can signal a firm's commitment, and Busenitz et al. (2005) and Sanders and Boivie (2004) proposed that the choice of a specific business model can signal a firm's ability to create and capture value. Wilson et al. (2007) proposed that commitment is also a signal of firm quality as it can signal that the firm is more likely to be successful.

In conclusion, the literature suggests that signaling theory can be used to communicate firm quality through various signals such as human capital, intellectual capital, social capital, firm age and size, strategic partnerships, the entrepreneur's willingness, business models, and commitment. These signals

can help investors and other stakeholders to assess the potential of a firm and make informed decisions about investment or partnership opportunities.

3 Model

We analyze a startup SaaS company equipped with an initial capital of K. In each corresponding period, the startup strategically determines its marketing effort level, which is expected to bolster sales, and sets the service price. The primary objective of these maneuvers is to maximize the likelihood of securing external funding. Investor evaluations hinge significantly on the firm's sales performance in the most recent period. The decision variables:

- m_t: the marketing effort of the SaaS company in time t, $t = 1, \dots, T$
- p_t: the unit price of service in time t, $t = 1, \dots, T$

Other notation:

- K: initial capital to be used within time T
- T: the expected length of the decision horizon for the use of capital K before the next round of seeking funding
- $g(m_t)$: effort cost incurred in each period. It is convex increasing in m_t.
- c: variable cost per unit
- m_t: the impact of the marketing effort on demand. It is concave increasing in m_t.
- $D_t(m_t, p_t)$: the anticipated market demand for software in period t is determined by the product price p_t in the form of $y(p_t)$ and affected by the market randomness ε, which has pdf of f_t, cdf of F_t, the support on $[A, +\infty]$, the mean of μ, and the standard deviation σ . More specific, we assume (1) additive demand of $y(a_t, p_t) + \epsilon$, where $y(a_t, p_t) = a_t - bp_t, b > 0$; (2) multiplicative demand of $y(a_t, p_t)\epsilon$, where $y(a_t, p_t) = a_t p_t^{-b}$ $(b > 1)$.

$$D_t(m_t, p_t) = y(a_t, p_t) + \sum_{i=1}^{t} \beta^{t-i} m_i + \epsilon$$

Demand at period t is affected by the marketing effort exerted from all the past periods, from1 to t. The impact is discounted at the rate of $\beta \leq 1$.

where a_t is the potential market size in period t, and $y(a_t, p_t)$ is decreasing in price p_t, and increases in a_t. The potential market size grows in time. That is, $a_{t_1} \geq a_{t_2}$ if and only if $t_1 \geq t_2$. $D_t(m_t, p_t)$ increases in a_t. $\frac{dD_t^*(m_t,p_t)}{da_t} = \frac{\partial D_t^*(m_t,p_t)}{\partial m_t}\frac{\partial m_t^*}{\partial a_t} + \frac{\partial D_t^*(m_t,p_t)}{\partial p_t}\frac{\partial p_t^*}{\partial a_t} + \frac{\partial D_t^*(m_t,p_t)}{\partial a_t} = \frac{\partial D_t^*(m_t,p_t)}{\partial a_t} > 0.$

As m_t and p_t are optimizing with respect to a_t, D_t still increase in a_t.

- $\Pi_t(q_t, p_t)$: profit in period t, driven by the available quantity q_t and the product price p_t as follows

$$\Pi_t(m_t, p_t) = p_t D_t(m_t, p_t) - g(m_t)$$
$$= p_t \left[y(a_t, p_t) + \sum_{i=1}^{t} \beta^{t-i} m_i + \epsilon \right] - g(m_t)$$

$$E[\Pi_t(m_t, p_t)] = p_t E[D_t(m_t, p_t)] - g(m_t) = p_t \left[y(a_t, p_t) + \sum_{i=1}^{t} \beta^{t-i} m_i + \mu \right] - g(m_t)$$

- $R_t(q_t, p_t)$: revenue in period t

$$E[R_t(m_t, p_t)] = p_t E[D_t(m_t, p_t)] = p_t \left[y(a_t, p_t) + \sum_{i=1}^{t} \beta^{t-i} m_i + \mu \right]$$

The startup's objective is to maximize its expected demand, subject to the budget constraint. We assume that the start up's profit is negative at the initial period given the small market size. There are two possible scenarios: (1) If the startup's profit at certain period turns positive before using up the initial capital, it does not need to look for funding. (2) If the profit never turns positive before using up the initial capital, we use s to denote the period in which the startup goes up to the investors for funding.

The startup's optimization programming is as follows:

$$\max_{\substack{s, m_1, m_2, \ldots, m_s \\ p_1, p_2, \ldots, p_s}} \quad E[D_s(m_s, p_s)] \tag{1}$$

$$\sum_{i=1}^{t} E[\Pi_i(m_i, p_i)] \geq 0 \tag{2}$$

$$p_t \geq 0 \tag{3}$$

$$s = 1,2, \ldots, T$$

$$t = 1,2, \ldots, s$$

Since budget constraints are not binding yet before reaching period s, therefore, $\lambda_t = 0$ for $t \leq s - 1$. At period s, the initial capital is used up, and budget constraint is binding. Therefore, $\lambda_s \geq 0$.

The Lagrangian function is as follows:

$$U(m_s, p_s) = E[D_s(m_s, p_s)] + \sum_{t=1}^{s} \lambda_t \left(K + \sum_{i=1}^{t} E[\Pi_i(m_i, p_i)] \right) + \sum_{t=1}^{s} \gamma_t p_t \tag{4}$$

$$\lambda_t(K + \sum_{i=1}^{t} E[\Pi_i(m_i, p_i)]) = 0 \quad (5)$$

$$\gamma_t p_t = 0 \quad (6)$$

where $\lambda_t \geq 0, \gamma_t \geq 0$.

Proposition 1

(a) At the last period, the startup will set the price p_s and effort to m_s use up all the funding and go to the investor. Therefore, $K + \sum_{i=1}^{s} E[\Pi_i(m_i, p_i)] = 0$.

(b) m_s^* and p_s^* are solved the following equations if $p_s^* > 0$.

$$p_s E[D_s(m_s, p_s)] = -[K + \sum_{i=1}^{s-1} p_i E[D_i(m_i, p_i)] - \sum_{i=1}^{s} g(m_i)] \quad (7)$$

$$E[D_s(m_s, p_s)] = -y_{p_s}{}'(a_s, p_s) g'(m_s) \quad (8)$$

m_s^* is solved by $K + \sum_{i=1}^{s-1} p_i E[D_i(m_i, p_i)] - \sum_{i=1}^{s} g(m_i) = 0$ if $p_s^* = 0$.

(c) The startup's price p_t is strictly positive in period t, $1 \leq t \leq s-1$. p_t^* maximizes the startup's profit in period t. m_t^* is higher than the cumulative profit (from period t to period s) maximizing m_t. m_t^* and p_t^* are solved by the following Equations.

$$E[D_t(m_t, p_t)] = -p_t y'(a_t, p_t) \quad (9)$$

$$g'(m_t) = \beta^{s-t} g'(m_s) + \sum_{i=t}^{s-1} p_i \beta^{i-t} \quad (10)$$

Proposition 1(a) outlines that at the final decision period, a SaaS startup will adjust its pricing and marketing efforts to fully utilize the remaining budget in anticipation of seeking additional funding. This strategy is grounded in the premise that maximizing current market demand can enhance the startup's appeal to potential investors.

According to Proposition 1(c), before reaching the last period (*t*<*s*), the startup picks the price that maximizes that period's expected profit. The effort level at each period has two effects: first, it positively affects the final period's demand; second, it affects the startup's expected profit. Therefore, the optimal effort level before reaching the last period is greater than the cumulative profit-maximizing effort level.

Adobe's Creative Cloud subscription model offers a real-life manifestation of Proposition 1. As Adobe transitioned to the cloud, it introduced a pricing strategy that was periodically adjusted based on market feedback and product enhancements. This approach allowed Adobe to remain competitive and attractive to new users while ensuring existing customers saw continual value in their subscriptions, exemplifying the lemma's principle of strategic price adaptation in response to evolving market conditions.

SaaS company like Slack provides another example. In its early stages, might have adjusted its service offerings or marketing strategies to attract a significant user base, thereby enhancing its valuation in the eyes of investors. As Slack approached a funding round, it could have strategically increased marketing efforts to boost user engagement and demonstrate rapid growth, an attractive metric for investors.

Lemma 1 For linear demand, both p_t and m_t are non-decreasing in t.

Both price and market effort increase over time as the market potential increases in t.

Lemma 1 states that both pricing and marketing efforts should not decrease over time, reflecting an understanding that as a SaaS startup grows and its market potential increases, its investment in attracting and retaining customers should also increase.

For example, Netflix's pricing strategy over the years illustrates this principle. As Netflix added more content and improved its service, it gradually increased its subscription price. Each price adjustment was coupled with increased marketing efforts to highlight the added value to current and potential subscribers, thereby justifying the higher price and sustaining growth in subscriber numbers.

4 Analysis

We consider a baseline scenario in which the sales effort only has impact on the current period's market size. Assume that demand is linear in price and the cost of marketing effort $g(m_t) = cm_t^2$, where c is the unit marketing effort cost.

Proposition 2 (Baseline scenario)

(a) Both price p_t and market effort m_t increase over time t as $1 \leq t \leq s$, where , $p_t = \frac{2c(a_t+\mu)}{4bc-1}$, and $m_t = \frac{a_t+\mu}{4bc-1}$.

(b) Expected profit at each period t $E[\Pi_t(m_t, p_t)] = \frac{c(a_t+\mu)^2}{4bc-1}$.

(c) Market size $E[D_i(m_i, p_i)] = \frac{2bc(a_t+\mu)}{4bc-1}$. Market size is growing linearly in a_t.

In the baseline scenario, the firm's price and market effort jointly maximize the expected profit at each period t. The expected profit is positive at every period t and optimal market size is positively related to a_t.

This proposition illustrates that in a scenario where marketing efforts impact only the current period's market size and demand is linear in price, a startup's pricing and marketing efforts should increase over time to maximize profit at each period. This reflects an understanding of the expanding market size and the need to invest more in marketing to capture the increasing potential.

Similar strategies have been used by Adobe. Adobe's shift from selling perpetual licenses to a subscription-based model (Adobe Creative Cloud) can serve as an application of this proposition. Adobe adjusted its pricing and marketing strategy to reflect the ongoing value provided to customers through constant updates and new features, ensuring continued growth in a changing market landscape.

5. Extensions

5.1 Uniform pricing

When selling price p does not change throughout the entire time horizon, similar to the previous discussion, (4), (5), (6) can be written as follows.

$$U(m_s, p) = E[D_s(m_s, p)] + \sum_{t=1}^{s} \lambda_t (K + \sum_{i=1}^{t} E[\Pi_i(m_i, p)]) + \gamma p = 0 \quad (11)$$

$$\lambda_s (K + \sum_{i=1}^{s} E[\Pi_i(m_i, p)]) = 0 \quad (12)$$

where $\lambda_s \geq 0$ and $\gamma p = 0$.

$\lambda_t = 0$ for $t \leq s - 1$.

In practice, it is common that the startup may set the price once and varies its marketing effort to maximize its market size. Next, we studies the strategic pricing decisions a SaaS startup faces when it chooses to set a uniform price throughout its operation until a funding event.

Proposition 3 (a) The startup's price p^* is either 0 or positive. If $p^* > 0$, it is lower than the price that maximizes the startup's cumulative profit from period 1 to period s.

(b) At the last period, the startup will set the effort to m_s use up all the funding and go to the investor. Therefore, $K + \sum_{i=1}^{s} E[\Pi_i(m_i, \mathrm{p})] = 0$. m_s^* is higher than Period s's profit maximizing m_s.

(c) m_s^* and p are solved by Equations (13) and (14) if $p > 0$.

$$\sum_{i=1}^{s} E[D_i(m_i, p)] = -\frac{K - \sum_{i=1}^{s} g(m_i)}{p} \quad (13)$$

$$y'(a_s, p)p = \frac{1}{g'(m_s)} \left[K - \sum_{i=1}^{s} g(m_i) - p^2 \sum_{i=1}^{s-1} y'(a_i, p) \right] \quad (14)$$

m_t^* is higher than the cumulative profit maximizing m_t. m_t^* and p_t^* are solved by Equations (9) and (10).

This proposition suggests that maintaining a fixed price in the early stages of a startup's lifecycle serves to attract and build a customer base by making the service more accessible. This price is strategically set lower than what could potentially be charged in later stages when demand and the startup's market presence have grown. The rationale behind this approach is to strike a balance between early user acquisition, facilitated by a more accessible price point, and later stages of growth, where increased demand justifies and even necessitates higher pricing to maximize profitability. To offset the lower initial pricing and to bolster demand further, increased emphasis is placed on marketing efforts. This ensures that while the startup sacrifices some degree of immediate profitability for user growth, it compensates through heightened market efforts that amplify its visibility and user base expansion.

Spotify's initial pricing strategy serves as an illustrative example of Proposition 3 in action. By adopting a freemium model, Spotify set its free tier pricing at p^* =0, attracting a vast user base while offering premium subscriptions at a price lower than the maximum to ensure broad appeal. This approach not only fueled rapid user base expansion but also solidified Spotify's market position, making it an attractive

investment opportunity. Spotify's strategy highlights the proposition's emphasis on user acquisition and market presence as prerequisites for attracting investment and achieving long-term profitability.

Lemma 2 Assume that in each period, the entrepreneur matches the effort in benchmark case. The optimal one price has the following relationship with the dynamic price.

$$p\sum_{i=t}^{s-1}\beta^{i-t}=\sum_{i=t}^{s-1}p_i\beta^{i-t}\,,t=1,\dots,s-1 \qquad (15)$$

Lemma 2 suggests that in a scenario where a startup matches its marketing effort with a benchmark case, there's a strategic interplay between setting a uniform price and dynamically adjusting it over time. It implies that the decision to adjust pricing or marketing efforts is influenced by both current market conditions and anticipated future growth. The lemma underlines the importance of strategic flexibility in pricing and marketing, allowing startups to adapt to market feedback and growth trajectories dynamically.

Lemma 3 Assume that in each period, the entrepreneur matches the effort in benchmark case and demand is linear. The optimal one price is higher than period 1 price while is lower than period s-1 price in the dynamic price.

This lemma posits that if a startup opts not to adjust prices dynamically but instead maintains a uniform price, this uniform price will inherently strike a balance between the initial lower price aimed at market penetration and the subsequent higher prices justified by increased demand and service value. The uniform pricing strategy, thus, represents a middle ground, attempting to capture both early-stage accessibility and later-stage profitability without the flexibility offered by dynamic adjustments.

5.2 Fixed price for period 1 to F-1 and optimal price in Period F

Next, we want to addresses a specific strategic scenario for SaaS startups where pricing is kept constant during the initial growth phases (from period 1 to F-1) and then adjusted in the final period, F in Proposition r.

Proposition 4. When there is a fixed price p for period 1 to F-1 and only the price in Period F can be changed. Then $p_F=0$**,** $\gamma_F\geq 0$. λ_F,γ_F and m_F are solved by $\lambda_F\big(K+\sum_{i=1}^{F}E[\Pi_i(m_F,0)]\big)=0$, $1+\lambda_F[-g'(m_F)]=0$ and $y'(a_F,0)+\lambda_F(a_F,0)\big[p_F y'+E[D_F(m_F,0)]\big]+\gamma_F=0$. p is solved by solving $\beta^{F-t}+\frac{1}{g'(m_F)}\Big[p\frac{1-\beta^{F-t}}{1-\beta}-g'(m_t)\Big]=0$

Proposition 4 suggests that a fixed pricing strategy in the early stages serves as a foundation for building a user base and market presence. It reflects an understanding that early-stage startups benefit from pricing stability, which simplifies the customer acquisition process by providing clear value propositions. However, as the startup approaches a significant milestone or funding round (period F), reevaluating and potentially adjusting the price becomes essential to align with the evolved market position, demand, and financial objectives.

The essence of Proposition 4 is that by the time period F is reached, the startup may find it optimal to adjust its pricing to either capitalize on increased market demand, reflect the added value of enhancements to the service, or to optimize financial metrics in anticipation of funding discussions. This

pricing adjustment is made with strategic intent, acknowledging the startup's more robust understanding of its market, customer base, and the competitive landscape.

Zoom Video Communications' strategic pricing adjustments leading up to its IPO offer an illustrative example of Proposition 4 in practice. Initially, Zoom attracted users with a simple, fixed pricing model that provided free access for basic use and a clear, straightforward subscription option for more advanced features. This pricing strategy was instrumental in rapidly expanding Zoom's user base and establishing its market presence.

As Zoom prepared for its initial public offering, it introduced more nuanced pricing tiers and additional features for enterprise customers. This adjustment reflected an evolved understanding of its customer segments' needs, the value provided by Zoom's platform, and a strategic move to optimize revenue as the company sought to present itself to investors. The introduction of these new pricing tiers and features was akin to the strategic adjustment described in Proposition 4, aimed at maximizing profitability and investment appeal by leveraging the company's established market strength.

In essence, Proposition 4 captures the strategic pivot from leveraging pricing as a tool for market entry and user base expansion to employing pricing as a mechanism for revenue optimization and value capture in later stages. This proposition underscores the importance of timing and market understanding in pricing strategies, emphasizing the dynamic nature of strategic decision-making in the SaaS domain.

Conclusion

This investigation into the strategic decision-making of SaaS startups reveals the complexity of aligning pricing and marketing to optimize funding opportunities. Our detailed model not only shows the challenges these startups face but also points out ways they can successfully manage to grow their customer base and make a profit at the same time. It’s clear that finding the right balance between these goals is crucial for attracting investors and that being flexible and timely in making these decisions is key.

When we look at different pricing strategies, such as changing prices over time versus keeping them the same, we see that being able to adjust prices as the market changes can really help a startup make more money in the long run. On the other hand, sticking with one price from the start offers simplicity and can help attract customers early on, even if it means making less money later. This choice highlights the importance of not just when to seek funding but also when to enter the market and how to set prices, affecting both how much the startup is worth and its chances of lasting success.

Moreover, this study shows that the way we think about what makes a startup successful is changing. Startups need to be ready to change their strategies based on what's happening in the market and what investors are looking for.

Future research could look more into how changes in the market affect these strategies, giving us deeper insight into what SaaS startups need to do to stay on top in a changing world.

In short, this work adds a lot to both academic discussions and practical advice for entrepreneurs in the competitive tech startup world. It gives valuable tips for new companies trying to grow and succeed over

time, and for investors looking for promising startups to support. As the SaaS sector keeps evolving, the strategies we've talked about will stay important for startups wanting to grow big and strong.

References

Ahlers, G. K., Cumming, D., Günther, C., & Schweizer, D. (2015). Signaling in equity crowdfunding. *Entrepreneurship theory and practice*, *39*(4), 955-980.

Baum, J. A., Calabrese, T., & Silverman, B. S. (2000). Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology. *Strategic management journal*, *21*(3), 267-294.

Baum, J. A., & Silverman, B. S. (2004). Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. *Journal of business venturing*, *19*(3), 411-436.

Becker-Blease, J. R., & Sohl, J. E. (2015). New venture legitimacy: the conditions for angel investors. *Small Business Economics*, *45*, 735-749.

Busenitz, L. W., Fiet, J. O., & Moesel, D. D. (2005). Signaling in venture capitalist—New venture team funding decisions: Does it indicate long–term venture outcomes? *Entrepreneurship theory and practice*, *29*(1), 1-12.

Connelly, B. L., Certo, S. T., Ireland, R. D., & Reutzel, C. R. (2011). Signaling theory: A review and assessment. *Journal of management*, *37*(1), 39-67.

Ferrati, F., & Muf.fatto, M. (2021). Reviewing equity investors' funding criteria: A comprehensive classification and research agenda. *Venture Capital*, *23*(2), 157-178.

Köhn, A. (2018). The determinants of startup valuation in the venture capital context: a systematic review and avenues for future research. *Management Review Quarterly*. 68, 3–36.

Leland, H. E., & Pyle, D. H. (1977). American Finance Association. *The Journal of Finance*, *32*(2).

Jokinen, Jarmo. (April 27, 2015). *Active users and startup valuations - Comparing apples to apples or apples to candy apples? [LinkedIn page]*. LinkedIn. Retrieved from https://www.linkedin.com/pulse/active-users-startup-valuations-comparing-apples-candy-jokinen/?trackingId=Uv5P48X8QX2TtpwkLS5MlA%3D%3D.

Plummer, L. A., Allison, T. H., & Connelly, B. L. (2016). Better together? Signaling interactions in new venture pursuit of initial external capital. *Academy of Management Journal*, *59*(5), 1585-1604.

Sanders, W. G., & Boivie, S. (2004). Sorting things out: Valuation of new firms in uncertain markets. *Strategic Management Journal*, *25*(2), 167-186.

Vismara, S. (2016). Equity retention and social network theory in equity crowdfunding. *Small Business Economics*, *46*, 579-590.

Wilson, F., Kickul, J., & Marlino, D. (2007). Gender, entrepreneurial self–efficacy, and entrepreneurial career intentions: Implications for entrepreneurship education. *Entrepreneurship theory and practice*, *31*(3), 387-406.

Appendix

Proof of Proposition 1 (a):

In the last period s,

$$\frac{\partial U(m_s,p_s)}{\partial m_s}=\frac{\partial E[D_s(m_s,p_s)]}{\partial m_s}+\lambda_s\frac{\partial E[\Pi_s(m_s,p_s)]}{\partial m_s}=1+\lambda_s\frac{\partial E[\Pi_s(m_s,p_s)]}{\partial m_s}=0 \qquad (P1)$$

$$\frac{\partial U(m_s,p_s)}{\partial p_s}=\frac{\partial E[D_s(m_s,p_s)]}{\partial p_s}+\lambda_s\frac{\partial E[\Pi_s(m_s,p_s)]}{\partial p_s}=y'(a_s,p_s)+\lambda_s\frac{\partial E[\Pi_s(m_s,p_s)]}{\partial p_s}+\gamma_s=0 \qquad (P2)$$

$$K+\sum_{i=1}^{s}E[\Pi_i(m_i,p_i)]=0 \qquad (P3)$$

In (P1), $\lambda_s\frac{\partial E[\Pi_s(m_s,p_s)]}{\partial m_s}$<0. Therefore, $\lambda_s>0$. Capital constraint is binding $K+\sum_{i=1}^{s}E[\Pi_i(m_i,p_i)]=0$. The startup will use up the funding at the period when it goes to the investor.

1 (b):

$$\frac{\partial E[\Pi_s(m_s,p_s)]}{\partial m_s} = p_s - g'(m_s)$$

$$\frac{\partial E[\Pi_s(m_s,p_s)]}{\partial p_s} = p_s y'^{(a_s,p_s)} + E[D_s(m_s,p_s)]$$

Therefore,

$$\frac{\partial U(m_s,p_s)}{\partial m_s} = 1 + \lambda_s[p_s - g'(m_s)] = 0 \qquad (P4)$$

$$\frac{\partial U(m_s,p_s)}{\partial p_s} = y'^{(a_s,p_s)} + \lambda_s\left[p_s y'^{(a_s,p_s)} + E[D_s(m_s,p_s)]\right] + \gamma_s = 0 \qquad (P5)$$

Based on (P4),

$$\lambda_s = \frac{1}{g'(m_S) - p_s} \qquad (P6)$$

Based on (P3), when the budget constraint is binding:

$$p_s E[D_s(m_s,p_s)] = -\left[K + \sum_{i=1}^{s-1} p_i E[D_i(m_i,p_i)] - \sum_{i=1}^{s} g(m_i)\right] \qquad (P7)$$

If $p_s > 0, \gamma_s = 0$

Plugging (P6) into (P5), we have the following expression:

$$E[D_s(m_s,p_s)] = -y'(a_s,p_s)g'(m_s) \qquad (P8)$$

As indicated in (P4), $g'(m_s) > p_s, E[D_s(m_s,p_s)] > -p_s y'(a_s,p_s)$. m_s and p_s are solved by (P7)-(P8).

If $p_s = 0, \gamma_s \geq 0$

(P5) and (P6) lead to

$$y'(a_s,0) + \frac{1}{g'(m_S)}\left[E[D_s(m_s,0)]\right] + \gamma_s = 0 \qquad (P9)$$

(P7) leads to

$$K + \sum_{i=1}^{s-1} p_i E[D_i(m_i, p_i)] - \sum_{i=1}^{s} g(m_i) = 0 \quad \text{(P10)}$$

γ_s and m_s are solved by (P9)-(P10).

Prove joint concavity.

1 (c): Now prove that $p_t^* > 0$ and $\gamma_t = 0$ for $t < s$.

Based on (P7), when the budget constraint is binding:
If p_t is zero while budget constraint is not binding, (t<s), the startup should always increase its price from zero to improve its profits given the same effort level. Therefore, $p_t > 0, t < s. \gamma_t = 0. \frac{\partial E[\Pi_t(m_t,p_t)]}{\partial p_t}\Big| p_t = p_t^* = 0, \frac{\partial \sum_{i=t}^{s} E[\Pi_i(m_i,p_i)]}{\partial m_t}\Big| m_t = m_t^* < 0.$

For $1 \leq t \leq s-1$,

$$\frac{\partial U(m_s,p_s)}{\partial m_t} = \frac{\partial E[D_s(m_s,p_s)]}{\partial m_t} + \lambda_s \frac{\partial \sum_{i=t}^{s} E[\Pi_i(m_i,p_i)]}{\partial m_t}$$

$$= \beta^{s-t} + \lambda_s\left[\sum_{i=t}^{s} p_i \beta^{i-t} - g'(m_t)\right] = 0 \quad \text{(P11)}$$

$$\frac{\partial U(m_s,p_s)}{\partial p_t} = \frac{\partial E[D_s(m_s,p_s)]}{\partial p_t} + \lambda_s \frac{\partial E[\Pi_t(m_t,p_t)]}{\partial p_t} + \gamma_t = \lambda_s \frac{\partial E[\Pi_t(m_t,p_t)]}{\partial p_t} + \gamma_t$$

$$= \lambda_s\left[p_t y'(a_t,p_t) + E[D_t(m_t,p_t)]\right] = 0 \quad \text{(P12)}$$

In period t, p_t^* maximizes its profit and m_t^* solves equation (P11).

(P12) leads to the following with $\gamma_t = 0$:

$$E[D_t(m_t,p_t)] = -p_t y'(a_t,p_t) \quad \text{(P13)}$$

$$\sum_{i=1}^{s-1} E[D_i(m_i,p_i)] = -\sum_{i=1}^{s-1} p_i y'(a_i,p_i) \quad \text{(P14)}$$

$$\sum_{i=1}^{s-1} E[\Pi_i(m_i,p_i)] = -\sum_{i=1}^{s-1} p_i^2 y'^{(a_i,p_i)} - \sum_{i=1}^{s-1} g(m_i) \quad \text{(P15)}$$

Plug in (P6) to (P11)

$$g'(m_t) = \beta^{s-t} g'(m_s) + \sum_{i=t}^{s-1} p_i \beta^{i-t} \quad \text{(P16)}$$

As indicated in (P11)

$$g'(m_t) \geq \sum_{i=t}^{s} p_i \beta^{i-t}$$

m_t^* and p_t^* are solved by Equations (P13) and (P16).

Proof of Lemma 1:

Linear demand: $y(a_t, p_t) = a_t - bp_t,\ y'(a_t, p_t) = -b, E[D_t(m_t, p_t)] = a_t - bp_t + \sum_{i=1}^{t} \beta^{t-i} m_i + \mu = bp_t$. Therefore, $p_t = \frac{a_t + \sum_{i=1}^{t} \beta^{t-i} m_i + \mu}{2b}$. As t increases, a_t increases. Cumulative effort is increased by m_t. $p_t > p_{t-1}$. Based on (P16), $g'(m_t)$=$\beta g'(m_{t+1}) + p_t$. Therefore, $g'(m_{t+1}) - g'(m_t) = (1-\beta) g'(m_{t+1}) - p_t > 0$.

Proof of Proposition 2:

For 1≤ $t \leq s-1$,

$$\frac{\partial U(m_s, p_s)}{\partial m_t} = \lambda_s (p_t - 2cm_t) = 0 \quad \text{(P12)}$$

$$\frac{\partial U(m_s, p_s)}{\partial p_t} = \lambda_s [a_t - 2bp_t + m_t + \mu] + \gamma_t = 0 \quad \text{(P13)}$$

Therefore, $p_t \geq$ c.

(P13) indicates that $p_t = \frac{a_t + m_t + \mu}{2b}$.

Therefore, $p_t = \frac{2c(a_t+\mu)}{4bc-1}$ and $m_t = \frac{a_t+\mu}{4bc-1}$. $E[D_t(m_t, p_t)] = 2bcm_t$.

Proof of Proposition 3:

At period s,

$$\frac{\partial U(m_s,p)}{\partial m_s}=\frac{\partial E[D_s(m_s,p)]}{\partial m_s}+\lambda_s\frac{\partial E[\Pi_s(m_s,p)]}{\partial m_s}=1+\lambda_s[p-g'(m_s)]$$
$$=0 \qquad \text{(P14)}$$

$$\frac{\partial U(m_s,p)}{\partial p}=\frac{\partial E[D_s(m_s,p)]}{\partial p}+\lambda_s\frac{\partial \sum_{i=1}^{s}E[\Pi_i(m_i,p)]}{\partial p}+\gamma$$
$$=y'(a_s,p)+\lambda_s\left[p\sum_{i=1}^{s}y'(a_i,p)+\sum_{i=1}^{s}E[D_i(m_i,p)]\right]+\gamma=0 \qquad \text{(P15)}$$

(i) $\gamma>0, p>0.$

Budget constraint (P10) leads to

$$\sum_{i=1}^{s}E[D_i(m_i,p)]=-\frac{K-\sum_{i=1}^{s}g(m_i)}{p} \qquad \text{(P16)}$$

Plug (P15) into (P16),

$$y'(a_s,p)=-\frac{\phi'(m_s)}{g'(m_s)}\left[p\sum_{i=1}^{s-1}y'(a_i,p)+\sum_{i=1}^{s}E[D_i(m_i,p)]\right]$$

$$E[D_s(m_s,p)]=-y'(a_s,p)g'(m_s)\ -\sum_{i=1}^{s-1}\left[py'(a_i,p)+E[D_i(m_i,p)]\right]$$

$$y'(a_s,p)p=\frac{1}{g'(m_s)}\left[K-\sum_{i=1}^{s}g(m_i)-p^2\sum_{i=1}^{s-1}y'(a_i,p)\right] \qquad \text{(P17)}$$

a_s and m_s are solved by Equations (P16) and (P17).

Compared to the benchmark case: $E[D_s(m_s,p_s)]=-y'(a_s,p_s)g'(m_s)$ (P18)

In (P15), $p\sum_{i=1}^{s}y'(a_i,p)+\sum_{i=1}^{s}E[D_i(m_i,p)]>0$

Therefore,

(ii) $\gamma\geq 0, p=0$

Plug in $p=0$, (P15) leads to

$$y'(a_s,0)+\frac{1}{g'(m_s)}\left[\sum_{i=1}^{s}E[D_i(m_i,0)]\right]+\gamma=0 \qquad \text{(P19)}$$

Budget constraint (28) leads to

$$K = \sum_{i=1}^{s} g(m_i) \tag{P20}$$

m_s and γ are solved by Equations (P19) and (P20).

At period $t \leq s-1$:

$$\frac{\partial U(m_s,p)}{\partial m_t} = \frac{\partial E[D_s(m_s,p)]}{\partial m_t} + \lambda_s \frac{\partial \sum_{i=t}^{s} E[\Pi_i(m_i,p)]}{\partial m_t} = \beta^{s-t} + \lambda_s \left[p \sum_{i=t}^{s} \beta^{i-t} - g'(m_t) \right] = 0 \ (32)$$

Plug λ_s into (21), $\beta^{s-t} + \frac{1}{g'(m_s)} \left[p \frac{1-\beta^{s-t}}{1-\beta} - g'(m_t) \right] = 0$

$$g'(m_t) = \beta^{s-t} g'(m_s) + p \frac{1-\beta^{s-t}}{1-\beta} \tag{P21}$$

Proof of Lemma 2: Following Equations (P16) and (P21).

Proof of Lemma 3:

Together with Lemma 1, we can easily prove that $p_1 \sum_{i=t}^{s-1} \beta^{i-t} = \sum_{i=t}^{s-1} p_1 \beta^{i-t} \leq p \sum_{i=t}^{s-1} \beta^{i-t} \leq \sum_{i=t}^{s-1} p_{s-1} \beta^{i-t} = p_{s-1} \sum_{i=t}^{s-1} \beta^{i-t}$, therefore, $p_1 \leq p \leq p_{s-1}$.

Proof of Proposition 4：

When selling price p does not change throughout the periods 1 to F-1, similar to the previous discussion:

$$U(m_F, p_F) = E[D_F(m_F,p_F)] + \lambda_F \left(K + \sum_{i=1}^{F} E[\Pi_i(m_F,p_F)] \right) + \gamma_F p_F \tag{P22}$$

$$\lambda_F \left(K + \sum_{i=1}^{F} E[\Pi_i(m_F,p_F)] \right) = 0 \tag{P23}$$

$$\gamma_F p_F = 0 \tag{P24}$$

where $\lambda_F \geq 0, \gamma_F \geq 0$.

At period F,

$$\frac{\partial U(m_F, p_F)}{\partial m_F} = \frac{\partial E[D_F(m_F, p_F)]}{\partial m_F} + \lambda_F \frac{\partial E[\Pi_F(m_F, p_F)]}{\partial m_F} = 1 + \lambda_F[p_F - g'(m_F)] = 0 \quad \text{(P25)}$$

$$\begin{aligned}\frac{\partial U(m_F, p_F)}{\partial p_F} &= \frac{\partial E[D_F(m_F, p_F)]}{\partial p_F} + \lambda_F \frac{\partial E[\Pi_F(m_F, p_F)]}{\partial p_F} + \gamma_F \\ &= y'(a_F, p_F) + \lambda_F(a_F, p_F)\left[p_F y' + E[D_F(m_F, p_F)]\right] + \gamma_F = 0 \quad \text{(P26)}\end{aligned}$$

Discussion: (i) If $p_F > 0$**,** $\gamma_F = 0, \lambda_F = 0$**.** p_F and m_F solve (P23), (P25) and (P26).

Equation (P22) can be expressed as:

$$E[D_F(m_F, p_F)] = -\frac{K + p\sum_{i=1}^{F-1} E[D_i(m_i, p)] - \sum_{i=1}^{F} g(m_i)}{p_F} \quad \text{(P27)}$$

Based on (P24) we derive

$$\lambda_F = \frac{1}{g'(m_F) - p_F} \quad \text{(P28)}$$

It conflict with $\lambda_F = 0$.

(ii) If $p_F = 0$**,** $\gamma_F \geq 0$. λ_F, γ_F and m_F are solved by $\lambda_F(K + \sum_{i=1}^{F} E[\Pi_i(m_F, p_F)]) = 0$, $1 + \lambda_F[p_F - g'(m_F)] = 0$ and $y'(a_F, p_F) + \lambda_F(a_F, p_F)\left[p_F y' + E[D_F(m_F, p_F)]\right] + \gamma_F = 0$.

At period $t \leq F - 1$:

$$\begin{aligned}\frac{\partial U(m_F, p_F)}{\partial m_t} &= \frac{\partial E[D_F(m_F, p_F)]}{\partial m_t} + \lambda_F \frac{\partial \sum_{i=t}^{F} E[\Pi_i(m_t, p_t)]}{\partial m_t} \\ &= \beta^{F-t} + \lambda_F \left[p\sum_{i=t}^{F-1} \beta^{i-t} - g'(m_t) + p_F \beta^{F-t}\right] \\ &= 0 \quad \text{(P29)}\end{aligned}$$

$$\begin{aligned}\frac{\partial U(m_F, p_F)}{\partial p} &= \frac{\partial E[D_F(m_F, p_F)]}{\partial p} + \lambda_F \frac{\partial \sum_{i=1}^{F-1} E[\Pi_i(m_t, p)]}{\partial p} + \gamma_F \\ &= \lambda_F \left[p\sum_{i=1}^{F-1} y'(a_i, p) + \sum_{i=1}^{F-1} E[D_i(m_i, p)]\right] + \gamma_F = 0 \quad \text{(P30)}\end{aligned}$$

$\lambda_F > 0$, therefore

$$\sum_{i=1}^{F-1} E[D_i(m_i, p)] = -p\sum_{i=1}^{F-1} y'(a_i, p) \quad \text{(P31)}$$

$$E[D_F(m_F, p_F)] = -\frac{K + p\sum_{i=1}^{F-1} E[D_i(m_i, p)] - \sum_{i=1}^{F} g(m_i)}{p_F} \quad \text{(P32)}$$

$$y'(a_F, p_F)p_F = \frac{1}{g'(m_F)}\left[K - p^2\sum_{i=1}^{F-1} y'(a_i, p) - \sum_{i=1}^{F} g(m_i)\right] \quad \text{(P33)}$$

Plug in $\lambda_F = \frac{1}{g'(m_F) - p_F}$ to (P14)

$$\beta^{F-t} + \frac{1}{g'(m_F)}\left[p\frac{1-\beta^{F-t}}{1-\beta} - g'(m_t)\right] = 0 \quad \text{(P34)}$$

Supply Chain Divergence in Chinese Global Firms: Conceptual Framework for Strategic Navigation

Paul Hong[1], MyeongCheol Choi[2,3], Mehrdad Jalali Sepehr[4]

[1]The University of Toledo, Toledo, USA. [2]Gachon University (Global Business, College of Business Administration), Seongnam, Korea, Republic of. [3]Visiting Scholar at the University of Toledo, Toledo, USA. [4]The university of Toledo, Toledo, USA

Abstract

This study constructs a conceptual framework for strategic navigation to understand the supply chain divergence among Chinese global firms as they engage with the complexities of international markets. By analyzing the strategic maneuvers of eight major Chinese global firms in their expansion into North American and European markets, as well as their operations in emerging economies, this research highlights the dual challenge of adapting to global market dynamics while maintaining efficient, responsive supply chains. Through a multiple case study approach, we examine the supply chain strategies employed by Chinese firms across various industries, revealing how they navigate geopolitical tensions, regulatory environments, and market demands. This analysis offers insights into the mechanisms behind the strategic divergence in supply chain models, providing valuable lessons for business leaders and policymakers on fostering resilience and competitive advantage in a global context. Our findings underscore the critical role of strategic flexibility and innovation in supply chain management for Chinese multinational corporations aiming to thrive in the global arena.

Key Words: Supply Chain Divergence; Market Dynamics, Chinese Global Firms,

Geopolitical Tensions, Competitive Positions

1. Introduction

The rise of Chinese global firms and their expanding influence in international markets has introduced a complex array of challenges and opportunities, fundamentally altering the landscape of global business and supply chain management. In this context, the concept of supply chain divergence becomes a pivotal area of study to understand how Chinese multinational corporations (MNCs) strategically navigate through the intricacies of global expansion. This research aims to construct a conceptual framework for

strategic navigation, focusing on the adaptation and differentiation strategies within supply chains as Chinese firms confront diverse market dynamics, regulatory environments, and geopolitical tensions. Unlike empirical studies that predominantly analyze outcomes, our approach seeks to delineate the theoretical underpinnings that guide these firms' strategic decisions in managing their supply chains across varied international contexts (Zámborský et al., 2023; Efferin & Hopper, 2007; Wang & Miao, 2016).

Central to our exploration is the analysis of how Chinese MNCs, such as Huawei, Lenovo, and Xiaomi, among others, leverage their supply chain operations to optimize performance and secure competitive advantages in both developed and emerging markets. This study does not aim to present empirical analysis results but rather to offer a comprehensive conceptual framework that illuminates the strategic maneuvers and supply chain adaptations employed by these firms. Through a qualitative synthesis of the strategic orientations and supply chain configurations of eight major Chinese global firms, this investigation highlights the dual challenge of adapting to global market dynamics while maintaining efficient, responsive supply chains, amidst the backdrop of a rapidly evolving global economic climate marked by technological advancements and shifting geopolitical alliances (Hyman, 2005; Liu et al., 2020; Polfuß & Sönmez, 2020).

By maintaining a focus on the interrelations between market dynamics, geopolitical tensions, and supply chain divergence, our study contributes to a deeper understanding of the strategic flexibility and innovation required in supply chain management for Chinese MNCs aiming to thrive globally. This introductory section sets the groundwork for discussing the evolving roles of Chinese MNCs within the global supply chain ecosystem, emphasizing the development of a conceptual framework designed to navigate the complexities of strategic supply chain divergence. It positions the study within the broader discourse on international business strategy and supply chain management, aiming to provide valuable insights for academics, business strategists, and policymakers engaged with the challenges and opportunities of global expansion presented by Chinese firms (Quitzow et al., 2017; Fletcher & Plakoyiannaki, 2011).

2. Theoretical Foundation

The theoretical foundation offers a multi-lens approach to dissecting the complex international strategies of Chinese firms (Voss et al., 2010). This research requires a theoretical insight into the power dynamics and the competitive behavior of states that can influence multinational corporate strategies, especially pertinent for state-owned enterprises in China navigating geopolitical tensions. There needs a theoretical lens to address rapidly changing environments—a necessity for Chinese firms operating in diverse and evolving global markets (Deng, 2012). Another important theoretical perspective is to shed light on how Chinese firms innovate their value proposition, revenue streams, and operational structures to create

competitive differentiation and value in foreign markets. The following three theories are chosen to address these pertinent issues.

2.1. Realism Theory

Realism theory, in the context of international relations, is grounded in the perspective that the international system is anarchic and that states are the primary actors, driven by the rational pursuit of power to ensure survival and security (Bell, 2017; Donnelly, 2000). Nations are driven by objective laws rooted in human nature, leading to a perpetual quest for power balance (Morgenthau, 1973). The concept of structural realism emphasizes how the anarchic structure of the international system compels states to prioritize survival, often resulting in a security dilemma, where the defensive actions of one state are viewed as threats by others, potentially leading to escalating tensions (Neuss, 2007; Mearsheimer, 2001).

Realism theory offers a unique lens through which to view the strategic maneuvers of firms in the global marketplace. Just as nations vie for power and security within the anarchic international system described by realism, firms—especially those from rapidly ascending economies like China—engage in a parallel pursuit of power within the market. They seek a balance of power not just through economic might, but through the strategic management of their supply chains. This includes diversifying supply sources to mitigate risks and leveraging market dynamics to enhance their competitive positioning (Ho et al., 2015; Singh & Hong, 2020, 2023; Tang, 2006). The inherent competition and the desire for security in supply chain operations reflect the realism theory's tenets, as firms act in ways that mirror the defensive postures of states, always striving to secure their survival in a volatile market environment.

2.2. Dynamic Capabilities Theory

Dynamic capability theory, a cornerstone of strategic management, concerns the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments (Teece et al., 1997; Teece, 2007). Dynamic capability theory provides a framework to understand how these firms adapt to diverse and dynamic market conditions (Haarhaus & Liening, 2020). Chinese firms, particularly those expanding globally, face environments that differ significantly from their home market in terms of culture, regulation, competition, and consumer behavior (Wang and Miao, 2016). The ability to dynamically adjust and innovate business processes, product offerings, and strategic approaches is essential for these firms to overcome the liabilities of foreignness and to capitalize on new opportunities (Herrera, 2016). Dynamic capabilities thus allow them to navigate strategic divergence—where their business strategies might differ substantially from their domestic strategies to meet the unique demands of each foreign market they enter (Ambrosini & Bowman, 2009; Teece, 2014).

Furthermore, dynamic capability theory underscores the importance of a firm's ability to sense and seize opportunities, and to maintain alignment with the evolving business environment (Matysiak et al., 2018). For Chinese global firms, which may start with a strong domestic focus, the capacity to learn, adapt, and potentially influence new contexts is a significant determinant of their international success or failure (Li & Liu, 2014). These capabilities become particularly important when responding to the fast-paced changes in technology, global trade policies, and competitive landscapes (Williamson, 2016). Therefore, the theory provides a valuable lens through which to assess how Chinese firms develop and deploy these capabilities to create competitive advantages overseas, manage strategic divergence effectively, and generate market responses that can range from enthusiastic acceptance to resistance or even backlash, affecting their global trajectories (Teece, 2018; Wen, 2020; Hong et al., 2024).

2.3. Business Model Theory

Business model theory examines the rationale of how an organization creates, delivers, and captures value. The business model canvas is a strategic management tool that visualizes multiple components of a business model, encouraging a holistic approach to understanding how firms operate, deliver value, and earn revenue (Osterwalder & Pigneur, 2010). The value proposition is the innovative offering that a company provides to customers, focusing on addressing unmet needs or creating new markets (Christensen & Raynor, 2018). Companies innovate their business models to capture opportunities in unmet, overlooked, or new markets, emphasizing adaptability and innovation in the model itself (Johnson, 2010).

Business model theory elucidates the strategic structuring by Chinese firms to generate value across international markets, guiding the adaptation of their business strategies and value propositions in response to diverse market conditions (Liu & Wang, 2023). This theory explores how these firms modify their models to align with the distinct economic, cultural, and regulatory landscapes they encounter, exemplified by a tech company localizing its offerings or a manufacturing firm optimizing its supply chain for efficiency in new markets (Wang et al., 2020). It underscores the importance of aligning a firm’s value proposition with its business model to effectively navigate global expansion challenges, including variations in consumer behavior and regulatory frameworks (Chin et al., 2021). The theory assists in understanding the strategic divergence and innovation required for Chinese firms to sustain and scale their operations internationally, responding adeptly to market dynamics (Rissanen et al., 2020). Ultimately, it sheds light on the differential success of Chinese companies globally, highlighting the significance of crafting business models that resonate with local markets versus those that falter due to misalignment with market expectations (Hennart et al., 2021)

Together, these three theories provide a comprehensive lens through which to analyze the strategies employed by firms from these Asian economies in their quest for global market expansion, particularly through the lens of supply chain agility. The intensification and prolongation of US-China competition,

changes in China's business environment, and instability in the global supply chain are prompting Chinese manufacturing companies to accelerate their expansion overseas (Hong & Park, 2020; Wang et al., 2020). The trade competition between the US and China, which began in the realm of commerce, has continuously expanded into areas such as technology and investment. Amidst this escalating US-China rivalry, we are witnessing a fragmentation and balkanization of the global supply chain (Hong & Park, 2020a; Sharma et al., 2020).

3. An Overview of Chinese Global Firms

Chinese global firms have become significant players on the global stage, marking their presence across various industries and sectors. As of 2023, the number of Chinese firms listed in the Global Fortune 500 stood at a remarkable figure, placing China second only to the United States (Nolan & Zhang, 2002; Sharma et al., 2020). This achievement underscores China's growing economic power and the global reach of its corporate entities (Hong et al., 2024). The Chinese firms that make up this list can be categorized into two distinct groups based on their operational characteristics and market focus (Li et al., 1999).

3.1. Growth of Chinese Global Fortune 500 Firms and Forbes 2000

Table 1 provides a comparative overview of the number of firms from various countries listed in the Global Fortune 500 and Forbes 2000 over the years from 2017 to 2023. It highlights the growth trajectory of Chinese and American firms specifically (Fortune, 2017). For China, there has been a fluctuation in the number of firms listed in the Global Fortune 500, starting at 133 in 2017, decreasing to 119 in 2019, then increasing to a peak of 143 in 2023. Additionally, in the Forbes 2023 listing, a remarkable jump to 302 Chinese firms is noted. In contrast, the USA has shown more stability and a slight upward trend in the Global Fortune 500 listings, beginning with 109 firms in 2017 and growing consistently to 136 in 2022 and 2023 (Fortune, 2023). The Forbes 2023 list shows a substantial lead with 610 American firms, indicating a significant presence of U.S. firms in the global corporate landscape. Table 1 also includes data for other countries, but the focus here is on China and the USA, which are the top two countries in terms of the number of firms listed in these prestigious rankings. It is notable that the USA maintains a lead over China in both the Global Fortune 500 and Forbes 2000 lists, reflecting the extensive global reach and influence of American firms. However, the substantial increase in Chinese firms, especially as reflected in the Forbes 2023 list, indicates a rapid expansion of Chinese corporate influence globally (Forbes, 2023).

Table 1. The Trends of Chinese Global Firms in the list of Global Fortune 500 and Forbes 2000

unty/Year	17	18	19	20	21	22	23	23*

ina	3	0	9	4	5	4	3	2
SA	9	6	1	1	2	6	6	0
ɔan								2
ınce								
rmany								
ɾ								
ırea								
ɾitzerland								
nada								
therlands								

Note: 2017-2023 Global Fortune 500 Firms 2023* Forbes 2023

Source: Global Fortune 500 and Forbes 2000 (Author's Own)

3.2. Ownership and Influence: Chinese State-Owned Enterprises and Global Private Firms

Chinese state-owned companies and Chinese global firms, in the strict sense, differ primarily in terms of ownership and their strategic objectives. Chinese state-owned enterprises (SOEs) are fully or majority-owned by the government and often serve strategic national interests, operating in critical sectors like energy, transportation, and telecommunications (Alon et al., 2014). Their goals frequently align with the state's developmental objectives, and they benefit from direct government support, which can include financial subsidies, regulatory advantages, and protected domestic market share. Additionally, their management decisions are often influenced by government policies and objectives, and they are sometimes used as instruments of state policy (Jones & Zou, 2017).

In contrast, Chinese global firms in the strict sense are usually private entities or publicly traded companies with diverse ownership that includes private investors, both domestic and foreign (Deng, 2012; Hong et al., 2017). They are profit-driven, strive for competitiveness in both domestic and international markets, and their strategic decisions are primarily influenced by market forces, shareholder value, and corporate governance structures (Polfuß & Sönmez, 2020). These firms often operate in a wider array of sectors, including technology, consumer goods, and services, and they typically adopt a more global outlook in their operations, seeking to expand their market reach, diversify their operations, and enhance their competitiveness on the international stage (Wang et al., 2020; Zámborský et al., 2023).

However, there is a growing perception that Chinese global firms, although not state-owned, are heavily influenced by the Chinese government and the Chinese Communist Party (CCP) (Opper et al., 2002). This perception stems from several factors. Firstly, China's political and economic model blurs the lines between public and private sectors, with the state wielding considerable influence over the economy and private firms. The CCP has established mechanisms to maintain a presence within private companies, such as party committees that can influence decision-making. Secondly, the Chinese government's industrial policies, such as "Made in China 2025," and initiatives like the Belt and Road Initiative, outline strategic sectors for international expansion, where private firms are encouraged to align their overseas investments with the

state's geopolitical and economic interests (Li, 2018). This alignment can offer these firms advantages, such as access to financing from state-owned banks and diplomatic support, but it also leads to assumptions that their operations may serve or align with the broader strategic interests of the state (Efferin & Hopper, 2007).

Moreover, the regulatory environment in China can compel private firms to comply with government directives, which may include providing data or technological support that benefits state security and diplomacy objectives (Chan, 2009). As Chinese firms go global, their close ties with the Chinese state, whether through direct support or through regulatory compliance, raise concerns among international regulators, competitors, and governments about issues such as data security, intellectual property rights, and market fairness (Alon et al., 2014; Jones & Zou, 2017). These concerns are amplified by the CCP's emphasis on national champions and the strategic importance of technology and information in national development. As a result, Chinese global firms often face scrutiny and skepticism in international markets, impacting their global expansion strategies and market responses (Chen, 2014).

4. Conceptual Framework

A conceptual framework in the context of business and management research is a structure that researchers use to outline the possible courses of action or to present a preferred approach to an idea or thought process. It is built on a set of concepts and the proposed relationship between these, which guides the research by determining what things will be measured, and what conceptual and statistical relationships will be looked for. In this study the conceptual framework is likely to map out the factors that influence Chinese firms' performance in global markets, such as market trends, geopolitical tensions, strategic market orientation, supply chain agility, and overall market performance (Kazancoglu et al., 2021).

This framework identifies the multiple variables that can affect their global success or failure. It suggests that the strategic choices made by these firms, such as diversifying markets and differentiating products, are influenced by global market dynamics and can lead to varying degrees of supply chain agility This, in turn, impacts market performance, including financial performance and competitive advantage (Liu & Atuahene-Gima, 2018). By conceptualizing these relationships, researchers and practitioners can better understand how and why Chinese firms achieve different levels of success in international markets. This understanding can inform the development of strategies that are more likely to lead to successful market performance and help firms navigate the complexities of global expansion amidst political and economic challenges (Li et al., 2018).

Figure 1 is a conceptual framework depicting the relationship between various business elements: Global Market Dynamics, Strategic Market Orientation, Supply Chain Agility, and Market Performance. The left side of the diagram shows 'Global Market Dynamics' with two components: 'Global Market Trends' and 'Geopolitical Tension Exposure.' There are arrows labeled P1 and P2, suggesting propositions or pathways leading from these two components towards the central concept of 'Strategic Market Orientation,' which itself comprises 'Market Diversification' and 'Product Differentiation.'

From 'Strategic Market Orientation,' an arrow labeled P3 points towards 'Supply Chain Agility,' which includes 'Supply Chain Responsiveness' and 'Supply Chain Flexibility.' From here, two pathways are

indicated: one, labeled P4, leading to 'Market Performance,' and the other, labeled P5, looping back towards 'Global Market Dynamics,' suggesting a feedback loop.

'Market Performance' is shown on the right side of the diagram and has two components: 'Financial Performance' and 'Competitive Advantage.'

This framework is important because it visually represents the hypothesized relationships between external market factors, internal strategic decisions, supply chain management, and overall market success. It suggests that a company's ability to understand and adapt to global trends, diversify, and differentiate in the market, and maintain an agile supply chain can lead to better financial performance and a competitive edge. This can be valuable for strategic planning, decision-making, and identifying areas for improvement within an organization. Building on the conceptual framework of Figure 1, Table 2 provides a structured overview of key factors and variables that influence the strategic approaches of global Chinese firms in the face of market dynamics and supply chain divergence. It is segmented into four major constructs and eight key variables and definitions, providing insight into how Chinese firms can navigate different market landscapes through their strategic divergence and supply chain agility practices.

Table 2 lays the foundation for a comprehensive analysis of the external and internal factors affecting the performance and strategic decisions of Chinese firms in the global market. By defining and measuring these factors, this study examines the strengths and weaknesses of Chinese firms' strategies, understand how they adapt to and influence market and supply chain dynamics, and gauge their overall competitiveness. Moreover, it allows for a practical understanding of how Chinese firms can sustain their market positions amidst fluctuating geopolitical climates and rapidly changing market trends.

Table 2 provides a structured overview of key factors and variables that influence the strategic approaches of global Chinese firms in the face of market dynamics and supply chain divergence. It is segmented into four major constructs and eight key variables and definitions, providing insight into how Chinese firms can navigate different market landscapes through their strategic divergence and supply chain agility practices. It outlines various business concepts that are vital for understanding how firms interact with and adapt to the changing global market landscape. Starting with 'Global Market Trends,' it covers the broad shifts in the market that affect consumer behavior and technology, and 'Geopolitical Tension Exposure,' which dives into how companies navigate through political challenges and maintain growth. 'Market Diversification' and 'Product Differentiation' are strategies highlighting how companies, especially within the Chinese context, expand their reach and stand out in the market by offering unique products and tapping into different regional markets. Moving on to the supply chain aspect, 'Supply Chain Responsiveness' and 'Supply Chain Flexibility' reflect a company's ability to adapt to changes such as market demands, supply disruptions, and logistical challenges. This agility ensures that customer expectations are met without compromising operational efficiency. The final concepts of 'Financial Performance' and 'Competitive Advantage' measure a company's economic health and its unique strengths that outshine competitors, respectively.

Understanding these factors is crucial for companies aiming to thrive in today's global economy. These elements form a blueprint for creating resilient, adaptable strategies that help companies respond to external pressures, innovate, and stay ahead financially and competitively. They represent a comprehensive view of the necessary components for success, from how a firm positions itself in the market to how it operates its supply chain and secures its financial footing.

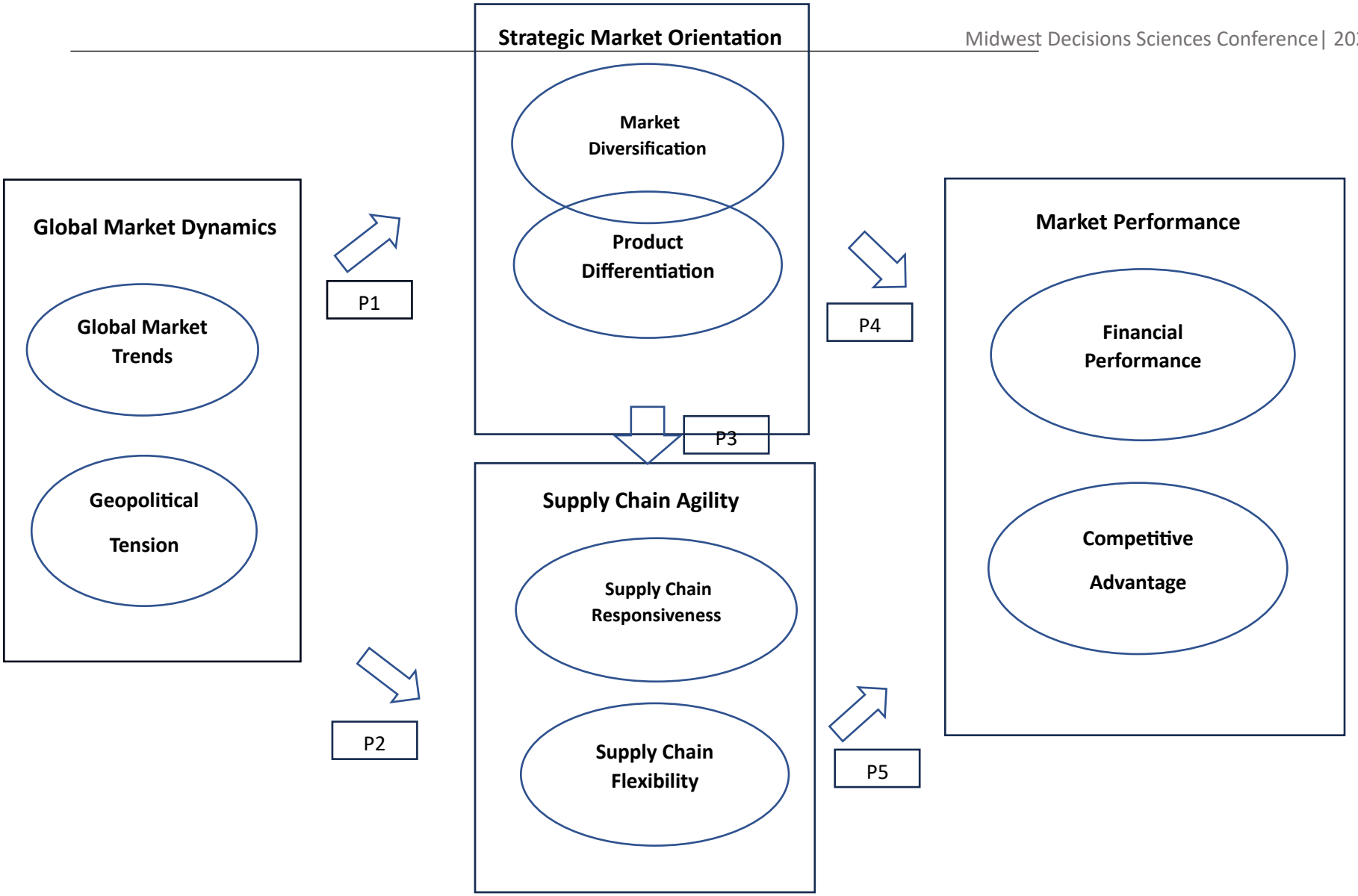


Figure 1. Conceptual Framework: Market Dynamics, Strategic Orientation, SC Agility and Market Performance

Table 2. Market Dynamics and Strategic Divergence

Key Factors and Definition	Key Variables and Definition
Global Market Trends refer to the prevailing movements and directions in the worldwide market that impact the industry including shifts in consumer behavior, technological advancements, and economic factors that drive the supply and demand on a global scale in shaping the competitive landscape and fostering innovation (Alshanty & Emeagwali, 2019; Aslam et al., 2018; Piercy, 2016; Wilden & Gudergan, 2015).	▪ **Advanced Market Priorities** include sophisticated consumer demands, ambitious standards for product quality, and a focus on sustainable and ethical practices. Advanced markets often prioritize innovation, brand reputation, and service excellence. ▪ ▪ **Emerging Market Requirements** represent the needs and conditions specific to developing economies. They often focus on accessibility, affordability, and basic functionality of products and services. In emerging markets, there's usually a higher sensitivity to price and a need for products that can perform under less developed infrastructure conditions.
Geopolical Tension Exposure are the series of strategic actions and regulatory measures implemented by governments to support, enhance, and foster growth and contextual accommodation. (Grimes & Du, 2022; Khan et al., 2021; Nygaard, 2023; Yang & Chan, 2023).	▪ **Trade Barrier Prevalence** encompasses the frequency and impact of tariffs, quotas, and trade wars that can arise from geopolitical tensions. It reflects the degree to which such barriers could affect a firm's ability to operate internationally, impacting costs and supply chains. ▪ **Regulatory Shift Frequency** measures the rate at which regulations affecting business operations change due to political actions which complicate compliance, market access, and investment decisions, particularly in sectors sensitive to geopolitical relations**.**
Market Diversification refers to the strategic approach undertaken by Chinese firms to broaden their market base across different regions and sectors that aims to mitigate risks by reducing dependency on a single market or region and to capture a variety of growth opportunities by catering to diverse customer needs and protecting against market volatility. (Gaur & Delios, 2015; Miyajima et al., 2015; Tang et al., 2019).	▪ **Geographical Expansion** is the extent to which Chinese firms establish their presence in multiple countries or regions in terms of the number of new markets entered, the percentage of revenue derived from international markets, or the spread of physical operations globally. ▪ **Sectoral Spread** is the degree to which Chinese firms operate across different industries or offer a wide range of products and services in terms of the diversity of their product lines, the range of sectors they serve, and their ability to adapt to different industry dynamics assessed through the diversity of their product lines, the range of sectors they serve, and their ability to adapt to different industry dynamics.

Product Differentiation refers to the strategy implemented by firms to distinguish their products or services from those of competitors for attracting a diverse customer base and achieving pricing power. (Duanmu et al., 2018; Mohammadi et al., 2019; Schmalensee, 1982; Zhao et al., 2017).	▪ **Innovative Features and Design** measures the extent to which Chinese firms incorporate unique characteristics or design elements into their products that meet or create new customer needs through the number of patents filed, investment in research and development (R&D), or the launch of products with new functionalities that are distinct from existing offerings in the market. ▪ **Brand Perception and Value** is the degree to which Chinese firms successfully establish a strong, positive brand identity and value proposition in the eyes of consumers through brand awareness surveys, customer satisfaction ratings, and market share in target segments.

Table 2. Market Dynamics and Supply Chain Divergence

Key Factors and Definition	Key Indicators and Definition
Supply Chain Responsiveness refers to the agility of a firm's supply chain in responding to changes in market demand, fluctuations in supply, or disruptions in logistics and distribution for maintaining operational efficiency, ensuring timely delivery of products, and meeting customer expectations in various markets. (Asamoah et al., 2021; Singh, 2015; Richey et al., 2022).	▪ **Adaptability to Demand Fluctuations** measures the extent to which Chinese firms can adjust their production and supply chain processes in response to changes in market demand by the speed at which a firm can scale production up or down, the flexibility of its inventory management systems, and its ability to shift sourcing strategies as required. ▪ **Efficiency in Logistics and Distribution** is the degree to which Chinese firms manage the logistics and distribution aspects of their supply chain to ensure prompt and reliable delivery of products including the effectiveness of their transportation networks, warehousing operations, and order fulfillment processes in terms of delivery lead times, the accuracy of order processing, and the cost-effectiveness of logistics operations.
Supply Chain Flexibility refers to the capability of a firm's supply chain to adapt efficiently to various changes and uncertainties within the market environment, including shifts in customer demand, supply interruptions, and changes in global trade regulations. (Gong, 2008; Stevenson & Spring, 2009; Tiwari et al., 2015).	▪ **Variability Handling in Supply Sources** assesses the ability of Chinese firms to manage variations in supply sources without compromising the stability or performance of their supply chain evaluating the diversity of their supplier base, the robustness of their supplier relationships, and the strategies employed to mitigate risks associated with supplier reliability and raw material availability. ▪ **Customization Capacity** measures the extent to which Chinese firms can tailor their products and services to meet specific customer requirements without incurring significant delays or costs offering a wide range of product variants, customize products in response to individual customer preferences, and adjust manufacturing processes to accommodate custom orders.
Financial Performance Financial Performance is the measure of a company's profitability, revenue growth, return on investment, and overall financial health as reflected in financial statements sustainability and shareholder value in a competitive market environment (Gu et al., 2024; Vickery et al., 2003; Wagner et al., 2012).	▪ **Profit Margin Improvement** gauges the effectiveness of Chinese firms in enhancing their profit margins, an essential aspect of financial performance analyzing the ratio of net income to revenue over time, indicating the firm's efficiency in controlling costs and maximizing income from sales. ▪ **Revenue Growth Rate** measures the pace at which a Chinese firm's revenue is increasing over a specified period, serving as an indicator of its market expansion, customer base growth, and overall financial health by comparing annual or quarterly revenue figures, highlighting the firm's success in capturing market share, entering new markets, and responding to market demands.
Competitive Advantage refers to the unique attributes or capabilities a firm possesses that allow it to achieve superior performance relative to its	▪ **Innovation Leadership** assesses the extent to which Chinese firms lead in innovation within their industry, which is a critical component of competitive advantage evaluating the firm's investment in research and development (R&D), the number of new patents it secures, the introduction of breakthrough products or services, and the overall impact of these innovations on market standards and customer expectations.

competitors in the marketplace. (Alfalla-Luque et al., 2018; Li et al., 2006; Wu et al., 2017)	▪ **Supply Chain Efficiency** refers to how effectively Chinese firms manage their supply chain operations to reduce costs, improve speed, enhance flexibility, and maintain the quality of goods and services optimizing logistics and distribution, managing supplier relationships for resilience and cost-effectiveness, and leveraging technology for supply chain visibility and coordination.

5. Proposition Development

Proposition Development refers to the process of formulating testable statements or hypotheses that aim to explain the relationship between specific variables within the strategic management framework. These propositions are based on observed phenomena or established theories and are crafted to be empirically evaluated through research and data analysis. It bridges theoretical constructs with real-world practices, enabling to examine how Chinese firms adopt to achieve a competitive advantage in the face of global market dynamics and supply chain challenges. Propositions serve as the backbone of scholarly inquiry, providing a structured approach to understanding complex relationships and contributing to the body of knowledge on strategic management and international business.

5.1. Global Market Dynamics and Strategic Market Orientation

There have been the broad shifts in technology, consumer behaviour, and economic factors that set the stage for competitive interactions on a worldwide scale (Alshanty & Emeagwali, 2019). As these dynamics evolve, they exert a considerable influence on how Chinese firms orient themselves strategically within the market (Wilden & Gudergan, 2015). For instance, as international consumer trends increasingly Favor digital integration and sustainability, and as geopolitical relationships shift, these external factors prompt Chinese firms to diversify and differentiate their market approaches to maintain competitive positions (Aslam et al., 2018; Liu & Wang, 2023). Advanced Market Priorities, like sustainable practices and innovation, along with Emerging Market Requirements, such as cost-effectiveness and functional robustness, shape how these firms position their products and services to align with shifting consumer expectations and regulatory landscapes (Piercy, 2016; Liu et al., 2020).

Furthermore, Strategic Market Orientation is how firms respond to these dynamics through targeted approaches such as Market Diversification and Product Differentiation (Gaur & Delios, 2015; Mohammadi et al., 2019). As Chinese firms encounter varying levels of Trade Barrier Prevalence and experience shifts due to Regulatory Shift Frequency, their ability to penetrate new markets and spread across sectors (Geographical Expansion and Sectoral Spread) becomes critical (Grimes & Du, 2022; Yang & Chan, 2023). These firms must navigate trade barriers and regulatory changes, aligning their operations to mitigate risks and leverage opportunities (Khan et al., 2021; Nygaard, 2023). The agility with which they can adjust their product offerings and branding strategies (Innovative Features and Design, Brand Perception and Value) in response to global market trends and geopolitical tensions directly impacts their competitive stance (Tiwari et al., 2015). Therefore, the intensity and direction of Global Market Dynamics, particularly through variables like Advanced Market Priorities and Emerging Market Requirements, are inextricably linked to the effectiveness of Strategic Market Orientation of Chinese firms (Deng, 2012). The more pronounced and targeted the global market trends and geopolitical shifts are, the more significant is the influence on the firms' strategic development of their market diversification and product differentiation efforts (Yang & Chan, 2023; Nygaard, 2023). This strategic orientation, in turn, shapes the firms' competitive advantage in the global arena. Therefore, it is posited,

Proposition 1. The more pronounced and aligned the Global Market Dynamics, as reflected by Advanced Market Priorities and Emerging Market Requirements, the more effectively will Chinese

firms develop their Strategic Market Orientation, resulting in more robust Market Diversification and Product Differentiation efforts.

5.2. Global Market Dynamics and Supply Chain Agility

Global Market Dynamics include broad shifts such as technological advancements, changes in consumer behaviour, and various economic factors. These dynamics are crucial for shaping the competitive landscape within which Chinese firms operate (Stevenson & Spring, 2009; Singh, 2015). As these market dynamics unfold, they significantly influence the agility required in a firm's supply chain to maintain operational effectiveness. supply chain agility, encompassing supply chain responsiveness and flexibility, becomes a vital attribute, allowing firms to swiftly adjust to these global changes, manage disruptions, and capitalize on new opportunities (Li et al., 2014; Li et al., 1999).

As Chinese firms experience the effects of Global Market Trends, including Advanced Market Priorities and Emerging Market Requirements, their supply chains must be adept at managing these influences (Sharma et al., 2020; Wang et al., 2016). For instance, adapting to digital integration and sustainability requires supply chains that are not only responsive but also flexible enough to implement rapid changes in production processes, sourcing, and distribution (Gong, 2008; Richey et al., 2022) This is further complicated by Geopolitical Tension Exposure, where Trade Barrier Prevalence and Regulatory Shift Frequency could necessitate sudden adjustments in supply chain strategies. To effectively manage these shifts, Chinese firms must have a supply chain that can manage variability in supply sources (Variability Handling in Supply Sources) and can also customize outputs to meet market demands (Customization Capacity) (Yang et al., 2023). Therefore, in alignment with the interactions depicted in the conceptual framework, the following proposition is developed:

Proposition 2. The more dynamic the Global Market Dynamics, as indicated by the rapid evolution of Advanced Market Priorities and the diverse requirements of Emerging Markets, the greater the need for Supply Chain Agility in Chinese firms. This agility, determined by the firm's capacity for Adaptability to Demand Fluctuations and Efficiency in Logistics and Distribution, directly influences the firm’s ability to sustain its competitive advantage in the global marketplace.

5.3. Strategic Market Orientation and Supply Chain Agility

Strategic Market Orientation encompasses the targeted approaches Chinese firms take to align and continuously adapt their market strategies in response to Global Market Dynamics (Miyajima et al., 2015). This orientation involves decisions related to Market Diversification and Product Differentiation to meet the demands of diverse and evolving markets. In turn, the agility of the supply chain plays a critical role in enabling these strategic orientations. Supply Chain Agility, which includes both responsiveness and flexibility, allows firms to rapidly align their operations with their strategic market goals, ensuring that products meet the specific needs of different markets and can be delivered in a timely and cost-effective manner (Duanmu et al., 2018; Tiwari et al., 2015).

As Chinese firms prioritize Market Diversification, they extend their reach across various regions and industries, which requires a supply chain that can handle the complexities of multiple market demands and regulatory environments (Schmalensee, 1982; Zhao et al., 2017; Asamoah et al., 2021). Similarly, Product Differentiation demands a supply chain capable of adjusting manufacturing processes and logistics to cater to the unique features and variations of products tailored for different consumer segments. In both instances, the supply chain must exhibit Adaptability to Demand Fluctuations to scale production up or down as needed and possess Customization Capacity to meet specific customer requirements. The synergy between Strategic Market Orientation and Supply Chain Agility is pivotal; one dictates the market engagement strategy, and the other enables its execution (Asamoah et al., 2021; Aslam, et al., 2018). Therefore, the following proposition can be formulated:

Proposition 3. The effectiveness of a Chinese firm's Strategic Market Orientation, characterized by Market Diversification and Product Differentiation, is contingent upon its Supply Chain Agility. A firm's ability to adapt its supply chain operations to accommodate diverse and changing market needs — as measured by its Adaptability to Demand Fluctuations and Customization Capacity — enhances its capability to implement its strategic market orientations successfully. This relationship is critical for maintaining competitive performance and achieving sustainable growth in the global market**.**

5.4. Strategic Market Orientation and Market Performance

Strategic Market Orientation in the context of Chinese global firms is a critical factor influencing Market Performance. As seen in Figure 1 and detailed in Table 1, Market Performance is gauged by indicators such as Financial Performance and Competitive Advantage, which ultimately reflect the effectiveness of a firm's strategies in the marketplace (Alfalla-Luque et al., 2018; Miyajima et al., 2015). Strategic Market Orientation, which comprises decisions on Market Diversification and Product Differentiation, directly contributes to a firm's ability to penetrate new markets, satisfy diverse customer needs, and stand out from the competition (Mohammadi et al., 2019).

For instance, a firm's commitment to Market Diversification allows it to spread its risk and capitalize on opportunities across different regions and sectors. This expansion requires not only a responsive supply chain but also one that can support the varied market demands and withstand the competitive pressures in multiple markets (Gaur & Delios, 2015). On the other hand, Product Differentiation enables a firm to create unique value propositions that can lead to a strong Brand Perception and Value, enhancing customer loyalty and potentially leading to increased market share. Both these elements of Strategic Market Orientation are pivotal in driving a firm's Market Performance, especially when it comes to achieving superior Profit Margin Improvement and Revenue Growth Rate, as these measures are indicative of a firm's success in capturing market share and growing its business (Wagner et al., 2012; Wu et al., 2017). Therefore, based on the interdependencies outlined in the conceptual framework and the detailed variables provided in Table 1, the following proposition is developed:

Proposition 4. The degree of a Chinese firm's Strategic Market Orientation, as manifested through comprehensive Market Diversification and robust Product Differentiation, is positively associated with its Market Performance. A firm's strategic efforts to expand geographically

(Geographical Expansion) and across sectors (Sectoral Spread), as well as to create distinct and innovative products (Innovative Features and Design), will lead to improved Financial Performance and a stronger Competitive Advantage. This connection underscores the importance of a well-conceived market strategy in achieving financial success and a sustainable competitive position in the global market.

5.5. Supply Chain Agility and Market Performance

Supply Chain Agility, which includes Supply Chain Responsiveness and Flexibility, is instrumental for Chinese global firms in achieving favourable Market Performance (Asamoah et al., 2021; Tiwari et al., 2015). As indicated in Figure 1 and Table 1, Market Performance encompasses Financial Performance, such as Profit Margin Improvement and Revenue Growth Rate, as well as a broader Competitive Advantage. Supply Chain Agility enables firms to swiftly adapt to market changes and disruptions, which is particularly crucial in the volatile global market landscape where rapid response to customer demand and efficient product delivery are key competitive differentiators (Gu et al., 2024; Vickery et al., 2003; Wagner et al., 2012).

In an environment marked by frequent and unpredictable shifts, the capacity for Adaptability to Demand Fluctuations allows a firm to modulate production and inventory in line with fluctuating consumer demands and market conditions. Efficiency in Logistics and Distribution ensures that products are delivered within the expected time frames, maintaining customer satisfaction and operational cost-effectiveness (Gong, 2008). These aspects of Supply Chain Agility are linked to a firm's ability to not only maintain but also improve its market position and financial returns. They are critical enablers that allow firms to exploit market opportunities and navigate around potential supply chain disruptions with minimal impact on performance (Richey et al., 2022). Considering the relationships and variables defined in the conceptual framework and Table 1, the following proposition can be developed:

Proposition 5. Supply Chain Agility, as characterized by a firm's Adaptability to Demand Fluctuations and Efficiency in Logistics and Distribution, has a positive correlation with Market Performance. The greater the Supply Chain Agility of a Chinese firm, the better it can manage the dynamic requirements of global markets, which in turn leads to enhanced Financial Performance and sustains Competitive Advantage. This suggests that investing in agile supply chain capabilities is a strategic imperative for Chinese firms aiming to achieve superior performance and gain a competitive edge in the global market.

6. Navigating Paths Chinese Firms in Global Markets

This section outlines the strategies and challenges Chinese companies face as they expand into global markets. It provides a detailed analysis of how Chinese firms adapt their strategies to navigate the complex landscape of international business. By examining the diverse paths these firms take—ranging from leveraging government support and capitalizing on low-cost advantages to innovating and localizing their offerings—it highlights the strategic decisions that lead to divergence in outcomes among Chinese firms, offering insights into the broader implications for their global competitiveness and market responses.

6.1. Classification of Chinese Global Firms

The first group consists of Chinese state-owned enterprises (SOEs) that primarily operate within China's domestic market (Chan, 2009). These firms are significant in number and play a crucial role in the Chinese economy, often dominating sectors such as banking, energy, telecommunications, and heavy industries (Alon et al., 2014). Their operations are closely aligned with state objectives, and they benefit from government support in various forms, including policy advantages and financial backing. The primary focus of these companies is to serve the domestic market, and their strategies are geared towards fulfilling national economic and development goals (Jones & Zou, 2017).

The second group includes Chinese global firms that operate not only within China but also in various international markets. These firms have expanded their reach beyond national borders, entering global markets through a combination of organic growth, mergers and acquisitions, and strategic partnerships (Nolan & Zhang, 2002). They operate in a wide range of industries, including technology, manufacturing, consumer goods, and financial services, among others. Unlike the domestically focused SOEs, these global firms engage in international competition and seek to establish themselves as leading players in their respective sectors on the world stage. Their global operations are characterized by a mix of innovation, competitive pricing, and adaptation to local market conditions in different countries (Sharma et al., 2020).

This paper focuses on the latter category of Chinese global firms that have a dual operational focus, both in China and in global markets. These firms represent a dynamic and influential segment of China's international economic engagement, reflecting the country's ambitions to play a more prominent role in the global economy (Voss et al., 2010; Wang & Miao 2016). Their strategies, challenges, and successes offer valuable insights into the evolving landscape of global business and the shifting balance of economic power. Through their international ventures, these Chinese global firms not only contribute to China's economic growth but also have a significant impact on global industry trends, competition, and cooperation (Polfuß, & Sönmez, 2020)**.**

6.2. Selection Criteria of Chinese Global Firms

The selection of eight Chinese global firms for this study was predicated on a multifaceted set of criteria designed to illuminate the intricate dynamics of international business expansion and strategic supply chain management (Alkhawajah, 2019). At the forefront of these criteria is market diversification, with each firm demonstrating a robust operational presence across both advanced and emerging markets (Chacon & Rajawat, 2019). This broad market engagement is instrumental in assessing how these entities tailor their strategies and operational frameworks to meet diverse demands and navigate the challenges inherent in varied market environments. Such a strategic approach to market diversification not only underlines the global ambitions of these firms but also sets the stage for a deeper exploration of their adaptability and resilience in the face of global market fluctuations (Li, 2009).

Furthermore, the firms under study exhibit distinct patterns of supply chain divergence, marked by varying degrees of supply chain responsiveness and flexibility (Richey et al., 2022). These attributes are pivotal in supporting their global market strategies and efforts at product differentiation, reflecting a spectrum of

supply chain management approaches (Gu et al., 2024). From highly adaptable and responsive systems designed to swiftly cater to the changing needs of a diverse clientele, to more streamlined operations aimed at achieving efficiency on a grand scale, the selection encapsulates the strategic variance among Chinese global firms. This divergence in supply chain strategy, underpinned by the necessity to balance efficiency with responsiveness, offers a rich vein of analysis for understanding how supply chain configurations can drive or deter global competitiveness (Mohammadi et al., 2019).

The firms, including Huawei with its cutting-edge telecommunications equipment, Lenovo's stronghold in computing, and the appliance and electronics successes of Haier, Xiaomi, HiSense, and TCL, represent a cross-section of China's industrial foray into global markets (Kerstin, 2023). Each company's journey—whether marked by recovery efforts, fluctuating profitability, or robust market expansion—highlights the nuanced interplay between market acceptance and supply chain strategy. By delving into these firms' strategic navigation of global markets, this study aims to shed light on the complex relationship between diverse supply chain practices and international market success. This analysis is expected to contribute significantly to the discourse on strategic navigation within the framework of supply chain divergence, offering insights into the mechanisms through which Chinese global firms secure their foothold in the international arena.

6.3. Classification by Product Diversification and Market Performance

Supply chain divergence refers to the variation in supply chain strategies and operations among firms or within different parts of a single firm’s global operations. This divergence can stem from a firm’s attempt to adapt its supply chain to different market conditions, product lines, or consumer demands. In essence, it's the strategic deviation from a one-size-fits-all approach to a more tailored, market-specific approach that optimizes efficiency, responsiveness, and competitiveness within diverse global contexts.

Figure 2 displays supply chain diversification and global market performance, categorizing Chinese global firms. Supply chain diversification is a comprehensive strategy aimed at bolstering resilience and mitigating risks within the global market landscape. This approach includes geographical diversification to minimize dependence on single markets, supplier diversification to ensure continuity of supply, and product and service diversification to reduce reliance on narrow revenue streams. Additionally, it involves enhancing logistical and operational flexibility, adopting strategic stockpiling and advanced inventory management, leveraging technology for improved supply chain visibility and efficiency, and adhering to robust risk management and compliance practices. Collectively, these measures strengthen the supply chain against disruptions, ensuring a steady flow of goods and services under various conditions.

On the other hand, the scale of market performance measures a company's success through a range of financial and non-financial indicators. Revenue growth and profit margins are the primary financial metrics, while market share offers a comparative measure of competitive advantage. Customer satisfaction and loyalty metrics emphasize the importance of quality and service in sustaining a business. Operational efficiency reflects the prudent use of resources, and the capacity for innovation and product development highlights a company's ability to adapt to changing market demands. Furthermore, performance in sustainability and corporate social responsibility (CSR) is increasingly crucial, influencing consumer choices and investment decisions, and underscoring the significance of environmental, social, and governance (ESG)

considerations in achieving long-term success. Together, these dimensions of market performance illustrate the multifaceted nature of business success in today's dynamic marketplace.

Table 3. Chinese Global Firms: Supply Chain and Financial Snapshot (As of March 2022)

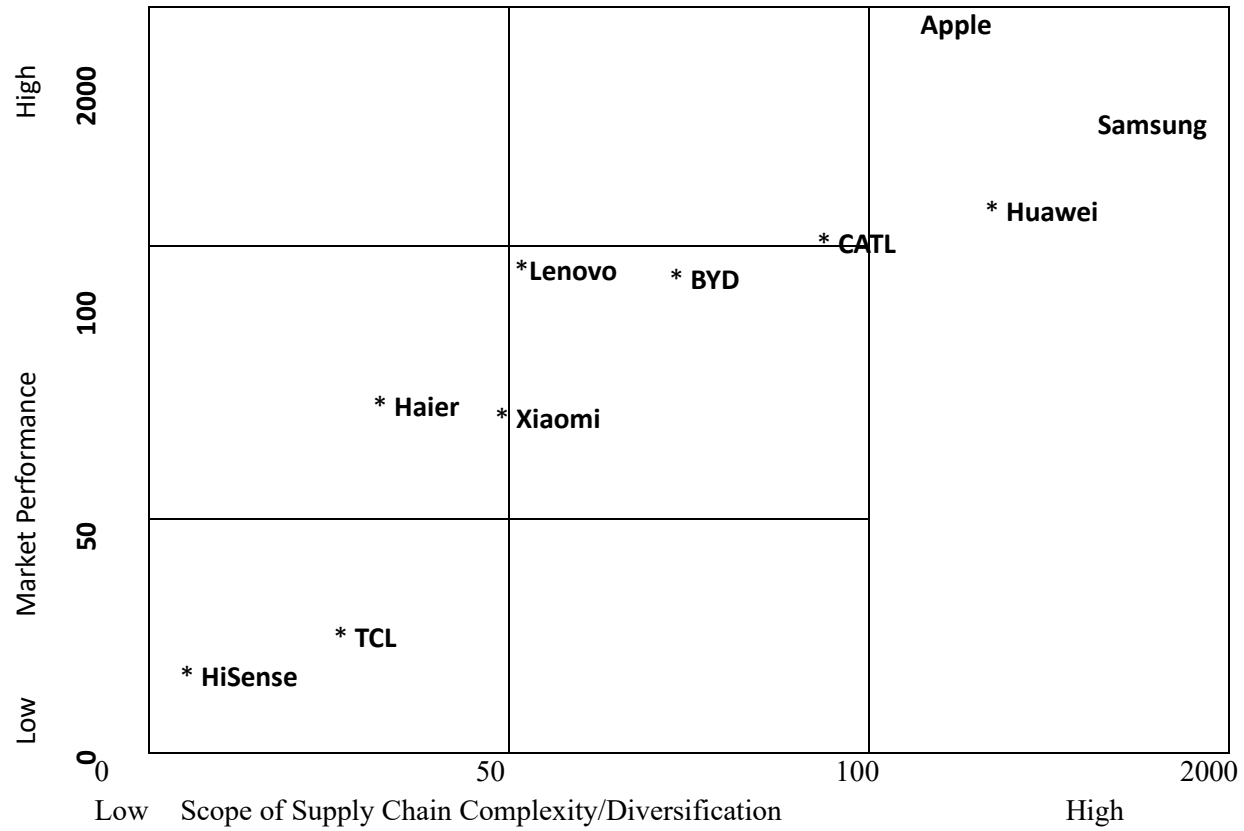
Firm Description (Founding Year; Headquarter Location)	**Supply Chain Complexity Measures: End Inventory/ Other Current Asset**	**Normalized Scores For Supply Chain Complexity**	**Market Performance Measures: Sales/Net Income**	**Normalized Scores for Market Performance**
Huawei Technologies Co., Ltd (1987. Shenzhen, China) is known for telecommunications networks, equipment, and smart devices.	Inventory: NA Current Asset: $111,481,438.85	Inventory: N/A Current Assets: 249.08 Normalized Average Index: 249.08	Revenue: $92,379.00 Net Income: $5,180.00	Revenue: 195.39 Net Income: 117.16 Normalized Average Index: 156.27
Contemporary Amperex Technology Co. Limited (CATL) (2011, Ningde, China) is one of the leading global manufacturers of lithium-ion batteries for electric vehicles and energy storage systems.	Inventory: $11,031.50 Other Current Assets: $44,757.69	**Inventory: 100** **Current Assets: 100** **Normalized Average Index: 100**	Revenue: $47,279.71 Net income: $4,421.46 Normalized Average Index: 100	Revenue: 100 Net Income: 100 Normalized Average Index: 100
Lenovo (1984, Beijing, China) operates in more than 60 countries and sells its products in around 160 countries worldwide.	Inventory: $8,300.66 Other Current Assets: $20,696.21	Inventory: 75.25 Current Assets: 46.24 Normalized Average Index: 60.74	Revenue: $71,618.22 Net income: $2,029.82	Revenue: 151.48 Net Income: 45.91 Normalized Average Index: 98.69
Build Your Dreams (BYD) Co Ltd (1995, Shenzhen, China) produces automobiles, battery-powered bicycles, buses, forklifts, solar panels, and rechargeable batteries.	Inventory: $11,382.33 Other Current Assets: $23,265.66	Inventory: 103.18 Other Current Assets: 51.98 Normalized Average Index: 77.58	Revenue: $61,015.92 Net income: $2,391.72	Revenue: 129.05 Net Income: 54.09 Normalized Average Index: 91.57
Haier Group Corporation (1984, Qingdao, China) is a multinational home appliances and consumer electronics company producing refrigerators, washing machines, air conditioners, and TVs.	Inventory: $5,977.37 Other Current Assets: $12,782.71	Inventory: 54.18 Other Current Assets: 28.56 Normalized Average Index: 41.37	Total Revenue: $35,037.92 Net income: $2,116.68	Revenue: 74.11 Net Income: 47.87 Normalized Average Index: 60.99
Xiaomi (2010, Beijing, China) offers a broad range of products, including mobile apps, laptops, and home appliances.	Inventory: $7,257.25 Other Current Assets: $15,824.01	Inventory: 65.79 Other Current Assets: 35.35 Normalized Average Index: 50.57	Total Revenue: $40,294.10 Net income: $355.98	Revenue: 85.22 Net Income: 8.05 Normalized Average Index: 46.64
TCL (1981, Huizhou, China), is a global manufacturer of smart products and provider of internet application services operating in over 160 countries.	Inventory: $2,590.09 Other Current Assets: $11,149.91	Inventory: 23.48 Other Current Assets: 24.91 Normalized Average Index: 24.20	Revenue: $23,975.85 Net Income: $37.60 Normalized Average Index: 25.78	Revenue: 50.71 Net Income: 0.85 Normalized Average Index: 25.78
HiSense (1969, Qingdao, China) is one of the growing consumer electronics and appliance brands in the world.	Inventory: $602.75 Other Current Assets: $3,612.24	Inventory: 5.46 Other Current Assets: 8.07 Normalized Average Index: 6.77	Revenue: $6,581.03 Net Income: $241.60	Revenue: 13.92 Net Income: 5.46 Normalized Average Index: 9.69

Table 3. Chinese Global Firms: Supply Chain and Financial Snapshot (As of March 2022)

Firm Description (Founding Year; Headquarter Location)	**Supply Chain Complexity Measures: End Inventory/ Other Current Asset**	**Normalized Scores For Supply Chain Complexity**	**Market Performance Measures: Sales/Net Income**	**Normalized Scores for Market Performance**
Apple Inc. (1976, Cupertino, California, USA) is renowned for its wide range of consumer electronics, software, and online services, including the iPhone, iPad, Mac computers, iOS operating system, and the iTunes media store.	Inventory: $4,946 Other Current Assets: $130,459	Inventory: 44.84 Other Current Assets: 291.48 Normalized Average Index: 168.16	Revenue: $394,328.00 Net Income: $99,803.00	Revenue: 834.03 Net Income: 2257.24 Normalized Average Index: 1545.64
Samsung Electronics Co., Ltd. (1969, Suwon, South Korea) is a global leader in consumer electronics, semiconductors, and home appliances, known for its smartphones, TVs, and memory chips.	Inventory: $38,619 Other Current Assets: $161,629,611	Inventory: 350.08 Other Current Assets: 361.12 Normalized Average Index: 355.60	Revenue: $223,651.21 Net Income: $40,500.21	Revenue: 473.04 Net Income: 915.99 Normalized Average Index: 694.52

Note: For comparison purpose Apple and Samsung are added We use 1 USD =7.00 Yuan; All data areas of March 2022.
We use CATL as the basis. Divide all data by CATL data * by 100. All data is from Finance.Yahoo.com. Present from smallest to largest.

Table 3 provides a comparative snapshot of key Chinese tech companies, focusing on their supply chain complexity and market performance. This comparison benchmarks against CATL's figures, which serve as a baseline index set at a value of 100. The analysis includes financial data from Apple and Samsung for a broader comparison. Metrics such as inventory, other current assets, sales, net income, and their normalized equivalents enable a uniform comparison across all listed firms. The data, sourced from Finance.Yahoo.com as of March 2022, excludes Huawei, whose data was extracted from its annual report on its website. Total revenue and net income serve as proxies for market performance, while inventory and other current assets represent supply chain complexity. All data were converted to million USD. The normalization of data utilized the min-max method. This analysis revealed that, by removing the outlier (Huawei), CATL would achieve the highest rank according to its normalized value of Supply Chain Complexity (X) and Market Performance (Y). Nonetheless, the inclusion of other large companies was deemed necessary for evaluating validity and presenting insights for strategic benchmarking. To this end, we divided all original indicators of companies by their respective CATL counterparts' values and then multiplied them by 100 to obtain normalized values. This approach allowed CATL to maintain its position and facilitated the inclusion of outliers (major companies like Samsung, Huawei, and Apple) in the performance measurement. To obtain a single value for market performance, we calculated the average of the normalized values of total revenue and net income. Similarly, for supply chain complexity, we calculated the average of the normalized values of inventory and other current assets. Figure 2 then displays the normalized average index of market performance and the scope of supply chain complexity.



Note: 0-100 normalized scores for Chinese Firms. 100-2000 normalized scores for Huawei, Samsung Apple

Figure 2. Supply Chain Diversification vs. Market Performance of Chinese Global Firms

Figure 2, derived from Table 3, presents a visual analysis of the correlation between supply chain diversification and market performance among Chinese global firms. It maps the nexus between the breadth of product lines and market agility, suggesting that a diversified product range, as seen with Haier and Xiaomi, often correlates with stronger market performance.

This figure appears to be a scatter plot illustrating the relationship between the scope of supply chain complexity/diversification and market performance for various global firms, particularly those based in China. The horizontal axis (X-axis) represents the scope of supply chain complexity/diversification. The scale for Chinese firms ranges from 0 to 100, while it has been extended up to 2000 to accommodate international giants like Huawei, Samsung, and Apple. The vertical axis (Y-axis) shows market performance, presumably measured by financial metrics like revenue and net income. The scale is likely normalized, given that the axis starts from 0 and goes up to an unspecified high value. CATL's figures are used as a baseline for normalization, with a value of 100 serving as a reference point on both axes. The positions of the firms on the plot indicate their relative standings in terms of market performance and supply chain complexity. For example, firms clustered near the bottom-left corner have lower market performance and less complex/diversified supply chains, while firms toward the top-right corner like Apple and Samsung score high on both axes. The plot differentiates between the scales used for Chinese firms and the much larger scales needed for the international firms (Huawei, Samsung, Apple), as indicated by the note below the chart. This suggests that the international firms are outliers in terms of the scale of their operations, which could distort the analysis if not accounted for.

This is in line with Lin et al. (2018) who postulate that product diversification can be beneficial for global reach. The figure also shows CATL, BYD, and Lenovo with a more streamlined supply chain, maintaining robust market standings, which indicates that factors beyond diversification play a role in global success, a concept supported by Wu & Zhao (2007) and Onawole (2020). Huawei's position reflects the delicate balance of external pressures impacting market performance. Overall, the figure encapsulates the varied strategies Chinese firms employ to navigate global market challenges and the resultant effects on their competitive stance.

7. Implications

The paper's limitations include its reliance on selected data from only certain Chinese firms, which may not fully represent the diverse range of companies and industries in China. This selection could lead to biased findings that aren't generalizable across all Chinese global firms. The lack of comprehensive data limits the paper's ability to capture the complete picture of Chinese firms' global strategies and operations. Despite these limitations, this paper provides valuable implications—both theoretical and managerial aspects.

7.1. Theoretical implications

Firstly, international Business Theory. The conceptual framework depicted suggests that the growth trajectory of Chinese global firms could serve as a new archetype for analyzing the internationalization process. Traditional models, such as the Uppsala Internationalization Process Model, emphasize gradual market entry based on knowledge accumulation and incremental commitment (Forsgren, 2002; Johanson & Vahlne, 2009). However, the aggressive market diversification and product differentiation strategies indicated in the framework imply a more dynamic and possibly non-linear path to global expansion. This could lead to the development of updated international business models that factor in the rapid scaling capabilities fueled by globalization and digitalization, particularly for firms originating from rapidly developing economies (Ghauri, Strange & Cooke, 2021;Verbeke & Hutzschenreuter, 2021).

Building on the paper's findings, Figure 2 suggests that firms from emerging economies such as China are crafting distinct pathways to globalization that do not necessarily follow the trajectories established by Western multinationals. For example, firms plotted with high market performance and low supply chain diversification may be leveraging other competitive advantages, such as innovation or localized business models, to succeed globally. This contradicts traditional international business theories which often posit that diversification across markets and supply chains is a requisite for achieving high performance in global markets (Narasimhan & Kim, 2002; Lin et al., 2021; Wang, Zhou & Zhao, 2024).

Secondly, strategic management theory. The conceptual model also presents a case for an evolved understanding of strategic agility within the field of strategic management. The interplay between supply chain agility and market performance—mediated by strategic market orientation—highlights the role of proactive and responsive strategy formulation in achieving competitive advantage (Green Jr et al., 2006; Kurniawan et al., 2021). The resilience of supply chains, shaped by responsiveness and flexibility in the face of external pressures such as geopolitical tension, suggests that modern strategic management theories need to incorporate the concept of 'dynamic capabilities' more thoroughly. These capabilities allow firms to reconfigure their resources and adapt strategies quickly in response to environmental changes, which could be essential for survival and success in the current global business environment.

Furthermore, the strategic responses of Chinese firms across different quadrants in Figure 2 illustrate a range of agility and resilience in managing their supply chains under global crises (Kazancoglu et al., 2022; Vega et al., 2023). Firms with high supply chain diversification and high market performance may be demonstrating superior agility, using their diversified supply chains to buffer against disruptions like geopolitical tensions. Conversely, those with less diversification but still high market performance could be displaying resilience, perhaps due to strong regional supply chain control or investment in technology that mitigates the need for broader supply chain complexity with increasing diversification (Mizgier et al., 2015; Whitney et al., 2015; Zhou, 2011). These insights could refine theoretical models in strategic management by highlighting alternative forms of resilience beyond supply chain diversification, such as digital transformation or strategic alliances, which are equally pivotal in navigating complex international environments.

7.2. Managerial implications

Firstly, supply chain diversification. Managers of multinational firms can glean the importance of diversifying supply chains to mitigate risks associated with geopolitical tensions and reliance on single markets or suppliers, aiding in strategic decision-making.

The global business landscape has witnessed a significant rise in the prominence of Chinese firms, as evidenced by an increasing number of these entities joining the ranks of the Global Fortune 500 and experiencing substantial sales growth across diverse global markets. This trend is indicative of the opportunities that lie ahead for Chinese firms in leveraging their competitive edge to expand their market footprint worldwide. The expansion and success of these firms can be attributed to strategic innovations in marketing and technological advancements, which have enabled them to adapt swiftly to global crises such as COVID-19 and capitalize on emerging market demands (Wang et al., 2020; Hu, Xi & Zhang, 2021). Such dynamics underscore the agility and resilience of Chinese global firms in navigating the complexities of international expansion, underscoring their potential for sustained growth and global market penetration.

Secondly, adaptability and resilience. The paper underscores the necessity for managers to cultivate adaptability and resilience within their firms, encouraging the adoption of flexible strategies that can withstand global market shocks and capitalize on emerging opportunities.

Chinese firms face significant challenges in North America and Europe, exacerbated by mounting trade tensions and geopolitical conflicts. Additionally, the strict COVID-19 policies and prolonged lockdowns mandated by the Chinese government have further complicated their operational and strategic maneuvers. The imposition of tariffs and the prevailing uncertainty have inflicted anxiety and operational pain on these firms, severely impacting their performance and strategic decisions in the trade war context (Benguria et al., 2022; Lafrogne-Joussier et al., 2023). These factors have not only strained trade relationships but have also necessitated a reevaluation of supply chain dependencies, compelling Chinese firms to reconsider their strategies in these critical markets.

In response to these multifaceted challenges, different Chinese firms have adeptly navigated their supply chain diversification strategy to diffuse their business portfolios and optimize their global market performance. Recognizing the importance of reducing dependency on single markets or suppliers, these firms have embarked on a strategic reconfiguration of their global value chains. This involves adopting trade policies and firm strategies that enable adaptive reconfigurations to mitigate the impacts of supply shocks and geopolitical tensions (Gereffi, Lim & Lee, 2021). By diversifying their supply chains and exploring new markets, Chinese firms are not only enhancing their resilience to global shocks but are also positioning themselves to capture new growth opportunities. This strategic shift is indicative of a broader trend among Chinese global firms to adapt their business models and strategies in pursuit of sustained success in the global market arena, reflecting a nuanced understanding of the dynamic interplay between geopolitical challenges and business opportunities.

8. Conclusion

In conclusion, this paper has developed a robust conceptual framework for analysing the supply chain divergence within Chinese global firms, identifying key variables and measurable indicators to construct a coherent narrative of strategic navigation in global markets. Our systematic approach, grounded in extensive literature, has enabled us to chart a course for understanding the intricate linkages between market dynamics, strategic orientation, supply chain agility, and overall market performance.

Reflecting on the historical progress and strategic resilience, Chinese global firms have demonstrated remarkable adaptability and growth over the past 30 years. This journey from emerging players to dominant global forces underscores their commitment to innovation, strategic diversification, and market adaptation. These strategies, crafted to navigate the complexities of global commerce, have ensured their sustainability and competitiveness, irrespective of the changing geopolitical landscapes.

Looking forward, future research will delve deeper into the dynamic nature of these firms' business models and their diverse adaptation strategies. By incorporating relevant data to evaluate the propositions laid out in this framework, we aim to report on analysis results that validate or refine the proposed relationships. This empirical endeavour will augment the theoretical contributions of this study with practical insights, offering a more nuanced understanding of how strategic decisions in global markets influence supply chain configurations and, consequently, competitive performance.

The implications of our findings extend beyond the academic realm, providing managers and policymakers with a strategic lens through which to view the global expansion endeavours of these firms. It underscores the importance of strategic flexibility and innovation in navigating the multifaceted nature of international business, highlighting pathways to sustainable growth and market presence.

Considering these findings, the call to action is clear: there is a pressing need for further exploration into the resilience and strategic agility of Chinese global firms. As these firms continue to navigate the global business environment, their sustained growth and relevance in the face of evolving market demands and geopolitical uncertainties remain paramount. This exploration is not only crucial for the firms themselves but also for the broader global economy, as we seek to understand and support the mechanisms through which these enterprises thrive.

By focusing on these areas, our conclusion not only encapsulates the study's contributions but also sets the stage for future research and discussion. It reinforces the ongoing relevance and significance of exploring the complex, dynamic strategies of Chinese global firms within the ever-changing landscape of international business.

References

Alfalla-Luque, R., Machuca, J. A. D., & Marin-Garcia, J. A. (2018). Triple-A and competitive advantage in supply chains: Empirical research in developed countries. *International Journal of Production Economics*, 203, 48-61.

Alkhawajah, W. (2019). Huawei: An information and communications technology company. Journal of *Information Technology and Economic Development*, 10(1), 1-10.

Alon, I., Wang, H., Shen, J., & Zhang, W. (2014). Chinese state-owned enterprises go global. Journal of Business Strategy, 35(6), 3-18.

Alshanty, A. M., & Emeagwali, O. L. (2019). Market-sensing capability, knowledge creation and innovation: The moderating role of entrepreneurial-orientation. Journal of Innovation & Knowledge, 4(3), 171-178.

Ambrosini, V., & Bowman, C. (2009). What are dynamic capabilities and are they a useful construct in strategic management? International Journal of Management Reviews, 11(1), 29-49.

Asamoah, D., Nuertey, D., Agyei-Owusu, B., & Akyeh, J. (2021). The effect of supply chain responsiveness on customer development. The International Journal of Logistics Management, 32(4), 1190-1213.

Aslam, H., Blome, C., Roscoe, S., & Azhar, T. M. (2018). Dynamic supply chain capabilities. International Journal of Operations & Production Management, 38(12), 2266-2285.

Bell, D. (2017). Political realism and international relations. Philosophy Compass, 12(2), e12403.

Benguria, F., Choi, J., Swenson, D. L., & Xu, M. J. (2022). Anxiety or pain? The impact of tariffs and uncertainty on Chinese firms in the trade war. Journal of International Economics, 137, 103608.

Chacon, M. D. M., & Rajawat, A. (2019). A case study on Huawei technologies. Journal of the Community Development in Asia (JCDA), 2(3), 29-36.

Chan, H. S. (2009). Politics over markets: Integrating state-owned enterprises into Chinese socialist market. Public Administration and Development, 29(1), 43-54.

Chen, E. I. h. (2014). U.S.-China Trade Relations and Economic Distrust. The Chinese Economy, 47(3), 57-69.

Chin, T., Hu, Q., Rowley, C., & Wang, S. (2021). Business models in the Asia-Pacific: dynamic balancing of multiple cultures, innovation, and value creation. Asia Pacific Business Review, 27(3), 331-341.

Christensen, C. M., & Raynor, M. E. (2018). The innovator's solution: warum manche Unternehmen erfolgreicher wachsen als andere. Vahlen.

Deng, P. (2012). The Internationalization of Chinese Firms: A Critical Review and Future Research*. International Journal of Management Reviews, 14(4), 408-427.

Donnelly, J. (2000). Realism and international relations. Cambridge University Press.

Duanmu, J.-L., Bu, M., & Pittman, R. (2018). Does market competition dampen environmental performance? Evidence from China. Strategic Management Journal, 39(11), 3006-3030.

Efferin, S., & Hopper, T. (2007). Management control, culture, and ethnicity in a Chinese Indonesian company. Accounting, Organizations and Society, 32(3), 223-262.

Fletcher, M., & Plakoyiannaki, E. (2011). 10. Case selection in international business: key issues and common misconceptions. Rethinking the case study in international business and management research, 171.

Forbes. (2023). Forbes Global 2000 List 2023: The Top 200. https://www.forbes.com/sites/forbesstaff/2023/07/07/forbes-global-2000-list-2023-the-top-200/?sh=48512ce97ec7

Forsgren, M. (2002). The concept of learning in the Uppsala internationalization process model: a critical review. *International business review*, *11*(3), 257-277.

Fortune. (2017). Fortune Global Forum 2017. https://fortune.com/conferences/global-forum-2017/speakers

Fortune. (2023). Fortune Global Forum 2023. https://fortune.com/conferences/fortune-global-forum-2023

Gammeltoft, P., & Hobdari, B. (2017). Emerging market multinationals, international knowledge flows and innovation. International Journal of Technology Management, 74(1-4), 1-22.

Gaur, A., & Delios, A. (2015). International Diversification of Emerging Market Firms: The Role of Ownership Structure and Group Affiliation. Management International Review, 55(2), 235-253.

Gereffi, G., Lim, H. C., & Lee, J. (2021). Trade policies, firm strategies, and adaptive reconfigurations of global value chains. Journal of International Business Policy, 4(4), 506-522.

Ghauri, P., Strange, R., & Cooke, F. L. (2021). Research on international business: The new realities. International Business Review, 30(2), 101794.

Gong, Z. (2008). An economic evaluation model of supply chain flexibility. European Journal of Operational Research, 184(2), 745-758.

Green Jr, K. W., McGaughey, R., & Casey, K. M. (2006). Does supply chain management strategy mediate the association between market orientation and organizational performance? *Supply Chain Management: An International Journal*, *11*(5), 407-414.

Grimes, S., & Du, D. (2022). China's emerging role in the global semiconductor value chain. Telecommunications Policy, 46(2), 101959.

Gu, J., Shi, X., Wang, J., & Xu, X. (2024). Examining the impact of market power discrepancy between supply chain partners on firm financial performance. International Journal of Production Economics, 268, 109100.

Hennart, J.-F., Majocchi, A., & Hagen, B. (2021). What's so special about born globals, their entrepreneurs or their business model? Journal of International Business Studies, 52(9), 1665-1694.

Haarhaus, T., & Liening, A. (2020). Building dynamic capabilities to cope with environmental uncertainty: The role of strategic foresight. Technological Forecasting and Social Change, 155, 120033.

Herrera, M. E. B. (2016). Innovation for impact: Business innovation for inclusive growth. Journal of Business Research, 69(5), 1725-1730.

Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply chain risk management: a literature review. International journal of production research, 53(16), 5031-5069.

Hong, P.C., Wang, K., Zhang, X. and Park, Y. (2017), "Trend analysis of Global Fortune 500 firms: a comparative study of Chinese and Japanese firms", Benchmarking: An International Journal, Vol. 24 No. 1, pp. 50-61.

Hong, P., & Park, Y. (2014). Building network capabilities in turbulent competitive environments: Business success stories from the BRICs. CRC Press:Boca Raton, FL, USA.

Hong, P., & Park, Y. W. (2020a). Beyond Rising Asia and American Hegemony: Prospect. In P. Hong & Y. W. Park (Eds.), Rising Asia and American Hegemony: Case of Competitive Firms from Japan, Korea, China, and India (pp. 241-251). Springer Singapore.

Hong, P., & Park, Y. W. (2020b). Supply Chain Integration in China: Case Study. In P. Hong & Y. W. Park (Eds.), Rising Asia and American Hegemony: Case of Competitive Firms from Japan, Korea, China, and India (pp. 211-226). Springer Singapore.

Hong, P. C., Park, Y. S., Hwang, D. W., & Sepehr, M. J. (2024). A growth theory perspective on the competitive landscape of shipbuilding: a comparative study of Japan, Korea, and China. Maritime Economics & Logistics.

Hu, F., Xi, X., & Zhang, Y. (2021). Influencing mechanism of reverse knowledge spillover on investment enterprises' technological progress: an empirical examination of Chinese firms. Technological Forecasting and Social Change, 169, 120797.

Hyman, R. (2005). Shifting dynamics in international trade unionism: Agitation, organisation, bureaucracy, diplomacy. Labor History, 46(2), 137-154.

Jin, Y., Gao, X., & Wang, M. (2021). The financing efficiency of listed energy conservation and environmental protection firms: evidence and implications for green finance in China. Energy Policy, 153, 112254.

Johanson, J., & Vahlne, J. E. (2009). The Uppsala internationalization process model revisited: From liability of foreignness to liability of outsidership. Journal of international business studies, 40, 1411-1431.

Johnson, M. W. (2010). Seizing the white space: Business model innovation for growth and renewal. Harvard Business Press.

Jones, L., & Zou, Y. (2017). Rethinking the Role of State-owned Enterprises in China's Rise. New Political Economy, 22(6), 743-760.

Kazancoglu, I., Ozbiltekin-Pala, M., Mangla, S. K., Kazancoglu, Y., & Jabeen, F. (2022). Role of flexibility, agility, and responsiveness for sustainable supply chain resilience during COVID-19. Journal of Cleaner Production, 362, 132431.

Khan, K., Su, C.-W., Tao, R., & Umar, M. (2021). How do geopolitical risks affect oil prices and freight rates? Ocean & Coastal Management, 215, 105955.

Kurniawan, R., Budiastuti, D., Hamsal, M., & Kosasih, W. (2021). Networking capability and firm performance: the mediating role of market orientation and business process agility. Journal of Business & Industrial Marketing, 36(9), 1646-1664.

Lafrogne-Joussier, R., Martin, J., & Mejean, I. (2023). Supply shocks in supply chains: Evidence from the early lockdown in China. IMF economic review, 71(1), 170-215.

Li Sun, S. (2009). Internationalization strategy of MNEs from emerging economies: The case of Huawei. Multinational Business Review, 17(2), 129-156.

Li, D.-y., & Liu, J. (2014). Dynamic capabilities, environmental dynamism, and competitive advantage: Evidence from China. Journal of Business Research, 67(1), 2793-2799.

Li, J., Khatri, N., & Lam, K. (1999). Changing strategic postures of overseas Chinese firms in emerging Asian markets. Management Decision, 37(5), 445-457.

Li, L. (2018). China's manufacturing locus in 2025: With a comparison of “Made-in-China 2025” and “Industry 4.0”. Technological Forecasting and Social Change, 135, 66-74.

Li, S., Ragu-Nathan, B., Ragu-Nathan, T. S., & Subba Rao, S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. Omega, 34(2), 107-124.

Lin, X., Liu, B., Han, J., & Chen, X. (2018). Industrial upgrading based on global innovation chains: A case study of Huawei technologies Co., Ltd. Shenzhen. International Journal of Innovation Studies, 2(3), 81-90.

Lin, Y., Fan, D., Shi, X., & Fu, M. (2021). The effects of supply chain diversification during the COVID-19 crisis: Evidence from Chinese manufacturers. Transportation Research Part E: Logistics and Transportation Review, 155, 102493.

Liu, X., Liu, H., Jia, J., Xiao, N., Xu, J., Zhao, Y., Xu, Z., Zhang, Y., & Sun, S. (2020). Enterprises as the Main Body of Developing Innovation Design. In Y. Lu, Y. Pan, & Z. Xu (Eds.), Innovative Design of Manufacturing (pp. 87-112). Springer Singapore.

Low, B. (2007), "Huawei Technologies Corporation: from local dominance to global challenge?", Journal of Business & Industrial Marketing, 22(2), 138-144.

Matysiak, L., Rugman, A. M., & Bausch, A. (2018). Dynamic Capabilities of Multinational Enterprises: The Dominant Logics Behind Sensing, Seizing, and Transforming Matter! Management International Review, 58(2), 225-250.

Mearsheimer, J. J. (2001). The tragedy of great power politics. WW Norton & Company.

Mearsheimer, J. J. (2014). The Tragedy of Great Power Politics, updated ed. New York and London: WW Norton.

Mearsheimer, J. J. (2021). The inevitable rivalry: America, China, and the tragedy of great-power politics. Foreign Aff., 100, 48.

Mizgier, K. J., Wagner, S. M., & Jüttner, M. P. (2015). Disentangling diversification in supply chain networks. International Journal of Production Economics, 162, 115-124.

Miyajima, K., Mohanty, M. S., & Chan, T. (2015). Emerging market local currency bonds: Diversification and stability. Emerging Markets Review, 22, 126-139.

Mohammadi, P., Fathi, S., & Kazemi, A. (2019). Differentiation and financial performance: a meta-analysis. Competitiveness Review: An International Business Journal, 29(5), 573-591.

Morgenthau, H. J. (1973). Politics among nations.

Narasimhan, R., & Kim, S. W. (2002). Effect of supply chain integration on the relationship between diversification and performance: evidence from Japanese and Korean firms. Journal of operations management, 20(3), 303-323.

Liu, G., & Wang, W. (2023). Strategic orientation for Chinese firms in the digital economy: a business model process formalization perspective. Asia Pacific Business Review, 1-24.

Nelson, R. R. (1985). An evolutionary theory of economic change. harvard university press.

Neuss, B. (2007). Kenneth N. Waltz, Theory of International Politics, New York 1979. In S. Kailitz (Ed.), Schlüsselwerke der Politikwissenschaft (pp. 481-485). VS Verlag für Sozialwissenschaften.

Nolan, P., & Zhang, J. (2002). The Challenge of Globalization for Large Chinese Firms. World Development, 30(12), 2089-2107.

Nygaard, A. (2023). The Geopolitical Risk and Strategic Uncertainty of Green Growth after the Ukraine Invasion: How the Circular Economy Can Decrease the Market Power of and Resource Dependency on Critical Minerals. Circular Economy and Sustainability, 3(2), 1099-1126.

Opper, S., Wong, S. M. L., & Ruyin, H. (2002). Party power, market, and private power: Chinese Communist Party persistence in China's listed companies. Research in Social Stratification and Mobility, 19, 105-138.

Osterwalder, A., & Pigneur, Y. (2010). Business model generation: a handbook for visionaries, game changers, and challengers (Vol. 1). John Wiley & Sons.

Piercy, N. F. (2016). Market-led strategic change: Transforming the process of going to market. Taylor & Francis.

Pisano, G. P. (1997). The development factory: unlocking the potential of process innovation. Harvard Business Press.

Polfuß, J., & Sönmez, D. (2020). Country-of-origin as a dynamic concept: an analysis of Chinese consumer electronics brands in Germany. Journal of Chinese Economic and Foreign Trade Studies, 13(3), 115-138.

Quitzow, R., Huenteler, J., & Asmussen, H. (2017). Development trajectories in China’s wind and solar energy industries: How technology-related differences shape the dynamics of industry localization and catching up. Journal of Cleaner Production, 158, 122-133.

Richey, R. G., Roath, A. S., Adams, F. G., & Wieland, A. (2022). A Responsiveness View of logistics and supply chain management. Journal of Business Logistics, 43(1), 62-91.

Rissanen, T., Ermolaeva, L., Torkkeli, L., Ahi, A., & Saarenketo, S. (2020). The role of home market context in business model change in internationalizing SMEs. European Business Review, 32(2), 257-275.

Schmalensee, R. (1982). Product Differentiation Advantages of Pioneering Brands. The American Economic Review, 72(3), 349-365. http://www.jstor.org/stable/1831537

Sharma, P., Cheng, L. T., & Leung, T. Y. (2020). Impact of political connections on Chinese export firms' performance–Lessons for other emerging markets. Journal of Business Research, 106, 24-34.

Singh, R. K. (2015). Modelling of critical factors for responsiveness in supply chain. Journal of Manufacturing Technology Management, 26(6), 868-888.

Stevenson, M., & Spring, M. (2009). Supply chain flexibility: an inter-firm empirical study. International Journal of Operations & Production Management, 29(9), 946-971.

Tang, C., Tang, Y., & Su, S. (2019). R&D internationalization, product diversification and international performance for emerging market enterprises: An empirical study on Chinese enterprises. European Management Journal, 37(4), 529-539.

Teece, D. J. (2019). China and the Reshaping of the Auto Industry: A Dynamic Capabilities Perspective. Management and Organization Review, 15(1), 177-199.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. Strategic Management Journal, 18(7), 509-533.

Tiwari, A. K., Tiwari, A., & Samuel, C. (2015). Supply chain flexibility: a comprehensive review. Management Research Review, 38(7), 767-792.

Vega, D., Arvidsson, A., & Saiah, F. (2023). Resilient supply management systems in times of crisis. International Journal of Operations & Production Management, 43(1), 70-98.

Verbeke, A., & Hutzschenreuter, T. (2021). The dark side of digital globalization. Academy of Management Perspectives, 35(4), 606-621.

Vickery, S. K., Jayaram, J., Droge, C., & Calantone, R. (2003). The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships. Journal of Operations Management, 21(5), 523-539.

Voss, H., Buckley, P. J., & Cross, A. R. (2010). The Impact of Home Country Institutional Effects on the Internationalization Strategy of Chinese Firms. Multinational Business Review, 18(3), 25-48.

Wagner, S. M., Grosse-Ruyken, P. T., & Erhun, F. (2012). The link between supply chain fit and financial performance of the firm. Journal of Operations Management, 30(4), 340-353.

Wang, H., & Miao, L. (2016). “Going Global Strategy” and Global Talent. In H. Wang & L. Miao (Eds.), China Goes Global: How China’s Overseas Investment is Transforming its Business Enterprises (pp. 144-152). Palgrave Macmillan UK.

Wang, Q., Zhou, H., & Zhao, X. (2024). The role of supply chain diversification in mitigating the negative effects of supply chain disruptions in COVID-19. International Journal of Operations & Production Management, 44(1), 99-132.

Wang, Y., Hong, A., Li, X., & Gao, J. (2020). Marketing innovations during a global crisis: A study of China firms’ response to COVID-19. Journal of Business Research, 116, 214-220.

Wilden, R., & Gudergan, S. P. (2015). The impact of dynamic capabilities on operational marketing and technological capabilities: investigating the role of environmental turbulence. Journal of the Academy of Marketing Science, 43(2), 181-199.

Williamson, P. J. (2016). Building and Leveraging Dynamic Capabilities: Insights from Accelerated Innovation in China. Global Strategy Journal, 6(3), 197-210.

Whitney, D. E., Luo, J., & Heller, D. A. (2014). The benefits and constraints of temporary sourcing diversification in supply chain disruption and recovery. Journal of purchasing and supply management, 20(4), 238-250.

Wu, D., & Zhao, F. (2007). Entry modes for international markets: Case study of Huawei, a Chinese technology enterprise. International Review of Business Research Papers, 3(1), 183-196.

Wu, K.-J., Tseng, M.-L., Chiu, A. S. F., & Lim, M. K. (2017). Achieving competitive advantage through supply chain agility under uncertainty: A novel multi-criteria decision-making structure. International Journal of Production Economics, 190, 96-107.

Yang, C., & Chan, D. Y.-T. (2023). Geopolitical risks of strategic decoupling and recoupling in the mobile phone production shift from China to Vietnam: Evidence from the Sino-US trade war and COVID-19 pandemic. Applied Geography, 158, 103028.

Zámborský, P., Yan, Z. J., Michailova, S., & Zhuang, V. (2023). Chinese Multinationals' Internationalization Strategies: New Realities, New Pathways. California Management Review, 66(1), 96-123.

Zhao, E. Y., Fisher, G., Lounsbury, M., & Miller, D. (2017). Optimal distinctiveness: Broadening the interface between institutional theory and strategic management. *Strategic Management Journal*, 38(1), 93-113.

Zhou, Y. M. (2011). Synergy, coordination costs, and diversification choices. Strategic Management Journal, 32(6), 624-639.

Exploring Strategic National Research and Development Factors for Sustainable Adoption of Cellular Agriculture Technology

Merhdad Jalali Sepehr[1], Narges Mashhadi Nejad[2]

[1]PhD student at the University of Toledo, Toledo, USA. [2]PhD candidate at the University of Toledo, Toledo, USA

Abstract

This research is focused on a multidisciplinary approach which is the sustainable adoption of agricultural technologies at the national level. In this sense, the present study would explore the strategic national research and development factors as well as some socioeconomic features to conceptualize about the long-term successful adoption of advanced agricultural technologies such as cellular agriculture. First, at this study we classify the agricultural technologies into three types: mechanical, automated, and precision and cellular agriculture technologies. Then, a literature review was conducted to identify the strategic national factors necessary for successful adoption of this technology, and relevant theories in this field were reviewed. The study found that various factors, such as the national education system, government policies on innovation, trade agreements, national reference laboratories, technical and scientific institutions, as well as cultural and socio-economic factors, have a significant impact on the adoption and success of cellular agriculture. The study also reviewed the theories of Technology Acceptance Model (TAM), UTAUT2, and Diffusion of Innovation (DOI) Theory to determine which theory would be most suitable for the research. the Diffusion of Innovation (DOI) Theory was deemed most appropriate. This theory is often used to analyze customer behavior but adapting it for national-level analysis is a unique contribution of this research. Then we conceptualize about and illustrate the impact of each influential factor on the sustainable adoption of cellular agriculture technology by a nation and seven propositions have been presented as the result.

Key words: Cellular agriculture, Technology adoption, Diffusion of Innovation theory, National Research and Development factors

1. Introduction:

Agriculture is one of the most important sectors which the food and the lives of people, some other creatures, and the ecological sustainability are related to that (Horrigan et al., 2002; Ruzzante et al., 2021). In other words, development specialists believe that agriculture is one of the sectors to which the Sustainable Development Goals SDGs are related. These goals are in the three pillars of environment, society, and economic, for example they are focused on no poverty, zero hunger, good health and well-being, reduced inequalities, responsible consumption and production, climate action, life below water, and life on land (Bastan et al., 2018). There is a variety of major research fields which are related to the agriculture such as Agronomy, Soil science, Horticulture, Animal science, agricultural education, Agricultural engineering, Agribusiness. Agricultural technologies would be mostly related to the agricultural engineering; however, technology and innovation are multidisciplinary subjects (Garcia & Calantone, 2002), and they would go through the evolution and development over time (Gambatese & Hallowell, 2011). According to components, products and applications, and support and infrastructure (Adomavicius et al., 2007). Concerning this, the market would face different types of the technologies over time. Returning to the agriculture sector, People have been cultivating and rearing animals for food since the beginning of time. They created strategies and technologies to nurture crops and boost yield. Agricultural technology has grown over time, becoming more advanced and efficient. Agriculture's evolution has helped to feed a growing population and enhance food security, from primitive hand tools to sophisticated machinery and technology (Burchardt, 2007; Maat, 2021). The history of the agriculture would back to the *Prehistoric period* 2.5 million years ago to 1,200 B.C. (Hansen, 1988), Wheat, barley, and peas were the first plants domesticated in the Middle East. Rice was later domesticated in Asia, while maize was domesticated in Central and South America (Nasu & Momohara, 2016)Then the agriculture would go through the ancient period, medieval period, Industrial Revolution, 20th century to present day. Meanwhile the available technologies in each period have evolved and the agricultural

technologies have almost experienced all types of innovations namely incremental innovation, modular innovation, architectural innovation, radical innovation (Klerkx et al., 2012; Maat, 2021). Therefore, the chosen period would play an important role in the technology analysis. In this study, our focus is on the 20th century to the present day and in this research a typology of the agricultural technologies would be presented. By reviewing the agricultural technologies in this period, we would see that over the last century, the organization of farms, farm households, and rural communities has changed dramatically (Dimitri et al., 2005). The main reason was the emergence of agricultural machinery and equipment (Kester et al., 2013). In this study, we call it as the first type of the agricultural technologies.

The first type or agricultural machineries are instruments and gadgets meant to assist in various agricultural processes such as planting, harvesting, irrigation, soil preparation, and pest control (Ajit K. Srivastava et al., 2013). Many of the equipment in the first type would be considered at the radical innovation category. Before them many of the tools were manual and there is overturned in core concepts and the linkage between core concepts and components have completely changed.

Then, there is the emergence of information systems and automated devices. Many of these devices have upgraded the previous type of the agricultural technologies (Muangprathub et al., 2019; Ramin Shamshiri et al., 2018; Ryu et al., 2015; Siddique et al., 2018; Vij et al., 2020).Therefore there is an incremental innovation; because machine learning, computer vision, IoT, advanced sensors, drones would reinforce the productivity of farming and there would be no dramatic change between core concepts and components (Hafeez et al., 2022).

However, the third type of the agricultural technologies namely cellular agriculture technology is completely radical innovation. Cellular agriculture is seen as a game changer because it deviates dramatically from traditional agricultural approaches. Unlike traditional farming, which involves growing crops or rearing animals, cellular agriculture focuses on developing cells in a laboratory. This new branch of agriculture uses modern biotechnology techniques to produce animal-based products such as meat, dairy, and eggs without using living animals. This revolutionary agricultural approach has the potential to alter the food business by

providing a sustainable and cruelty-free method of producing food. Cellular agriculture is currently focused on generating animal-based goods such as meat, dairy, and eggs. However, some scientists are investigating the possibility of employing this technique to create plant-based products. For example, some companies are developing plant-based meat alternatives using cellular agriculture techniques, while others are studying the use of plant stem cells to grow fruits and vegetables in a lab. However, research in this field is still in its early phases, and more work is needed to enhance the technology for creating plant-based products (Rischer et al., 2020).

Cellular agriculture is important for the future for several reasons. The first reason is related to the environmental issues. Animal agriculture contributes significantly to environmental problems such greenhouse gas emissions, deforestation, and water pollution (Mattick, 2018). Cellular agriculture, on the other hand, provides a more sustainable and environmentally friendly alternative by producing animal products without using conventional farming methods (Tuomisto, 2022). By providing a sustainable and effective technique of food production, cellular agriculture offers a substantial benefit in tackling food security and malnutrition concerns (Tuomisto, 2022). Given that the global population is expected to reach 10 billion by 2050, it is critical to investigate ways to enhance food production while lowering our environmental effect. Cellular agriculture has the potential to reduce the danger of zoonotic diseases, which are illnesses spread from animals to people. We can reduce the likelihood of these diseases spreading and causing global pandemics by reducing our reliance on extensive animal husbandry, as we saw with the COVID-19 outbreak (Stephens et al., 2018).

So far, we have explained about the environmental and social impacts of the cellular agriculture. Moreover, the traditional animal husbandry sector routinely participates in harsh and destructive to animal well-being practices. Cellular agriculture, on the other hand, provides a humane option by producing animal products without harming animals (Nyyssölä et al., 2022)

However, because this sector is still in its early phases, it is uncertain what the specific effects of cellular agriculture will be on the global and national economies. Nonetheless, cellular agricultural integration could

result in several economic benefits, such as the creation of new jobs in the field, eventual cost reductions, and environmental economic benefits (Helliwell & Burton, 2021; Nyika et al., 2021; Smith et al., 2022)

After presenting the three major types of agriculture technologies and explaining about the most recent one, and its benefits from the three pillars of the sustainability. In the following at the section 2, literature review presents the effective national factors for technology adoption. Then, Section 3 propose the methodology and theory used in this research. Section 4 presents the propositions as the result of this study, and we would discuss about the sustainable adoption of each type of technology by the countries.

2. Literature review

(Freeman, 1995) explain about the national system of innovation and they mention although global and trade relationship is important for success of innovation in a country, internal factors such as national education system, trade agreement, technical and scientific institutions, government policies, cultural traditions, national institutions are fundamental and essential factors.

The national education system is critical in developing a skilled workforce capable of integrating and utilizing new technologies. The education system can give individuals with the necessary skills and knowledge to comprehend new technologies by introducing educational programs and training efforts (Mariani et al., 2013). STEM education is critical for the effective adoption of new technologies, and the national education system can promote it through a variety of approaches, including related courses, workshops, and training programs. The education system can equip students to efficiently use and utilize advanced technologies by providing them with the essential skills and information (Mater et al., 2020)

Collaboration between the national education system and industry is critical in promoting the use of emerging technologies. By developing collaborations, business may provide resources, technology, and expertise to improve educational quality and promote the technology adoption (Boothby et al., 2010; Che et al., 2018; Mater et al., 2020). Spending in research and development is critical for successful technology adoption. The

national education system can help by providing funds, incentives, and resources to researchers and inventors working on that form of technology (Qiu & Anadon, 2012; Tsai & Wang, 2004)

Government policies is another important factor for successful technology adoption (Doss, 2006). Having robust intellectual property protection can stimulate investment in new technology since it offers legal protection for innovative products and ideas. This protection can also encourage technology transfer by creating incentives for companies to license or sell their technology to other entities (Deng et al., 2019; Ongori & Migiro, 2010; Park & Ginarte, 1997)

Another fundamental factor has been the trade agreement. Forming trade agreements and strategic collaborations with leading countries in technology can provide a number of benefits, including access to their experience, resources, and infrastructure. It can also help to broaden the market for goods and services (Dekimpe et al., 2000; Fatima, 2017; Wang & Zhao, 2022)

The available infrastructure and organization for controlling the quality of the products of the newly adopted technology is another essential factor for technology adoption. National reference laboratories and accredited third-party quality control laboratories are critical to the successful implementation of new technologies (Poon et al., 2006; White & Terner, 2001). National reference laboratories are entities that have specialized facilities and are tasked with developing national laboratory testing standards. They also conduct research to encourage the development and use of innovative laboratory technology. These laboratories have a high level of technical competency, expertise, and quality control systems in place to assure the accuracy and dependability of test results. They also offer direction, training, and help to other laboratories. In this regard, they would pave the way for more innovation. Many organizations are experimenting with various types of labs, centers of competence, and initiatives to enhance innovation capability in general (Osorio et al., 2019; Santarsiero et al., 2020; Schuurman, 2015)

National reference laboratories can work with business partners and government organizations to produce recommendations and laws that encourage the safe and effective use of new laboratory technology. This

collaboration can aid in the formulation and implementation of industry standards, with national reference laboratories playing an important role. They can provide counsel on the best practices for adopting and employing new technologies, ensuring that they are safe and effective, based on their research and technical experience. National reference laboratories can assist build a regulatory framework that fosters innovation while simultaneously maintaining the safety and quality of test results by collaborating with industry and government partners. Hence here there may be collaboration and relationship between the government policy factor and also reference laboratories (Valverde et al., 2022)

Advanced technological and scientific institutions would also pave the way for technology adoption. These organizations have the expertise, resources, and infrastructure needed to conduct research, develop novel technologies, and teach the current scientists and engineers in the country to adapt other knowledge to get the best out of the emerging technology (Tebaldi & Elmslie, 2008)

The main reason that in this research we discern the education system from such organizations is that, in most countries such organizations are public or private and they have short term specific technical courses in which experienced researchers would participate to update their knowledge about a specific type of the technology (Lynn et al., 1996). Hence sometimes they are affiliated to universities, but their approach is completely technical and industrial (Donges et al., 2022). These institutions can identify areas where technology adoption can have the greatest impact and build plans to implement it by collaborating with business and government partners (Alexander, 2012; Nelson & Nelson, 2002).

The effect of institutions on innovation is more obvious in high-tech innovation, implying that innovation could be a crucial avenue via which institutions ultimately affect economic growth (Donges et al., 2022). So far, our literature review has had a general attitude for technological adoption; however, for cultural and socioeconomic challenges a specific view on agricultural products would be adopted in addition to the general view. (Lee et al., 2013) studied the impact of the cultural differences on technology adoption. Their research looks at how cultural variations affect mobile phone adoption rates.

(Steers et al., 2008a) examines two case studies of successful national technology adoption, each involving a distinct disruptive technology and country/region. It emphasizes how country cultural variations influenced the adoption process in both situations. Using Davis' Technology Acceptance Model (TAM),

(Phillips et al., 1994) studied the impact of culture and demand certainty on the uptake of technology across different countries. (Steers et al., 2008b) examine the national cultural impact on the technology adoption. The authors showcase two case studies of technology adoption in different countries and regions, which involve two completely different types of disruptive technologies. Both case studies exhibit successful adoption of the technology and emphasize the role of cultural differences in the adoption process. The authors present two case studies of technology adoption in various countries and regions, involving two very distinct sorts of disruptive innovations. Both case studies demonstrate successful technology adoption and emphasize the importance of cultural differences in the adoption process. According to (Steers et al., 2008b) examination of Brazil, the country's leaders depended on culturally embedded logic principles to guide their activities toward the development of a specific technical system trajectory. This resulted in a self-perpetuating path dependency system steeped in Brazil's cultural past. This argument can aid in the formation of new theories and conceptions, as well as the testing of existing ones. According to their examination of Korea, the country's adoption of Internet-based technology was fueled by a cultural urge to develop and maintain personal networks, which is considered as critical for both cultural and economic survival. Unlike traditional theories that emphasize development stage and industrialization, they contend that three socio-cultural elements - adoption timing and strategy, evolving consumption patterns, and the logic linking the two - were critical in Korea's effective acceptance of new technology.

(Syed et al., 2014) investigated the impact of culture on technology adoption, using UTAUT model and Hofstede’s Cultural Dimensions as the framework. The research involved a comparison of data from Pakistan and the USA, which represent two very different cultures, to examine the adoption of internet banking technology. The comparison between Pakistan and the United States demonstrates that the impact of many factors on technology adoption varies between the two civilizations. In the United States, the influence of

performance and effort expectancy on behavioral intention is stronger, as is the effect of behavioral intention on use behavior, whereas in Pakistan, the influence of social influence on behavioral intention is greater, as is the effect of facilitating conditions on use behavior.

(Huang et al., 2019) explored how cultural values affected the willingness of university instructors in China and Spain to use technology. The study discovered significant and consistent correlations between subjective norms and behavioral intention among both Chinese and Spanish adopters of technology

(Jayasekara & Fredriksson, 2021) looks at how cultural influences as well as intellectual property rights (IPR) protection influence technology adoption rates. The study analyzed data from 83 nations and 24 technologies between 1980 and 2000. According to the findings, a culture that values individualism, a strong IPR protection regime, and their combined influence are favorably associated with technology adoption. These findings hold true across a wide range of robustness tests.

(Curry et al., 2021) evaluated the numerous socioeconomic elements that benefited or impeded the adoption process in four case studies linked to technology adoption. These case studies were carried out in various parts of the developing world and covered a variety of adoption scenarios. Local social, cultural, economic, and physical elements, as well as external economic forces and institutional organizations at various levels, influence farming methods and systems in many developing countries. Sociocultural values and moral frameworks influence agricultural practices, such as how labor is mobilized and compensated, how land is owned and used, what crops and livestock are chosen, and how production, distribution, and consumption are controlled. These practices are all reflections of cultural values.

The adoption of maize and cow pea production technologies remains low and inconsistent, and the variables influencing farmers' decisions to employ these technologies on the farm are unknown. According to the findings, socioeconomic considerations play a significant effect in affecting farmer technology uptake (Adams et al., 2021)

On four major crops in Denmark, the economic profitability of implementing precision farming technologies and controlled traffic farming was assessed. And it has found that adopting these new technologies at the national level would benefit the Danish economy by increasing farmers' revenue and reducing fuel use and pesticide and herbicide use. According to the findings, applying new production methods in Denmark would have a long-term economic impact, with soil fertility rising over time, leading to increased yields (Baaken, 2022)

3.Methodology

A literature review was conducted as part of the study's methodology to investigate the effective national factors influencing technology adoption. The literature evaluation supported the identification of seven effective variables for national technology adoption in this study. We would design and offer seven propositions that link these seven factors to the adoption of cellular agriculture technology. Depending on the circumstances and conditions involved, numerous theories may be appropriate for national technology adoption. Following that, the relevant potential theories for this study will be explained, and one of them that is more appropriate for the domain and idea of this study will be chosen.

The Technologies Acceptance Model (TAM) is a theoretical framework designed to explain how people acquire and use new technologies. Davis pioneered it in 1989 (Davis, 1985), and other scholars have since expanded on it. TAM asserts that user acceptance of a new technology is primarily governed by two factors: the consumers' assessment of how valuable the technology is and how simple it is to use. The more useful and simpler a technology is regarded to be, the more likely users are to adopt and use it. To put it another way, perceived usefulness is a user's perception of how a technology will improve their effectiveness, productivity, or performance. A farmer, for example, may feel that employing automated and precision agriculture technologies will result in higher crop yields while saving time and resources (Taherdoost, 2018) In contrast, perceived simplicity of use relates to the user's belief that the technology is straightforward to grasp and operate. This could include things like the interface of the system, instructional materials, and training resources. According to the TAM, two key criteria, perceived usefulness and perceived ease of use, influence

users' attitudes toward technology and their willingness to adopt it. Users' opinions are influenced by their impressions of how beneficial and simple the technology is to use. Meanwhile, their intentions to use technology are influenced by their attitudes as well as external factors such as social norms and environmental pressures. TAM has grown in popularity in studies on technology adoption in a variety of industries, including healthcare, education, and business. TAM assists researchers and practitioners in developing effective strategies to stimulate adoption and maximize the benefits of new technologies by identifying the factors that influence user acceptance of innovative technology (Koufaris, 2002)

UTAUT2 is a theoretical framework that describes how different aspects such as performance expectancy, effort expectancy, social influence, and facilitating conditions influence people's willingness to use technology. Performance expectancy refers to how consumers believe the technology will improve their performance, whereas effort expectancy refers to how easy the technology will be to use (Tamilmani et al., 2021)

Social influence refers to external factors such as social norms and peer pressure that influence a user's decision to adopt technology. The user's view of the resources and support available for using the technology is referred to as facilitating conditions. Individual and demographic criteria, such as age, gender, and prior familiarity with technology, are also taken into account by the UTAUT2 (Tamilmani et al., 2017)

The Diffusion of Innovation (DOI) Theory, developed by E.M. Rogers in 1962 (Rogers, 2010) is one of the early social science ideas that describes how an idea or product develops popularity and spreads through a certain population or social system over time. The adoption of a new concept, habit, or product by individuals as part of the social system is the result of this diffusion process. Adoption entails a shift in a person's past actions, such as utilizing or purchasing a new product or engaging in a new behavior. The individual considers the concept, behavior, or product as innovative or novel, which helps the dissemination process, which is crucial for adoption. Adoption of an innovation is a slow process within a social system, with certain individuals more willing to adopt the innovation before others. According to research, the characteristics of persons who adopt an innovation early differ from those who adopt it later. As a result, understanding the characteristics of the target group is critical when promoting an innovation to ensure its successful adoption.

There are five well-established adopter categories, and while the majority of the population falls into the intermediate categories, it is still necessary to understand the characteristics of the target demographic. To effectively promote an innovation, many tactics are used to appeal to the various adopter types.

Individuals who are enthusiastic about trying new things and being the first to adopt an innovation are considered *innovators*. They are daring, curious about new ideas, and eager to take chances. They are frequently the ones who generate and refine fresh ideas. It is not necessary to go out of your way to appeal to this demographic because they are naturally interested in fresh advancements. Those who are considered early adopters and prefer taking on leadership roles are *early adopters*. They are at ease with change and understand the advantages of embracing new ideas. As a result, they do not need to be persuaded to change. To appeal to this group, offering how-to manuals and information on how to implement the invention can be effective because they are curious about the innovation and how it might be used. The *early majority* is a group of people who are not leaders but are more inclined than the ordinary person to adopt new ideas. They do, however, seek confirmation that the invention is effective before implementing it. Success stories and evidence of the usefulness of the innovation are great techniques for appealing to this demographic. The *Late Majority* are those who are cautious to adopt new ideas or technology and will only do so if the majority of people have already done so. Strategies should focus on presenting information about the amount of people who have tried and successfully embraced the innovation to appeal to this audience. This will aid in the development of trust and boost the likelihood of adoption. *Laggards* are those that are exceedingly traditional and conservative in their thinking. They are the most resistant to change and the most difficult to persuade. Strategies for appealing to this group could include presenting data, fear-based appeals, and pressure from other adopter groups.

One of the points in this study is to categorize the nations regarding their adoption situation and how is the global diffusion pattern of the three types of the agriculture technology. In this regard, The Diffusion of Innovation (DOI) Theory seems the most suitable theory for this study.

4. Results

As the result of the literature review and the adopted theory, Diffusion Of Innovation DOI, in this research we would propose seven propositions in the following.

The adoption of cellular agriculture technology necessitates a skilled workforce, given its intricacies in animal product growth and production within a laboratory environment. Thus, the national education system must prioritize creating a workforce with expertise in biology, chemistry, and engineering to effectively operate and manage cellular agriculture facilities. To accomplish this, the education system should provide specialized training programs, offer internships, and support research initiatives in cellular agriculture (Bello-Pintado et al., 2018; Meyer, 2011). When the national education system and industry work together, it can help a country's adoption of cellular agricultural technology in a variety of ways. They may establish educational programs that suit industry expectations by working collaboratively, ensuring that graduates have the skills needed to work in cellular agriculture (Charles, 2006)

This relationship also allows industry leaders to share their knowledge with students and lecturers, bridging the theoretical and practical divide. Joint research projects can also lead to new advances in cellular agriculture, which benefit both the industry and the educational system. Overall, such partnership can help a country's cellular agriculture industry flourish and succeed (Mehta, 2004; Miyazaki & Islam, 2007; Verspagen, 2006a)

Proposition 1: *The National Education System impact the adoption of cellular manufacturing technology in a country.*

Government policies have a huge impact on a country's adoption of cellular agricultural technology. Favorable policies that give fund, incentives, and infrastructure support can encourage enterprises to invest in and embrace the technology, while addressing ethical and regulatory concerns can provide consumers and businesses with trust. Unfavorable laws that prohibit or create barriers to the use of cellular agriculture, on the other hand, can stymie the industry's growth and success. As a result, government policies are critical in deciding a country's acceptance and prosperity of cellular agricultural technology (Lin & Kaewkhunok, 2021)

Strong Intellectual Property (IP) protection can encourage investors and companies to invest in the progress of cellular agriculture technologies. This can be accomplished by safeguarding innovative ideas and innovations, giving corporations with returns on investment and allowing them to fund more research and development activities (Chen & Puttitanun, 2005; Pisano, 2006)

Excessively strict or exclusive IP protection may impede the adoption of novel technologies, particularly for smaller players in the field who may lack the capacity to engage in license negotiations or to withstand legal challenges to infringement allegations. This could raise consumer prices and limit the potential benefits of cellular agriculture in boosting food security, sustainability, and public health (Gangopadhyay & Mondal, 2012; Sweet & Eterovic Maggio, 2015; Verspagen, 2006b).

Proposition2: *Government innovation policies affect the successful technology adoption of cellular agriculture.*

The ability to tap into the knowledge, resources, and infrastructure of advanced nations in the realm of cellular agriculture can potentially facilitate the uptake of this technology by other countries (Trajtenberg, 2001). Drawing upon the expertise and capabilities of established actors in this field, emerging nations could potentially expedite their own development and implementation of cellular agriculture. This might encompass access to information and optimal practices for the cultivation and production of cell-based foods, as well as access to R&D centers, financing channels, and regulatory frameworks (Aarikka-Stenroos et al., 2014; Trajtenberg, 2001)

Aside from accelerating technology transfer, collaboration with leading nations in cellular agriculture may present opportunities to strengthen the capacity and expertise of local talent. By promoting the creation of a robust innovation ecosystem, this might potentially create a workforce that is well-equipped to support the expansion of the sector in the recipient country. This could serve to reinforce the industry's foundations, resulting in long-term sustainable growth and expansion (Zhang et al., 2010)

Choosing worldwide strategic alliances from top countries in cellular agriculture such as the United States, Israel, the Netherlands, and the United Kingdom would pave the path for potential adopters and these relationships would be created by trade agreements between the nations.

Proposition 3: *Trade agreements with pioneer countries in cellular agriculture affect the successful adoption of cellular agriculture technology by the adopter country.*

A country can encourage the adoption of technology by establishing uniform and transparent standards for products and processes, ensuring that product quality and safety are standardized across the industry. This can increase consumer confidence and trust, leading to the creation of a stable market for cellular agricultural products. Furthermore, dependable quality control is especially important in the context of novel and developing technologies, such as cellular agriculture, where established regulations and standards may be limited. Defining clear methods for reviewing and certifying cell-based products can assist guarantee that they are safe to eat and match consumer expectations (Sugii et al., 2022), and the national reference laboratories are among the effective organizations on quality and reliability of products safety, especially agricultural ones in a country (Cools et al., 2004). Standardization and quality control can also help to encourage global trade and collaboration by ensuring that items meet universal standards and expectations across borders (Botonaki et al., 2006).This can assist the sharing of knowledge and skills, as well as the growth of the market of cellular agriculture products in different countries (Fafchamps et al., 2008)

Proposition 4: *National reference laboratories and qualified third-party quality control laboratories affect the successful adoption of cellular agriculture technology.*

To accelerate the adoption of emerging technologies like cellular agriculture, specialized technical courses provided by scientific and technical institutions can be highly beneficial. This is because the establishment of courses and laboratories in universities for these technologies is a time-consuming process, and most potential contributors to these technologies have already completed their education. Technical courses can provide these experienced professionals with targeted and specific knowledge that is essential for the successful adoption

of the technology. This can lead to a faster and more efficient adoption of the technology (Douthwaite et al., 2011; Keck, 1993)

Therefore, providing specialized technical courses to experienced researchers can be beneficial for the adoption of cellular agriculture technology. To contribute to the progress of this rapidly changing field, it is crucial for researchers to be aware of the latest advancements and techniques. Technical courses offer a platform for researchers to learn new skills and methodologies and also to share their own insights with others in the field. This way, technical courses can help to keep researchers up to date with the developments in cellular agriculture technology and contribute to the progress of the field.

By enhancing the skills and knowledge of experienced researchers, technical courses can play an important role in fostering innovation and expediting the development of new technologies and products in cellular agriculture. Furthermore, technical courses can assist in addressing industry challenges such as increasing the cost-effectiveness and scalability of cell-based manufacturing methods. Furthermore, technical training courses can aid in the formation of a professional community by encouraging collaboration and knowledge sharing across various organizations and locations. This can help the business grow and create a more robust and varied ecosystem of researchers, entrepreneurs, and investors (Bieber et al., 2002)

Proposition 5: *Technical and scientific institutions affect the successful adoption of cellular agriculture technology in a country.*

The acceptance and adoption of novel foods, including those created using cellular agriculture, can be influenced by cultural attitudes (Ab Rashid & Bojei, 2020). The willingness to try new foods can vary depending on cultural background, with some cultures being more open to experimentation and others preferring traditional foods. Cultural attitudes can influence the acceptance and adoption of cellular agriculture technology because dietary choices are directly linked to cultural behaviors and conventions. It may take longer for cell-based goods to be adopted if a society is deeply devoted to conventional foods and less inclined to try new ones (Haque et al., 2015)

Religious and ethical factors are ingrained features in many national cultures, and it can have an impact on the adoption of cellular agriculture technology since they influence people's attitudes and behavior regarding food choices. Certain religions, for example, may have dietary restrictions or guidelines prohibiting the consumption of certain types of food or requiring specific methods of food production. Similarly, ethical concerns about animal welfare and sustainability can have an impact on the acceptance of cell-based meat and other products. Some consumers may see these items as a more ethical and sustainable alternative to traditional animal agriculture, but others may be concerned about the use of biotechnology and food production in general. Understanding and addressing these religious and ethical concerns is therefore critical to assuring the acceptance and implementation of cellular agriculture (Tanko, 2020; Tanko & Ismaila, 2021). Although the focus of this study is on the national technology adoption, the potential market demand for the products of that technology would play an important role on its adoption (Heiman et al., 2020; Milliou & Petrakis, 2011)

Proposition 6: *Cultural factors affect the successful adoption of cellular agriculture technology in a country.*

Health consciousness (Wardle & Steptoe, 2003), purchasing power, and consumer literacy are among the factors which can be related to the socioeconomic factors and its role for accepting cellular agriculture products in a country (Botonaki et al., 2006)

The level of *health consciousness* in a country can influence cellular agriculture technology adoption. Countries that value health and sustainability may be more inclined to accept alternative protein sources such as cell-based products since they are regarded to be healthier and less harmful to the environment. Furthermore, health-conscious consumers may be more willing to pay a higher price for products perceived to be healthier, creating a market for cellular agriculture products (Hemminki et al., 2003; Su et al., 2022)

Countries with lesser levels of health concern, on the other hand, may present additional barriers to the acceptability and market growth of such products (Tandon et al., 2021)

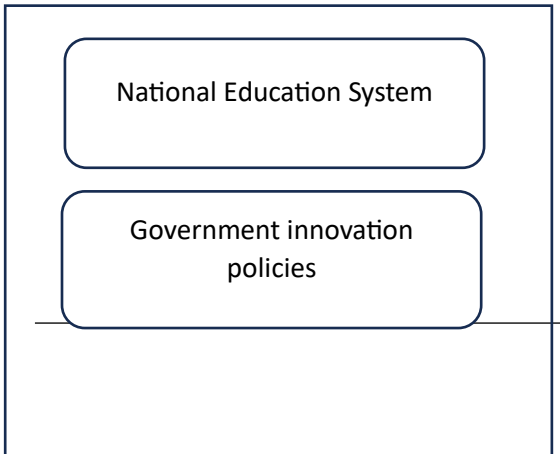
Consumers in countries with more *purchasing power* may be more interested in exclusive and specialist niches, such as cell-based meat, and may be willing to pay for these products. This could result in a more favorable market environment for cell-based goods in these countries (Khonje et al., 2015; Veeck & Burns, 2005)

The level of *consumer food literacy* regarding sustainability, animal welfare, and production processes of cell-based products can significantly impact their adoption in a country. Informed consumers who recognize the environmental and ethical advantages of cellular agriculture are more likely to support the industry and purchase cell-based products. This can create a virtuous cycle where increased demand for these products stimulates more investment and development of the technology (Batat, 2016). In contrast, a lack of awareness can lead to reluctance or negative attitudes towards cell-based products. As a result, it is crucial to conduct consumer education and awareness campaigns to facilitate the successful adoption of cellular agriculture in a country (Rodríguez-Entrena & Salazar-Ordóñez, 2013)

Proposition 7: Socioeconomic factors affect the successful adoption of cellular agriculture technology in a country.

The eight proposition has a more comprehensive view and it synthesize the seven factors and the adopted theory in this research. In this sense, we would conceptualize about the relationship between the seven factors with the five different adopters' categories in Diffusion of Innovation Theory DIT, and we aim to know and conceptualize about the right type of technology for the right country. In this *DOI* defines *Relative Advantage*, *Compatibility*, *Complexity, Triability, and the Observability* as the five main factors that influence adoption of an innovation.

Figure 1 displays the research model of this study.



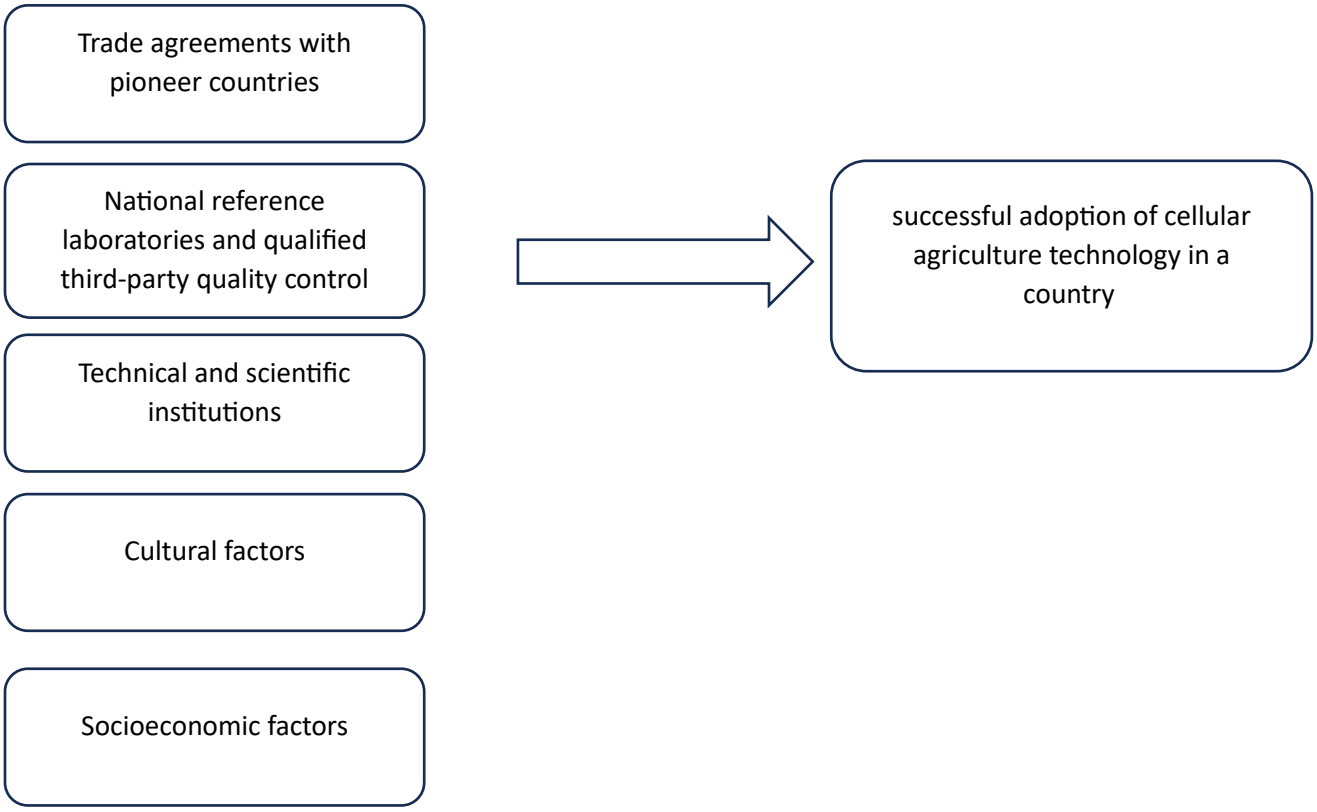


Figure 1. Illustration of the proposed Strategic National Research and Development Factors for Sustainable Adoption of Cellular Agriculture Technology

Conclusion:

The study classifies agricultural technologies into three types. The first type is mechanical agriculture, which includes tools and machines that aid in various agricultural activities like planting, harvesting, irrigation, soil preparation, and pest control. The second type is the development of information systems and automated devices, leading to the emergence of automated precision agriculture. These devices represent an advancement over the previous type of agricultural technologies by utilizing machine learning, computer vision, IoT, advanced sensors, and drones, which incrementally enhance farming productivity without causing any significant changes.

On the other hand, the third type of agricultural technology, known as cellular agriculture, represents a radical innovation that diverges significantly from conventional farming methods. This technology involves growing cells in a laboratory rather than cultivating crops or raising animals. A literature review was conducted to identify the strategic national factors necessary for successful adoption of this technology, and relevant theories in this field were reviewed. The study found that various factors, such as the national education system, government policies on innovation, trade agreements, national reference laboratories, technical and scientific institutions, as well as cultural and socio-economic factors, have a significant impact on the adoption and success of cellular agriculture.

The study also reviewed the theories of Technology Acceptance Model (TAM), UTAUT2, and Diffusion of Innovation (DOI) Theory to determine which theory would be most suitable for the research. After considering the aim of categorizing nations based on their adoption of agricultural technologies and analyzing global diffusion patterns of the three types of agricultural technologies, the Diffusion of Innovation (DOI) Theory was deemed most appropriate. This theory is often used to analyze customer behavior but adapting it for national-level analysis is a unique contribution of this research. The study aims to conceptualize the impact of each influential factor on the sustainable adoption of cellular agriculture technology by a nation.

The Diffusion of Innovation (DOI) Theory identifies five types of adopters, including innovators, early adopters, early majority, late majority, and laggards. This categorization can also be applied to nations' adoption of cellular agricultural technologies. The study's final eight propositions merge the seven influential factors with these five adoption categories. The adoption of agricultural technologies is generally incremental, and the diffusion process and life cycle of the technology can be emulated. However, the life cycle of each technology may differ among countries, and the rapid adoption of the latest advances may not be suitable for all nations. For instance, when cellular agriculture technology emerged, countries like the US, Israel, Netherlands, and the UK were innovator adopters and have had a sustainable adoption process. It was also concluded that the seven identified factors play an influential role in the adoption decision-making process.

The other point is the incremental adoption of such technologies, it means at the beginning, first type of the agricultural technologies would b adopted and diffused in a country and the mentioned seven national research and development factors are impactful in this importance and gradually by their growth the countries would reach to the maturity to adopt the following technologies. However, we have the adoption schism between the adoption of each type of technology and it can be studied what is the effect each of these factor(s) or their proxies on the adoption readiness of countries. This adoption process can also be quantified, and it has been presented as a future research idea in the following.

References:

Aarikka-Stenroos, L., Sandberg, B., & Lehtimäki, T. (2014). Networks for the commercialization of innovations: A review of how divergent network actors contribute. *Industrial Marketing Management*, *43*(3), 365–381.

Ab Rashid, N., & Bojei, J. (2020). The relationship between halal traceability system adoption and environmental factors on halal food supply chain integrity in Malaysia. *Journal of Islamic Marketing*, *11*(1), 117–142.

Adams, A., Jumpah, E. T., & Caesar, L. D. (2021). The nexuses between technology adoption and socioeconomic changes among farmers in Ghana. *Technological Forecasting and Social Change*, *173*, 121133.

Adomavicius, G., Bockstedt, J. C., Gupta, A., & Kauffman, R. J. (2007). Technology roles and paths of influence in an ecosystem model of technology evolution. *Information Technology and Management*, *8*(2), 185–202.

Ajit K. Srivastava, Carroll E. Goering, Roger P. Rohrbach, & Dennis R. Buckmaster. (2013). Engineering Principles of Agricultural Machines, Second Edition. *Engineering Principles of Agricultural Machines, Second Edition*.

Alexander, E. A. (2012). The Effects of Legal, Normative, and Cultural-Cognitive Institutions on Innovation in Technology Alliances. *Management International Review*, *52*(6), 791–815.

Keck, 1993. (n.d.). The national system for technical innovation in Germany. *Books.Google.Com*.

Baaken, M. C. (2022). Sustainability of agricultural practices in Germany: a literature review along multiple environmental domains. *Regional Environmental Change 2022 22:2*, *22*(2), 1–19.

Bastan, M., Ramazani Khorshid-Doust, R., Delshad Sisi, S., & Ahmadvand, A. (2018). Sustainable development of agriculture: a system dynamics model. *Kybernetes*, *47*(1), 142–162.

Batat, W. (2016). New paths in researching "alternative" consumption and well-being in marketing: alternative food consumption. *Marketing Theory*, *16*(4), 561.

Bello-Pintado, A., García Marco, T., & Zouaghi, F. (2018). Product/process definition, technology adoption and workforce qualification: impact on performance.

Bieber, M., Goldman-Segall, R., Hiltz, S. R., Im, I., Paul, R., Preece, J., Rice, R., Stohr, E., & Turoff, M. (2002). Towards knowledge-sharing and learning in virtual professional communities. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2002-January*, 2843–2852.

Boothby, D., Dufour, A., & Tang, J. (2010). Technology adoption, training and productivity performance. *Research Policy*, *39*(5), 650–661.

Botonaki, A., Polymeros, K., Tsakiridou, E., & Mattas, K. (2006). The role of food quality certification on consumers' food choices. *British Food Journal*, *108*(2), 77–90.

Burchardt, J. (2007). AGRICULTURAL HISTORY, RURAL HISTORY, OR COUNTRYSIDE HISTORY? *The Historical Journal*, *50*(2), 465–481.

Charles, D. (2006). Universities as key knowledge infrastructures in regional innovation systems.

Che, Y., Zhang, L., We, C. X., Auerbach, A., Chen, S., Dougan, W., Hanushek, E., Makridis, C., Shi, H., Willis, R., Peng, Y., Yuan, Z., Zhang, Z., & Zhao, J. (2018). Human Capital, Technology Adoption and Firm Performance: Impacts of China's Higher Education Expansion in the Late 1990s. *The Economic Journal*, *128*(614), 2282–2320.

Chen, Y., & Puttitanun, T. (2005). Intellectual property rights and innovation in developing countries. *Journal of Development Economics*, *78*(2), 474–493.

Cools, N., Delanote, V., Scheldeman, X., Quataert, P., De Vos, B., & Roskams, P. (2004). Quality assurance and quality control in forest soil analyses: A comparison between European soil laboratories. *Accreditation and Quality Assurance*, *9*(11–12), 688–694.

Curry, G. N., Nake, S., Koczberski, G., Oswald, M., Rafflegeau, S., Lummani, J., Peter, E., & Nailina, R. (2021). Disruptive innovation in agriculture: Socio-cultural factors in technology adoption in the developing world. *Journal of Rural Studies*, *88*, 422–431.

Davis, F. (1985). *A technology acceptance model for empirically testing new end-user information systems: Theory and results*. https://dspace.mit.edu/bitstream/handle/1721.1/15192/14927137-MIT.pdf

Dekimpe, M. G., Parker, P. M., & Sarvary, M. (2000). "Globalization": Modeling Technology Adoption Timing Across Countries. *Technological Forecasting and Social Change*, *63*(1), 25–42.

Deng, P., Lu, H., Hong, J., Chen, Q., & Yang, Y. (2019). Government R&D subsidies, intellectual property rights protection and innovation. *Chinese Management Studies*, *13*(2), 363–378.

Dimitri, C., Effland, A., & Conklin, N. C. (2005). *The 20th Century Transformation of U.S. Agriculture and Farm Policy*.

Donges, A., Meier, J.-M., & Silva, R. C. (2022). The Impact of Institutions on Innovation.

Doss, C. R. (2006). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural Economics*, *34*(3), 207–219.

Douthwaite, B., Beaulieu, N., Lundy, M., & Peters, D. (2011). Understanding how participatory approaches foster innovation.

Fafchamps, M., Hill, R. V., & Minten, B. (2008). Quality control in nonstaple food markets: evidence from India. *Agricultural Economics*, *38*(3), 251–266.

Fatima, S. T. (2017). Globalization and technology adoption: evidence from emerging economies.

Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics*, *19*(1), 5–24.

Gambatese, J. A., & Hallowell, M. (2011). Factors that influence the development and diffusion of technical innovations in the construction industry.

Gangopadhyay, K., & Mondal, D. (2012). Does stronger protection of intellectual property stimulate innovation? *Economics Letters*, *116*(1), 80–82.

Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management*, *19*(2), 110–132.

Hafeez, A., Husain, M. A., Singh, S. P., Chauhan, A., Khan, M. T., Kumar, N., Chauhan, A., & Soni, S. K. (2022). Implementation of drone technology for farm monitoring & pesticide spraying: A review. *Information Processing in Agriculture*.

Hansen, J. M. (1988). Agriculture in the Prehistoric Aegean: Data versus Speculation. *American Journal of Archaeology*, *92*(1), 39–52.

Haque, A., Sarwar, A., Yasmin, F., Tarofder, A. K., & Hossain, M. A. (2015). Non-muslim consumers' perception toward purchasing halal food products in malaysia. *Journal of Islamic Marketing*, *6*(1), 133–147.

Heiman, A., Ferguson, J., & Zilberman, D. (2020). Marketing and Technology Adoption and Diffusion. *Applied Economic Perspectives and Policy*, *42*(1), 21–30.

Helliwell, R., & Burton, R. J. F. (2021). The promised land? Exploring the future visions and narrative silences of cellular agriculture in news and industry media. *Journal of Rural Studies*, *84*, 180–191.

Hemminki, K., Zhang, H., & Czene, K. (2003). Socioeconomic factors in cancer in Sweden. *International Journal of Cancer*, *105*(5), 692–700.

Horrigan, L., Lawrence, R. S., & Walker, P. (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives*, *110*(5), 445–456.

Huang, F., Teo, T., Sánchez-Prieto, J. C., García-Peñalvo, F. J., & Olmos-Migueláñez, S. (2019). Cultural values and technology adoption: A model comparison with university teachers from China and Spain. *Computers & Education*, *133*, 69–81.

Jayasekara, D. N., & Fredriksson, P. G. (2021). Culture, intellectual property rights, and technology adoption. *The Quarterly Review of Economics and Finance*, *80*, 317–330.

Kester, C., Griepentrog, H. W., Hörner, R., & Tuncer, Z. (2013). *A survey of future farm automation – a descriptive analysis of survey responses*. 785–792.

Khonje, M., Manda, J., Alene, A. D., & Kassie, M. (2015). Analysis of Adoption and Impacts of Improved Maize Varieties in Eastern Zambia. *World Development*, *66*, 695–706.

Klerkx, L., Van Mierlo, B., & Leeuwis, C. (2012). Evolution of systems approaches to agricultural innovation: Concepts, analysis and interventions. *Farming Systems Research into the 21st Century: The New Dynamic*, 457–483.

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior. *Https://Doi.Org/10.1287/Isre.13.2.205.83*, *13*(2), 205–223.

Lee, S. G., Trimi, S., & Kim, C. (2013). The impact of cultural differences on technology adoption. *Journal of World Business*, *48*(1), 20–29.

Lin, B., & Kaewkhunok, S. (2021). The role of socio-Culture in the solar power adoption: The inability to reach government policies of marginalized groups. *Renewable and Sustainable Energy Reviews*, *144*, 111035.

Lynn, L. H., Reddy, N. M., & Aram, J. D. (1996). Linking technology and institutions: the innovation community framework. *Research Policy*, *25*(1), 91–106.

Maat, H. (2021). The history and future of agricultural experiments.

Mariani, M. G., Curcuruto, M., & Gaetani, I. (2013). Training opportunities, technology acceptance and job satisfaction: A study of Italian organizations. *Journal of Workplace Learning*, *25*(7), 455–475.

Mater, N. R., Haj Hussein, M. J., Salha, S. H., Draidi, F. R., Shaqour, A. Z., Qatanani, N., & Affouneh, S. (2020). The effect of the integration of STEM on critical thinking and technology acceptance model.

Mattick, C. S. (2018). Cellular agriculture: The coming revolution in food production. *74*(1), 32–35.

Mehta, S. (2004). The emerging role of academia in commercializing innovation. *Nature Biotechnology 2004 22:1*, *22*(1), 21–24.

Meyer, J. (2011). Workforce age and technology adoption in small and medium-sized service firms. *Small Business Economics*, *37*(3), 305–324.

Milliou, C., & Petrakis, E. (2011). Timing of technology adoption and product market competition. *International Journal of Industrial Organization*, *29*(5), 513–523.

Miyazaki, K., & Islam, N. (2007). Nanotechnology systems of innovation—An analysis of industry and academia research activities. *Technovation*, *27*(11), 661–675.

Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019). IoT and agriculture data analysis for smart farm. *Computers and Electronics in Agriculture*, *156*, 467–474.

Nasu, H., & Momohara, A. (2016). The beginnings of rice and millet agriculture in prehistoric Japan. *Quaternary International*, *397*, 504–512.

Nelson, R. R., & Nelson, K. (2002). Technology, institutions, and innovation systems. *Research Policy*, *31*(2), 265–272.

Nyika, J., Mackolil, J., Workie, E., Adhav, C., & Ramadas, S. (2021). Cellular agriculture research progress and prospects: Insights from bibliometric analysis. *Current Research in Biotechnology*, *3*, 215–224.

Nyyssölä, A., Suhonen, A., Ritala, A., & Oksman-Caldentey, K. M. (2022). The role of single cell protein in cellular agriculture. *Current Opinion in Biotechnology*, *75*, 102686.

Ongori, H., & Migiro, S. O. (2010). Information and communication technologies adoption in SMEs: literature review. *Journal of Chinese Entrepreneurship*, *2*(1), 93–104.

Osorio, F., Dupont, L., Camargo, M., Palominos, P., Peña, J. I., & Alfaro, M. (2019). Design and management of innovation laboratories: Toward a performance assessment tool. *Creativity and Innovation Management*, *28*(1), 82–100.

Park, W. G., & Ginarte, J. C. (1997). INTELLECTUAL PROPERTY RIGHTS AND ECONOMIC GROWTH. *Contemporary Economic Policy*, *15*(3), 51–61.

Phillips, L. A., Calantone, R., & Lee, M. T. (1994). International Technology Adoption: Behavior Structure, Demand Certainty and Culture. *Journal of Business & Industrial Marketing*, *9*(2), 16–28.

Pisano, G. (2006). Profiting from innovation and the intellectual property revolution. *Research Policy*, *35*(8), 1122–1130.

Poon, E. G., Jha, A. K., Christino, M., Honour, M. M., Fernandopulle, R., Middleton, B., Newhouse, J., Leape, L., Bates, D. W., Blumenthal, D., & Kaushal, R. (2006). Assessing the level of healthcare information technology adoption in the United States: A snapshot. *BMC Medical Informatics and Decision Making*, *6*(1), 1–9.

Qiu, Y., & Anadon, L. D. (2012). The price of wind power in China during its expansion: Technology adoption, learning-by-doing, economies of scale, and manufacturing localization. *Energy Economics*, *34*(3), 772–785.

Ramin Shamshiri, R., Weltzien, C., A. Hameed, I., J. Yule, I., E. Grift, T., K. Balasundram, S., Pitonakova, L., Ahmad, D., & Chowdhary, G. (2018). Research and development in agricultural robotics: A perspective of digital farming. *1-14*, *11*(4), 1–11.

Rischer, H., Szilvay, G. R., & Oksman-Caldentey, K. M. (2020). Cellular agriculture — industrial biotechnology for food and materials. *Current Opinion in Biotechnology*, *61*, 128–134.

Rodríguez-Entrena, M., & Salazar-Ordóñez, M. (2013). Influence of scientific–technical literacy on consumers' behavioural intentions regarding new food. *Appetite*, *60*(1), 193–202.

Rogers, E. (2010). *Diffusion of innovations*.

Ruzzante, S., Labarta, R., & Bilton, A. (2021). Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. *World Development*, *146*, 105599.

Ryu, M., Yun, J., Miao, T., Ahn, I. Y., Choi, S. C., & Kim, J. (2015). Design and implementation of a connected farm for smart farming system. *2015 IEEE SENSORS - Proceedings*.

Santarsiero, F., Schiuma, G., & Carlucci, D. (2020). Entrepreneurability: Innovation Labs as Engines of Innovation Capacity Development. *International Studies in Entrepreneurship*, *45*, 115–127.

Schuurman, D. (2015). *Bridging the gap between Open and User Innovation? : exploring the value of Living Labs as a means to structure user contribution and manage distributed innovation*.

Siddique, T., Barua, D., Ferdous, Z., & Chakrabarty, A. (2018). Automated farming prediction. *2017 Intelligent Systems Conference, IntelliSys 2017*, *2018-January*, 757–763.

Smith, D. J., Helmy, M., Lindley, N. D., & Selvarajoo, K. (2022). The transformation of our food system using cellular agriculture: What lies ahead and who will lead it? *Trends in Food Science & Technology*, *127*, 368–376.

Steers, R. M., Meyer, A. D., & Sanchez-Runde, C. J. (2008a). National culture and the adoption of new technologies. *Journal of World Business*, *43*(3), 255–260.

Steers, R. M., Meyer, A. D., & Sanchez-Runde, C. J. (2008b). National culture and the adoption of new technologies. *Journal of World Business*, *43*(3), 255–260.

Stephens, N., Di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., & Sexton, A. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. *Trends in Food Science & Technology*, *78*, 155–166.

Su, Y., Khaskheli, A., Raza, S. A., & Yousufi, S. Q. (2022). How health consciousness and social consciousness affect young consumers purchase intention towards organic foods. *Management of Environmental Quality: An International Journal*, *33*(5), 1249–1270.

Sugii, S., Wong, C. Y. Q., Lwin, A. K. O., & Chew, L. J. M. (2022).

Reassessment of adipocyte technology for cellular agriculture of alternative fat. *Comprehensive Reviews in Food Science and Food Safety*, *21*(5), 4146–4163.

Sweet, C. M., & Eterovic Maggio, D. S. (2015). Do Stronger Intellectual Property Rights Increase Innovation? *World Development*, *66*, 665–677.

Syed, H., Akhtar, &, & Malik, N. (2014). Comparative study of effect of culture on technology adoption in Pakistan and USA. *The Business & Management Review*, *5*.

Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. *Procedia Manufacturing*, *22*, 960–967.

Tamilmani, K., Rana, N. P., & Dwivedi, Y. K. (2017). A systematic review of citations of UTAUT2 Article and its usage trends. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *10595 LNCS*, 38–49.

Tamilmani, K., Rana, N. P., Wamba, S. F., & Dwivedi, R. (2021). The extended Unified Theory of Acceptance and Use of Technology (UTAUT2): A systematic literature review and theory evaluation. *International Journal of Information Management*, *57*, 102269.

Tandon, A., Jabeen, F., Talwar, S., Sakashita, M., & Dhir, A. (2021). Facilitators and inhibitors of organic food buying behavior. *Food Quality and Preference*, *88*, 104077.

Tanko, M. (2020). Is farming a belief in Northern Ghana? Exploring the dual-system theory for commerce, culture, religion and technology. *Technology in Society*, *63*, 101339.

Tanko, M., & Ismaila, S. (2021). How culture and religion influence the agriculture technology gap in Northern Ghana. *World Development Perspectives*, *22*, 100301.

Tebaldi, E., & Elmslie, B. (2008). *Do Institutions Impact Innovation?*

Trajtenberg, M. (2001). Innovation in Israel 1968–1997: a comparative analysis using patent data. *Research Policy*, *30*(3), 363–389.

Tsai, K. H., & Wang, J. C. (2004). R&D Productivity and the Spillover Effects of High-tech Industry on the Traditional Manufacturing Sector: The Case of Taiwan. *World Economy*, *27*(10), 1555–1570.

Tuomisto, H. L. (2022). Challenges of assessing the environmental sustainability of cellular agriculture. *Nature Food 2022 3:10*, *3*(10), 801–803.

Valverde, I., Espín, S., Gómez-Ramírez, P., Sánchez-Virosta, P., García-Fernández, A. J., & Berny, P. (2022). Developing a European network of analytical laboratories and government institutions to prevent poisoning of raptors. *Environmental Monitoring and Assessment*, *194*(2), 1–16.

Veeck, A., & Burns, A. C. (2005). Changing tastes: the adoption of new food choices in post-reform China. *Journal of Business Research*, *58*(5), 644–652.

Verspagen, B. (2006a). UNIVERSITY RESEARCH, INTELLECTUAL PROPERTY RIGHTS AND EUROPEAN INNOVATION SYSTEMS. *Journal of Economic Surveys*, *20*(4), 607–632.

Verspagen, B. (2006b). UNIVERSITY RESEARCH, INTELLECTUAL PROPERTY RIGHTS AND EUROPEAN INNOVATION SYSTEMS. *Journal of Economic Surveys*, *20*(4), 607–632.

Vij, A., Vijendra, S., Jain, A., Bajaj, S., Bassi, A., & Sharma, A. (2020). IoT and Machine Learning Approaches for Automation of Farm Irrigation System. *Procedia Computer Science*, *167*, 1250–1257.

Wang, X. H., & Zhao, J. (2022). Bilateral free trade agreements in a four-country model with a digital technology perspective. *Journal of Digital Economy*, *1*(3), 192–208.

Wardle, J., & Steptoe, A. (2003). Socioeconomic differences in attitudes and beliefs about healthy lifestyles. *Journal of Epidemiology & Community Health*, *57*(6), 440–443.

White, L., & Terner, C. (2001). E-health, phase two: the imperative to integrate process automation with communication automation for large clinical reference laboratories. *Journal of Healthcare Information Management : JHIM*, *15*(3), 295–305. https://europepmc.org/article/med/11642146

Zhang, H., Shu, C., Jiang, X., & Malter, A. J. (2010). Managing Knowledge for Innovation: The Role of Cooperation, Competition, and Alliance Nationality. *Https://Doi.Org/10.1509/Jimk.18.4.74*, *18*(4), 74–94.

Impact of Media Platforms' Sentiment on IPO Underpricing: Focusing on Social Network Service, Message Boards, and News

Changhee Han, University of Texas at Dallas, USA

Yukyung Cha, University of Texas at Dallas, USA

IPO underpricing refers to the financial occurrence that the initial price of stocks is undervalued rather than the actual value. Previous literature has hypothesized reasons for the occurrence, found various determining factors, and interpreted them in theoretical explanations. The information asymmetry theory has been applied in the research stream to explain underpricing in terms of relationships between IPO parties (issuing firms, underwriters, and investors). Our work utilized the financial text analysis to identify the information asymmetry between investors for IPO from 2020 to 2022. We chose three different web sources (Social Network Service, Financial Message Boards, and News), collected text data for each IPO stock, and estimated positive, negative, and neutral sentiment scores. This study aimed to identify effects of three tones in heterogenous web sources on IPO underpricing. In our experiment, a negative tone in the formal source decreased information gap between investors and reduced underpricing. Moreover, we found that an interaction between a negative tone and institutional investors can cause underpricing from underwriters. This study contributed to financial opinion mining in IPO research by analyzing texts from three different information sources and understanding IPO underpricing by comparing sentiment tones.

Additional Keywords and Phrases: Information asymmetry, digital media platforms, sentiment analysis, IPO underpricing

Introduction

An Initial Public Offering (IPO) is the shares issued in the transformation process of a private company into a public by offering shares to publicly traded stock markets. The transition allows public investors to participate in the stock exchange and buy newly issued stocks. The money paid for the stocks in the open market is directly delivered to a company. Also, the previous private investors sell their holdings for a fixed price. The potential investors expect a price increment and purchase the shares of private investors. Therefore, IPOs have been used to raise the company's capital equity. In this process, the listed shares are closed at a higher price than the initial offering, and this occurrence is called IPO underpricing [29].

Previous literature has analyzed the underpricing phenomenon and its determining factors in various theoretical approaches [24]. One research stream in IPO underpricing suggested that information asymmetric theories can explain the reason for underpricing. The theory assumes that the information asymmetry between market participants causes unexplainable economic phenomena [8]. Recent studies have used data analysis and empirical methods to identify the asymmetric information between market participants, issuing firms, underwriters, and investors.

Public data accessibility and the development of technical analysis have motivated researchers to analyze financial phenomena with data-driven research and explain these with a theoretical approach. With this trend, financial professionals have focused on the textual information posted on official corporate documents, social media platforms, and Internet news websites [21, 31, 39]. This is because financial text data reflects information and insights of the current market [13]. In the IPO context, existing literature has analyzed textual format data, including S-1 filings which is the official IPO document, Wikipedia, social media posts, and news articles [6, 11, 19, 27, 51]. In this research trend, to the best of our knowledge, there was no research that analyzed and compared the tone of different media sources and their effect on IPO underpricing with information asymmetry theory.

Various financial web media have expressed a wide range of different ideas to the same financial occurrence. Previous researchers paid attention to this difference in opinions, analyzed empirical approaches, and explained the result with information asymmetry [4, 12, 26]. Therefore, potential market participants can be affected by different media platforms regarding the same upcoming IPO events. Our research focused on opinion mining on various online platforms with theoretical explanations. Given this research purpose, we utilized sentiment analysis with FinBERT for text mining and analyzed the sentiment tones in three different media sources: professional financial news websites, financial messaging boards, and social media platforms. Our work measured the sentiment of web platform data and analyzed whether the tone can affect information asymmetry. Based on this purpose, we set two research questions.

- Research Question 1. Can sentiment tones in different online communities affect the information asymmetry between IPO underwriters and investors?
- Research Question 2. Can sentiment tones in different online communities affect the information asymmetry between informed investors and uninformed investors?

To answer these research questions, we collected the IPO companies' stock data, market trend information, and web opinions from financial informatics platforms, social media, financial message boards, and professional news. We measured the sentiment score of each platform's text with FinBERT, the state-of-the-art model of sentiment analysis in the financial field [49]. The model is pre-trained with financial statement data, and we fine-tuned the tone scoring with Financial Phrasebank data, the sentiment labeled financial news header data [34]. Moreover, we set hypotheses for each research question and analyzed the determining factors of underpricing.

To solve the first research question, we assumed each sentiment tone from distinct media platforms (i.e. social media, message board, and professional news) has an impact on underpricing. In this hypothesis test, we discovered that the negative tone in professional news can decrease future investment in IPO stocks. In the case of the second research question, we tested whether media users' tones and the institutional investors' market lead have an interaction effect on underpricing. We discovered that professional news and social media platforms have significant interaction effects, excluding financial message boards.

This research contributed to IPO investment decision support systems through public opinion mining and the information asymmetry theory. First, our study expanded the previous IPO literature by analyzing the

public opinions of various web platforms. We collected three online platforms' reactions to the IPO event and analyzed the sentiment score in each text. We found key determining factors of IPO underpricing with these scores and found platforms relevant to IPO. Secondly, we hypothesized sentiment tone's impact on IPO underpricing with a theoretical approach and tested the information asymmetry theory in that context. From these hypothesis tests, we confirmed that our results were associated with previous literature and provided a further extension of the research stream.

The paper is composed as follows: Section 2 introduces the previous literature on IPO underpricing and theoretical explanation and empirical study. Section 3 presents the FinBERT method and its fine-tuning process. Section 4 explains the entire process of the experiment and the result. Finally, in section 5, we discuss the experiment, and in section 6, our contribution to IPO literature.

Literature Review

Information asymmetry

IPO underpricing, which represents the positive return of the IPO stock on the first issued date, has been discussed by various theoretical frameworks [14, 16]. These studies interpreted IPO underpricing and influential factors of price movement within various theoretical models. One of the theories is asymmetric information, which hypothesizes that the market participants, issuing firms, private holders, underwriting banks, and informed investors have different information about the same IPO event. The information disparity between participants can be categorized into four combinations of participants: issuing firms and underwriting banks, issuing firms and investors, investors and underwriting banks, and informed investors and uninformed [24].

Firstly, in terms of the relationship between investment banks and issuing companies, the banks are motivated to issue the shares at a lower price. These underwriters have the advantage of their knowledge of market circumstances and offer the price for their own benefit [28]. In this process, lower prices will attract investors, and the banks can be beneficial while keeping issuing costs and increasing their reputation in the investment market [29].

Secondly, issuing firms and investors have an information gap. One notion that can explain this gap is an uncertain forecast of the IPO price [25]. The uncertainty is determined by the company's age, type, use of IPO proceeds, and IPO size. Efficient investors refuse to hold risks occurring from uncertainty and demand underpricing against risk. According to the Signaling theory, issuers have private information and recognize the true value of their IPO, evaluating themselves as high quality or low quality [29]. Investors cannot access this information, and it is hard to assess whether an IPO is high quality or not. Thus, by accepting underpricing, low-quality firms can pretend to be evaluated as high quality and motivate market participants to purchase. Also, high-quality issuers can start with a favorable impression in the market and propel another strategy to increase their market value. In another theory, issuers select reputable underwriters to solve the asymmetry between issuers and investors [10]. In the market, investors tend to be concerned about the IPO quality, and the underwriter's reputation can relieve investors. In the meantime, the underwriter requested underpricing for the company for its reputation. Thus, issuing firms use underwriters to certify their IPOs to investors.

Thirdly, in the case of the relationship between investors and underwriters, Loughran & Ritter (2002) suggested that institutional investors' market engagement causes an underwriter to compensate them with a lowered price [32]. Institutional investors tend to hold superior information and bid more aggressively than other investors, leading the market. These factors motivate underwriters and issuing firms to provide IPOs at a lowered price.

In the fourth place, scholars have captured information disparity between uninformed investors and informed investors. This theory hypothesizes that investors are of two types: one knows whether an issued stock is underpriced or not, and the other is not informed of any information. The informed investors only purchase stocks when the IPO is underpriced. The uninformed investors can only access IPO at an overrepresented price, eventually alleviating motivation in investment. Therefore, issuing firms lower the IPO price and attract all investors to participate in the IPO market.

These theories were studied by existing literature, and each of the theories was combined to interpret the IPO market movement. In our work, we tested two hypotheses based on these theoretical approaches.

Sentiment analysis

Previous literature has utilized data analysis techniques in financial contexts, for instance, stock market prediction, credit scoring, asset valuation, risk management, and unstructured data analysis. Natural language processing (NLP) techniques, unstructured data analysis methods, have affected financial researchers to extract useful information from documents like financial reports and corporate filings [13]. This textual data can improve decision-making in a financial context because text information represents more details than numeric information. With this in mind, researchers have focused on the methodologies and applications to capture market information in text, and one of them is sentiment analysis [36, 42].

Sentiment analysis, also recognized as opinion mining, measures a sentiment score for different tones, including neutral, negative, and positive, in text data. As text mining methods developed align with technical improvements, previous research has created various sentimental analysis methods, and the introduction of these methods in financial contexts has also been tried in previous literature [21]. Sentiment analysis methods can be categorized into two big approaches: lexicon-based approach and machine learning-based approach.

Lexicon-based methods measure text sentiment based on pre-defined words or phrases related to the context. Tetlock (2007) used a negative term dictionary to find a negative tone in financial news and predicted stock returns in the following week [44]. Loughran & McDonald (2011) improved an existing dictionary-based work by creating a financial term dictionary and [30], in the meantime, extracting common terms to reduce the misclassification of sentiment tone in the financial text [2].

Machine learning methods have an advantage in a domain-specific task because the methods are trained on the data and find patterns in the contexts [9]. Initial machine learning studies extracted word features with unigram, N-gram, TF-IDF, and Counter Vectorizer after text preprocessing which includes stop-word removal, stemming, and dictionary-based text filtering. Wang et al. (2015, February) applied Naïve Bayes, Support Vector Machine (SVM) [47], and Decision Trees on a unigram of StockTwits data and estimated tones of finance social media data. Atzeni et al. (2017) first represented text data into lexicon features and semantic features and applied learning methods such as Random Forest, Linear Regression, Lasso

Regression, Ridge Regression, and SVM [5]. As NLP tasks require overcoming discrete word representation, high-dimensional feature extraction methods, for instance, Word2Vec, Glove, FastText, and ELMo, are introduced [35]. In the meantime, high-dimension representation enabled the application of deep learning methods on text data. Dickinson & Hu (2015) applied Word2Vec to Twitter data to extract semantic information from investors' opinions [18]. Sohangir et al. (2018) compared logistic regression, Long short-term memory (LSTM) network, and Convolution neural network (CNN) in financial sentiment analysis tasks on StockTwits dataset and discovered that LSTM overperforms logistic regression and CNN trained over 6000 steps has the highest performance [43]. Even though performance improvement by feature extraction and neural network-based methods, studies discovered that existing methods showed low performance in context capturing of the long length of the text. In the case of word representation, NLP algorithms were hard to capture synonyms in text data, lacking in context recognition. This occurrence is called as the long-range dependency between words, meaning that sequential models are weak to capture the contextual information in the long text. To overcome these limitations, the attention mechanism, which embeds contextual information by remembering the order of words, is developed [46]. After the introduction of the attention, a transformer network, which applied the mechanism, overperformed in various NLP tasks [46]. In the sentiment analysis, the bi-directional encoded representation transformers (Devlin et al., 2018) show state-of-the-art performance [17]. FinBERT is a pre-trained version of Bidirectional encoder representations from transformers (BERT) that uses financial sentiment data. (Araci, 2019) showed the improved performance of FinBERT in sentiment analysis compared to other financial text analysis methods [1].

In the IPO context, previous literature utilized these methods and analyzed IPO text data, including compulsory IPO filing, news data, and social media. Ly & Nguyen (2020 February) utilized a word dictionary created by Loughran & McDonald (2011) to analyze an IPO prospectus and S-1 Filing and predicted future underpricing amounts through machine learning algorithms [31, 33]. Tsukioka et al. (2018) collected sentiment text from the financial message board, Yahoo Japan Finance, estimated a bullish index from the number of sentiment texts, and tested hypotheses to identify underpricing factors [45]. Gu & Kurov (2020) utilized a sentiment analysis tool in the Bloomberg API service to analyze Twitter data and discovered the relationship between text sentiment and IPO return [22]. Fedorova et al. (2022) applied FinBERT to measure the sentiment score of IPO news in the Reuters News and examined empirical tests to find determining factors in underpricing [19].

The purpose of our study is to find evidence of information asymmetry theory between investors by identifying their opinion differences in various text sources, specifically financial message boards, news sites, and social media. We hypothesized that the sentimental tone in text data has an impact on the IPO underpricing and tested the hypothesis. In this process, we used fine-tuned FinBert model for our analysis of public opinion about IPO.

MEthodology

Financial text is characterized by the unique terms used in only the finance context. Chan & Chong (2017) reviewed financial texts, which have their own purpose of guessing regarding index, ticker, or market [13]. In the IPO context, text data can denote upcoming information on a stock as well as connote the people's expectations of their investment profit. Therefore, our study required a text analysis method which can detect financial words and their context in paragraphs.

BERT has shown state-of-the-art performance in the language modeling research task. The model is based on transformer structure using an attention mechanism, developed for language modeling [17]. Attention head, also called self-attention, captures the important part of input text by weighting this. The features are extracted by splitting data into three vectors: key, query, and value. Each vector allocates different weights on the same text data, and the model finds a context-related token in the training process. This approach solved prior language modeling's dependency problem in that the importance of each word token shrinks in large text data modeling.

BERT is constituted of transformer encoder layers, normalization layers, and fully connected layers. Transformer encoder layers consist of multiple attention heads, and their parameters are updated in the training course. BERT trains text in a bidirectional way, meaning that it captures text information from the left and right sides. Studies explain that the high performance of BERT is from this training process that the model can understand the context of data. All transformer layers are wrapped by normalization layers. Finally, fully connected layers combine outputs from transformer layers and encode all network parameters in target prediction. Conventional BERT training includes two processes, one is pre-training, and the other is fine-tuning [41]. The pre-training course enables the algorithm to capture the context-sensitive words by predicting random masked word tokens and the next sentence in the data. Fine-tuning purposes for the downstream application by applying the model for the specific task, including question answering, machine translation, and sentiment analysis.

In our work, we used FinBERT for the text analysis method because the model is suitable for our task for the following reasons. First, the algorithm showed promising performance in specific word recognition by considering the context, and this is related to the given term's denotation in a financial context. Lastly, we used text data from professional news websites and financial message board sites, which texts have various lengths in each document.

We adopted FinBERT pre-trained on Reuter's financial context data that includes 46,143 news with 29M financial terms and 400K sentences. For the fine-tuning process, we used Financial Phrasebank data, which have the sentiment label annotated by financial experts [34]. Financial Phrasebank is divided into agreement levels measured by 16 annotators, and we used 100% agreement level data for our fine-tuning. Furthermore, FinBERT utilizes raw text format as its input data and converts the text into multiple attention heads through embedding vectors. Therefore, we removed regular expressions in text data as our preprocessing. FinBERT for sentiment analysis returns three probabilities for positive, negative, and neutral levels, and the algorithm selects the label which has the highest probability among the three labels.

Experiment

Data collection and preprocessing

This study selected 185 companies in IPO listings from 2020 to 2022 in the Nasdaq stock market and collected text opinions for each IPO in various internet communities. For the internet communities, we selected Reddit, Twitter, GlobeNewswire, Seeking Alpha, Reuters, Market Realist, PR Newswire, Yahoo Finance, Renaissance Capital, Forbes, The Motley Fool, and InvestorPlace and classified them into three categories: professional financial news releases, internet message boards, and social media platforms. We collected the first day of IPO price data with Refinitiv API and 68,310 social text data, 661 news data, and 651 message board data with a Python crawler.

Sentiment analysis

In the sentiment analysis, our study tokenized the text data and applied FinBERT pre-trained on financial context data (Araci, 2019) and fine-tuned it with Financial Phrasebank data [1, 34]. FinBERT classifies the text into three levels, positive, negative, and neutral, by estimating the sentiment probability of the text for each level. After that, the FinBERT algorithm calculates the sentiment score by subtracting the probability of negative from the probability of positive. Therefore, the score represents the degree of sentiment in text data.

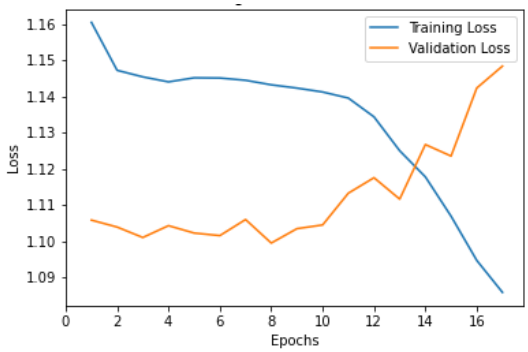


Figure 1 : Training and Validaion Loss Curve

We used a 100% agreement level of Financial Phrasebank data for the fine-training process; the agreement level indicates the validity of sentiment tone measured by financial experts [34]. In fine-tuning, we set our hyperparameters, epochs, learning rate, and batch size as 50, 2e-05, and 128, respectively. In the process, we identified the validation loss increased from epoch 14. Therefore, we stopped fine-tuning at epoch 13 to avoid overfitting (Figure 1).

Hypothesis tests and variable selection

Our purpose is the identification of information asymmetry between investors and determining factors of underpricing. Thus, our study set two approaches that the theory can be investigated in textual communication between IPO parties; one is the asymmetry between underwriters and investors, the other is the theory between uninformed and informed investors. In each approach, our hypothesis has the same dependent variable, an amount of underpricing, and we set the explanatory variables, a Hang Seng index, firm foundation year, sentiment score, and the total number of each score.

Previous IPO research has used different variables to explain underpricing, including the first-day return of the IPO, the standard deviation on the first day of the IPO issue, and the harmonic mean of the asking price and bid price. These variables commonly represent the scale of undervalued prices in the stock market. Therefore, we selected the return of IPO as our dependent variable, and we divided the return with an opened price to convert the return into percent value.

$$IPO_{Return} = \frac{(IPO_{Close} - IPO_{Open})}{IPO_{Open}} \quad (1)$$

In our study, we also used other variables to address the IPO's characteristics and market condition on the IPO issue date. The IPO companies' foundation year is meaningful to control the investing opinion of internet users because the foundation year usually represents intrinsic value in its property, and this fact can motivate people to react with specific sentiment tones to IPO issues [51].

In terms of market condition, we used the Relative Strength Index (RSI) indicator of the stock market index as our control variable. RSI represents the speed of price change in the stock market and is used as a signal for stock purchases. Our work applied this indicator to the Hang Seng Index (HSI) to consider global market trends and not be biased toward US market trends. Therefore, an RSI indicator of the HIS index shows the stock exchange trend and works as a control variable to explain IPO underpricing.

Also, we created a variable representing the relative proportion of sentiment scores based on the total number of sentiment scores,

$$Sentiment\ Ratio_S = \frac{N_s}{N_{pos}+N_{neu}+N_{neg}} \quad (2)$$

, where N denotes the number of sentiment contents per media channel, and S denotes each sentiment, such as positive, neutral, and negative. These variables enabled us to measure the level of sentiment and dominance of the media content related to the IPO under consideration.

In the following sub-section, we introduced the additional variables and set our hypotheses based on the information asymmetry theory. We employed the BERT result, the tone of the financial text, and transformed the result to test the hypothesis. Moreover, we also used additional IPO feature data for the hypothesis test. In our subsection, we explained the target theory, previous studies, and research gap not defined by previous literature, and we set the hypothesis with this process.

Uninformed and Informed Investors.

Previous literature has analyzed opinions in different media platforms, compared the impact on IPO pricing, and interpreted the result from an information asymmetry perspective. This is because each internet platform has a different formality and informational delivery level, so opinions on each platform can affect investors' minds differently. Considering this, the same tone in different media channels can heterogeneously impact the IPO investment. For instance, a negative tone in professional financial materials generally has more effect on investment decisions than a negative anonymous mention in social media. Therefore, this study tried to identify whether media platforms contribute to an information asymmetry effect among IPO investors.

H1: Media contents from different channels with different sentiments would affect information asymmetry between investors and accordingly affect the first-day return of IPO.

H1.a: Three media platforms with the positive tone have the same impact on the first-day return of IPO.

H1.b: Three media platforms with the negative tone have the same impact on the first-day return of IPO.

H1.c: Three media platforms with the neutral tone have the same impact on the first-day return of IPO.

Table 1: Three regression models with different sentiment content ratio

Model	Model 1	Model 2	Model 3
Y variable		First Day Return	
Positive_prof	-0.252		
	(-0.18)		
#_Positive_prof	-0.002		
	(-0.021)		
Positive_board	-0.106		
	(-0.188)		
#_Positive_board	0.027		
	(-0.026)		
Positive_social	-0.295		
	(-0.409)		
#_Positive_social	0		
	(0)		
Negative_prof		-4.908**	
		(-1.749)	
#_Negative_prof		0.380***	
		(-0.094)	
Negative_board		-0.126	
		(-1.431)	
#_Negative_board		-0.008	
		(-0.109)	
Negative_social		0.049	
		(-0.464)	
#_Negative_social		-0.001	
		(-0.002)	
Neutral_prof			-0.191
			(-0.322)
#_Neutral_prof			0.002
			(-0.043)
Neutral_board			0.192
			(-0.298)
#_Neutral_board			0.044
			(-0.044)
Neutral_social			0.037
			(-0.28)
#_Neutral_social			0
			(-0.001)
HSI RSI	-0.005*	-0.005*	-0.005*
	(-0.002)	(-0.002)	(-0.002)
Foundation year	-0.001	0	0
	(-0.001)	(-0.001)	(-0.001)
(Intercept)	0.419*	0.285*	0.263*
	(-0.167)	(-0.119)	(-0.126)
R-squared	0.049	0.11	0.039
P-value	0.349	0.007	0.517
F-test	1.124	2.732	0.901
Observations	185	185	185

Underwriters and Investors.

According to the theoretical explanation of the relationship between underwriters and investors, institutional investors have positioned on an important role because they lead a stock market, affect the underwriter's reputation, and determine the IPO's success. Previous studies explained that

institutional investors are affected by sentiment information in an online financial community [7, 38, 45]. However, these studies focused on the specific web community without comparing opinions between various financial communities. This research stream inspired further study as a comparison of opinions in different online platforms and the discovery of the more influential information to institutional investors. Therefore, we hypothesized that tones of IPO opinions from social media platforms, message boards, and professional news and their interactions with institutional investors' market participation would affect the IPO underpricing and tested how under-writers control the underpricing against institutional investors' market participation. We used the percentage of institutional investors' ownership on the first day of IPO as a variable and analyzed the interaction effect with all sentiment variables. We set three sub-hypotheses to identify the interaction effect between each same tone in different web communities and institutional investors' ownership.

H2: The interaction between media platforms' tones and institutional investors would be associated with the change in the first-day return of IPO.

H2.a: Interaction between Institutional investors and tones in the news will have no impact on IPO first-day return.

H2.b: Interaction between Institutional investors and tones in the board will have no impact on IPO first-day return.

H2.c: Interaction between Institutional investors and tones in social media will have no impact on IPO first-day return.

Table 2 Regression of Interaction Effects

Models	Base	News	Board	Social
Y variable		First Day Return		
Inst	-0.009*			
	(-0.004)			
Positive_prof : Inst		0.004		
		(-0.035)		
Inst : Ratio_Positive_prof		-0.004		
		(-0.009)		
Inst : Negative_prof		-1.630***		
		(-0.199)		
Inst : Ratio_Negative_prof		-0.187***		
		(-0.014)		
Inst : Neutral_prof		0.023		
		(-0.035)		
Inst : Ratio_Neutral_prof		0.007		
		(-0.007)		
Positive_board : Inst			0.017	
			(-0.044)	
Inst : Ratio_Positive_board			-0.009	
			(-0.012)	
Inst : Negative_board			-0.177	
			(-0.356)	
Inst : Ratio_Negative_board			-0.005	
			(-0.042)	
Inst : Neutral_board			-0.097	

Models	Base	News	Board	Social
			(-0.074)	
Inst : Ratio_Neutral_board			-0.024*	
			(-0.011)	
Positive_social : Inst				0.158
				(-0.086)
Inst : Ratio_Positive_social				-0.051*
				(-0.022)
Inst : Negative_social				0.093
				(-0.093)
Inst : Ratio_Negative_social				0.06
				(-0.088)
Inst : Neutral_social				0.089
				(-0.052)
Inst : Ratio_Neutral_social				-0.071*
				(-0.035)
(Intercept)	0.288*	0.138	0.319**	0.281*
	(-0.119)	(-0.088)	(-0.119)	(-0.121)
HSI RSI	-0.005*	-0.002	-0.005*	-0.005*
	(-0.002)	(-0.002)	(-0.002)	(-0.002)
Foundation year	0	0	0	0
	(-0.001)	(-0.001)	(-0.001)	(-0.001)
R-squared	0.051	0.522	0.11	0.097
p-value	0.022	0	0.008	0.02
F-test	3.274	24.003	2.717	2.356
Observations	185	185	185	185

Discussion

Sentiment and underpricing

To examine our first hypothesis, we tested three regression models. Table 1 reveals a significant influence of negative sentiment on IPO underpricing, particularly in news media only, with a p-value of 0.007. Along with the previous work, which confirmed that the initial return tends to react more largely to negative news articles than positive news articles (Seng et al., 2017), our result also highlights the impact of negative news [3, 19]. This result shows that the investors were informed more by negative news articles than other online information with the same tone.

Negative professional news is a robust predictor of lower first-day IPO returns. In Model 2, the statistically significant ($p < 0.05$) coefficient for "Negative_prof" suggests that an increase in negative score of content from professional news is associated with a decrease in the first-day return, representing an underpricing effect. Zou et al. (2020) explained that a negative opinion could indicate a risk in the stock exchange, and this risk-avoidance mindset reduces IPO underpricing. Moreover, higher numbers of negative news, as evidenced by the positive coefficient for "#_Negative_prof" in Model 2, correlate with increased IPO underpricing. It shows that negative news media has a greater impact on underpricing than other media platforms. Therefore, we can understand that negative news media is affecting information asymmetry between investors more than any other media platform. Thus, the negative news media can be more informatic. It shows that negative news media has a greater impact on underpricing than other media platforms.

Interaction effect on underpricing

According to the information asymmetry theory, between underwriters and institutional investors, studies assumed that this group was more informed about IPOs than other market parties. In our experiment, we have the same result of sentiment tone variables as the first hypothesis. Therefore, in this subsection, we only explained interaction effects on underpricing. (Table 2)

Therefore, we stopped fine-tuning at epoch 13 to avoid overfitting (Figure 1). Throughout all experiments, this study identified all regression models have a goodness of fit with the dependent variable. This finding supports the idea that institutional investors are likely to use the information in online media for IPO stock market participation [19].

In our first sub-hypothesis test, we discovered that negative professional news interacts significantly with institutional ownership. Negative interaction between professional news and institutional ownership correlates with decreased IPO underpricing, indicating their combined effect leads to lower underpricing. Considering the reputation of professional news, this result showed institution investors' decision strategy [7, 38]. In the result, the coefficient has negative values, meaning that the interaction between the increase in the number of negative opinions and institutional investors' participation can negatively affect underpricing. From the perspective of institutional investors, even though the market circumstance is negative, they lead the market to create an optimistic view of market participants [15]. This can be a strategic decision to resell the IPO at a higher price, and the underwriter can adjust the IPO price for their reputation [23]. The interpretation suggests that institutional investors may strategically use negative market sentiment to influence underpricing in the IPO market.

In the second and last experiments, we found another significant determining factor of underpricing. For instance, a neutral tone in financial board messages had a significant interaction effect on underpricing. Also, a positive tone and a neutral tone in social media had an interaction effect on underpricing. Unlike professional news, the coefficients of these variables were relatively low, having no great impact on underpricing. The small coefficients for interaction terms involving neutral tones suggest that neutral sentiment has limited influence on IPO underpricing. The interpretation implies that neutral sentiment likely represents basic market information with limited influence on investor decisions regarding IPO underpricing. Moreover, social media research found that public ideas on IPO can mediate the underpricing effect, and our result is in line with this previous work [37].

Conclusion

Our work illuminated that the different tones from different web opinion sources can affect the IPO's underpricing. We utilized the sentiment analysis method, which can analyze the tone of text data on various levels, including sentences, phrases, and documents. Previous literature also explained the sentiment tone in web opinion communities; however, to the best of our knowledge, this study is unique in the regard that we adopted a wide range of media sources, while previous studies used to focus on one media channel such as news or social media. We extracted negative, positive, and neutral sentiment scores from each media as well as the number of contents. Furthermore, we interpreted our hypotheses based on the information asymmetry theory in IPO underpricing. In our first hypothesis, we identified the information disparity between informed investors and uninformed investors. The negative tone of professional news negatively influenced the IPO underpricing, and the proportion of negative tone in

professional news resulted in the underpricing event. In the second hypothesis, we assumed the information asymmetry between underwriters and investors by addressing the institutional investors' market participation and its relationship with the tone of online communities. Our study identified the interaction effect with a negative tone of news media can negatively impact underpricing, and the effect with a negative tone can alleviate underpricing by underwriters.

In our study, we only considered a limited number of IPOs that occurred in the US market from 2020 to 2022. We also collected different sizes of data sources for each online community, which can create a biased effect on the experiment. Also, the shortcoming of this study is that we cannot measure the reputation of the three different media channels. Future research may consider calculating each channel's reputation score from user traffic and the number of sharing, enabling the study to diversify the interpretation of the result of the models. Furthermore, collecting more IPO data and its variables can improve model fit.

References

Araci, D. (2019). Finbert: Financial sentiment analysis with pre-trained language models. arXiv preprint arXiv:1908.10063.

Agaian, S., & Kolm, P. (2017). Financial sentiment analysis using machine learning techniques. International Journal of Investment Management and Financial Innovations, 3(1), 1-9

Seng, J. L., Yang, P. H., & Yang, H. F. (2017). Initial public offering and financial news. Journal of information and telecommunication, 1(3), 259-272.

Arruda, M. P. D., Girão, L. F. D. A. P., & Lucena, W. G. L. (2015). Information asymmetry and share prices: Analysis of the use of social networks in the Brazilian and US capital markets. Revista Contabilidade & Finanças, 26, 317-330.

Atzeni, M., Dridi, A., & Reforgiato Recupero, D. (2017). Fine-grained sentiment analysis on financial microblogs and news headlines. In Semantic Web Challenges: 4th SemWebEval Challenge at ESWC 2017, Portoroz, Slovenia, May 28-June 1, 2017, Revised Selected Papers (pp. 124-128). Springer International Publishing.

Bajo, E., & Raimondo, C. (2017). Media sentiment and IPO underpricing. Journal of Corporate Finance, 46, 139-153.

Barber, B. M., & Odean, T. (2008). All that glitters: The effect of attention and news on the buying behavior of individual and institutional investors. The review of financial studies, 21(2), 785-818.

Baron, D. P. (1982). A model of the demand for investment banking advising and distribution services for new issues. The journal of finance, 37(4), 955-976.

Birjali, M., Kasri, M., & Beni-Hssane, A. (2021). A comprehensive survey on sentiment analysis: Approaches, challenges and trends. Knowledge-Based Systems, 226, 107134.

Booth, J. R., & Smith II, R. L. (1986). Capital raising, underwriting and the certification hypothesis. Journal of financial economics, 15(1-2), 261-281.

Boulton, T., Francis, B. B., Shohfi, T., & Xin, D. (2021). Investor awareness or information asymmetry? Wikipedia and IPO underpricing. Financial Review, 56(3), 535-561.

Byard, D., & Wang, Y. (2016, October). The Impact of Public Disclosure on Information Asymmetry between Sophisticated and Unsophisticated Investors: Evidence from an Investor Social Media Network. In 2017 CAPANA Conference Paper.

Chan, S. W., & Chong, M. W. (2017). Sentiment analysis in financial texts. Decision Support Systems, 94, 53-64

Cirillo, A., Mussolino, D., Saggese, S., & Sarto, F. (2018). Looking at the IPO from the “top floor”: A literature review. Journal of Management and Governance, 22, 661-688.

Cornelli, F., Goldreich, D., & Ljungqvist, A. (2006). Investor sentiment and pre-IPO markets. The journal of finance, 61(3), 1187-1216.

Daily, C. M., Certo, S. T., Dalton, D. R., & Roengpitya, R. (2003). IPO underpricing: A meta–analysis and research synthesis. Entrepreneurship Theory and Practice, 27(3), 271-295.

Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2018). Bert: Pre-training of deep bidirectional transformers for language understanding. arXiv preprint arXiv:1810.04805

Dickinson, B., & Hu, W. (2015). Sentiment analysis of investor opinions on twitter. Social Networking, 4(03), 62.

Fedorova, E., Druchok, S., & Drogovoz, P. (2022). Impact of news sentiment and topics on IPO underpricing: US evidence. International Journal of Accounting & Information Management, 30(1), 73-94.

Gan, B., Alexeev, V., Bird, R., & Yeung, D. (2020). Sensitivity to sentiment: News vs social media. International Review of Financial Analysis, 67, 101390.

Garcia, D. (2013). Sentiment during recessions. The journal of finance, 68(3), 1267-1300.

Gu, C., & Kurov, A. (2020). Informational role of social media: Evidence from Twitter sentiment. Journal of Banking & Finance, 121, 105969.

Hu, Y., Dai, T., Li, Y., Mallick, S., Ning, L., & Zhu, B. (2021). Underwriter reputation and IPO underpricing: The role of institutional investors in the Chinese growth enterprise market. International Review of Financial Analysis, 78, 101956.

Jamaani, F., & Alidarous, M. (2019). Review of theoretical explanations of IPO underpricing. Journal of Accounting, Business and Finance Research, 6(1), 1-18.

Jenkinson, T., Ljungqvist, A., & Ljungqvist, A. P. (2001). Going public: The theory and evidence on how companies raise equity finance. Oxford University Press on Demand.

Khlifi, F. (2022). Web-based financial reporting, social media and information asymmetry: the case of Saudi Arabia. Journal of Financial Reporting and Accounting, 20(5), 994-1020.

Liew, J. K. S., & Wang, G. Z. (2016). Twitter sentiment and IPO performance: A cross-sectional examination. The Journal of Portfolio Management, 42(4), 129-135.

Liu, X., & Ritter, J. R. (2010). The economic consequences of IPO spinning. The Review of Financial Studies, 23(5), 2024-2059.

Ljungqvist, A. (2007). IPO underpricing. Handbook of empirical corporate finance, 375-422.

Loughran, T., & McDonald, B. (2011). When is a liability not a liability? Textual analysis, dictionaries, and 10-Ks. The Journal of finance, 66(1), 35-65.

Loughran, T., & McDonald, B. (2014). Measuring readability in financial disclosures. the Journal of Finance, 69(4), 1643-1671.

Loughran, T., & Ritter, J. (2004). Why has IPO underpricing changed over time?. Financial management, 5-37.

Ly, T. H., & Nguyen, K. (2020, February). Do words matter: Predicting IPO performance from prospectus sentiment. In 2020 IEEE 14th international conference on semantic computing (ICSC) (pp. 307-310). IEEE.

Malo, P., Sinha, A., Korhonen, P., Wallenius, J., & Takala, P. (2014). Good debt or bad debt: Detecting semantic orientations in economic texts. Journal of the Association for Information Science and Technology, 65(4), 782-796.

Mishev, K., Gjorgjevikj, A., Vodenska, I., Chitkushev, L. T., & Trajanov, D. (2020). Evaluation of sentiment analysis in finance: from lexicons to transformers. IEEE access, 8, 131662-131682.

Mitra, G., & Mitra, L. (Eds.). (2011). The handbook of news analytics in finance. John Wiley & Sons.

Mumi, A., Obal, M., & Yang, Y. (2019). Investigating social media as a firm's signaling strategy through an IPO. *Small Business Economics*, *53*, 631-645.

Nguyen, H., Calantone, R., & Krishnan, R. (2020). Influence of social media emotional word of mouth on institutional investors' decisions and firm value. Management Science, 66(2), 887-910

Ranco, G., Aleksovski, D., Caldarelli, G., Grčar, M., & Mozetič, I. (2015). The effects of Twitter sentiment on stock price returns. PloS one, 10(9), e0138441.

Rock, K. (1986). Why new issues are underpriced. Journal of financial economics, 15(1-2), 187-212.

Rogers, A., Kovaleva, O., & Rumshisky, A. (2021). A primer in BERTology: What we know about how BERT works. Transactions of the Association for Computational Linguistics, 8, 842-866.

Schumaker, R. P., Zhang, Y., Huang, C. N., & Chen, H. (2012). Evaluating sentiment in financial news articles. Decision Support Systems, 53(3), 458-464.

Sohangir, S., Wang, D., Pomeranets, A., & Khoshgoftaar, T. M. (2018). Big Data: Deep Learning for financial sentiment analysis. Journal of Big Data, 5(1), 1-25.

Tetlock, P. C. (2007). Giving content to investor sentiment: The role of media in the stock market. The Journal of finance, 62(3), 1139-1168

Tsukioka, Y., Yanagi, J., & Takada, T. (2018). Investor sentiment extracted from internet stock message boards and IPO puzzles. International Review of Economics & Finance, 56, 205-217.

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I. (2017). Attention is all you need. Advances in neural information processing systems, 30.

Wang, G., Wang, T., Wang, B., Sambasivan, D., Zhang, Z., Zheng, H., & Zhao, B. Y. (2015, February). Crowds on wall street: Extracting value from collaborative investing platforms. In Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (pp. 17-30).

Welch, I. (1989). Seasoned offerings, imitation costs, and the underpricing of initial public offerings. The journal of finance, 44(2), 421-449.

Yang, Y., Uy, M. C. S., & Huang, A. (2020). Finbert: A pretrained language model for financial communications. arXiv preprint arXiv:2006.08097.

Zhang, W., & Skiena, S. (2010, May). Trading strategies to exploit blog and news sentiment. In Proceedings of the international AAAI conference on web and social media (Vol. 4, No. 1, pp. 375-378).

Zou, G., Li, H., Meng, J. G., & Wu, C. (2020). Asymmetric effect of media tone on IPO underpricing and volatility. Emerging Markets Finance and Trade, 56(11), 2474-2490.

Diversity and Hospital Efficiency: A Data Envelopment Analysis Model

Ewelina Maselek[1], Yolanda Hacia[1], Noemi Rodriguez[1], Esad Sinanovic[1], Donghyup Woo[2], Lisa Frank[1], C. Christopher Lee[1]

[1]Central Connecticut State University, New Britain, USA. [2]University of Pittsburg at Greensburg, Greensburg, USA

ABSTRACT

The objective of this study was to explore whether hospitals in the United States that actively sought and hired a diverse workforce exhibited higher levels of efficiency. This research aimed to understand the intricate interplay between hospital diversity and efficiency, with the goal of enhancing overall hospital performance, fostering staff satisfaction, and improving patient care quality. For this investigation, we utilized data derived from the 2017 U.S. Hospital Survey conducted by the American Hospital Association (AHA). We focused on input variables such as the number of physicians, registered nurses, available hospital beds, and operating expenses. Additionally, we scrutinized output measures, including inpatient days and outpatient visits. The AHA survey encompassed hospitals that actively recruited foreign-educated nurses, contributing to the diversity aspect of organizational management. To assess hospital efficiency, we employed data envelopment models. In this sample, we classified 2,776 hospitals into two distinct groups based on their diversity levels, which later facilitated the application of the Mann-Whitney test to determine the impact of diversity on hospital efficiency. The empirical evidence underscores a robust correlation between diversity and efficiency.

Keywords: Hospital Diversity, Hospital Efficiency, Data Envelopment Analysis

INTRODUCTION

The organizational structure of a hospital plays a pivotal role in shaping both quality and efficiency simultaneously and in the same direction (Ludwig, 2010). In addition, the significance of quality in the context of a hospital visit cannot be overstated. Satisfying patients' needs and expectations not only contributes to increased market share but also enhances overall financial performance (Pink, 2003). Inefficiencies in healthcare resource utilization also stand as a prominent driver of escalating healthcare expenditures. Consequently, governments and healthcare providers are intensifying their focus on the productivity and quality of medical resources (Lin, 2019).

Diversity assumes a paramount role within the healthcare industry, as it aligns with a compelling case for an organization's diversity strategy (Clapp, 2010). The recognition of diversity as a strategic business advantage has prompted the integration of diversity metrics into business objectives (Clapp, 2010). The performance metrics of businesses acknowledged for their cultural competence and diversity management practices further bolster the business case for embracing diversity (Dreachslin, 2017).

This research seeks to unravel the impact of diversity on hospital efficiency, with a particular emphasis on biodemographic diversity. The four primary categories of diversity encompass functional diversity, diversity in leadership, educational diversity, and biodemographic diversity (Moon & Christensen, 2020). This study will specifically investigate how biodemographic diversity influences hospital efficiency.

In contemplating the rationale behind this study, it is essential to underscore the important role that diversity plays within a hospital setting. Diversity contributes to the attainment of various critical objectives within a hospital, including fostering higher employee morale, delivering improved care for diverse patient populations, and elevating employee retention rates, among others (Jordan, 2020). The nexus between diversity and efficiency serves as the cornerstone of the research inquiries explored in this project.

Promoting diversity translates into promoting efficiency, culminating in hospitals that perform optimally for both their staff and patients. To address the research questions, this study will investigate and compare hospital efficiency in contexts with and without diversity. The aim is to furnish hospital executives with a valuable resource to inform their decision-making processes. Such insights hold the potential to mitigate risks stemming from a lack of diversity, including communication barriers, limited perspectives, and a dearth of role models (Jordan, 2020).

The research methodology for this study will draw upon a comprehensive review of articles from diverse sources, alongside the analysis of empirical evidence. These sources will facilitate a nuanced understanding of the prevailing situation and its alignment with our research hypothesis. To collect data, this research will leverage the 2017 U.S. Hospital Survey dataset by the American Hospital Association (AHA). From this dataset, specific inputs and outputs will be selected to construct data envelopment models, allowing for the measurement of each hospital's efficiency scores. These scores will be classified into two groups: a control group comprising conventional hospitals and a test group encompassing hospitals characterized by greater diversity. Subsequently, statistical analysis will be conducted to assess the research hypothesis and ascertain whether a significant difference exists between the two groups.

The culmination of this research endeavor will furnish additional empirical evidence in support of formulating diversity, equity, and inclusion policies within the healthcare industry. Moreover, it will provide valuable insights for informed decision-making concerning hiring practices within healthcare institutions.

This study is organized into following sections. Section 2 reviews prior studies and establishes the research hypothesis. Section 3 outlines the research methodology, followed by the presentation of statistical results in Section 4. Section 5 engages in a discussion of the results vis-à-vis existing literature, elucidating managerial implications. Finally, Section 6 offers concluding remarks, summarizing the study's findings and their implications.

LITERATURE REVIEW

Blouch and Azeem (2019) collected data from four public and private hospital groups to establish an association between employee perception of diversity and organizational perception. The data was collected over different hierarchical levels and across all sectors. The respondents from the survey were tested using ANOVA and CAUSALMED through Statistical Analysis Software and concluded that employees of various industries and genders are similar in their values and perception. On the other hand, there were differences among employees' responses regarding the organization's perception of diversity management. No matter the gender or categories, employee perceptions of diversity connect to perceived organizational performance; thus, the relationship becomes more robust when the organization's perception of diversity becomes stronger.

Lin et al. (2019) collected data over the course of 13 years in 15 Taiwanese Veterans hospitals to develop DEA-based models aimed at assessing relative efficiencies. Various input variables were scrutinized, including the number of physicians, patient beds, other medical personnel, nurses, equipment, and floor area. The number of outpatient visits in each department was considered the output variable. An interesting discovery from this analysis was the positive impact of the New Hospital Accreditation, which emphasized patient, psychological, and societal needs, on hospitals' operational efficiency. The study also supports our hypothesis that improvements in operating efficiency are attainable.

Dreachslin (2017) contributes to the field by presenting research centered on diversity and patient culture, offering a blueprint for future healthcare leaders seeking to implement change. Employing a mixed-methods approach, this study included a control hospital and an intervention hospital. Five organizational competencies were assessed: diversity leadership, strategic human resource management, organizational climate, diversity climate, and patient cultural competence. Pre and post intervention assessments in these areas yielded valuable insights for executive leaders seeking to address diversity and efficiency concerns. It is notable that both hospitals were already meeting expectations in terms of diverse leadership. Moreover, the study revealed a decline in patient complaints following the intervention, signaling the initiation of initiatives geared towards enhancing patient satisfaction.

Kochan (2003) delved into the "business case" for diversity at four large firms, aiming to examine the relationships between race and gender diversity and business performance. The research was conducted through a large-scale field research project, involving collaboration between industry and university teams. Qualitative and quantitative data collected across the four

companies were analyzed, primarily relying on archival data. A significant finding emerged that gender diversity had a positive influence on constructive group processes, while racial diversity had an inhibiting effect. These constructive group processes, in turn, positively impacted performance ratings and group bonuses.

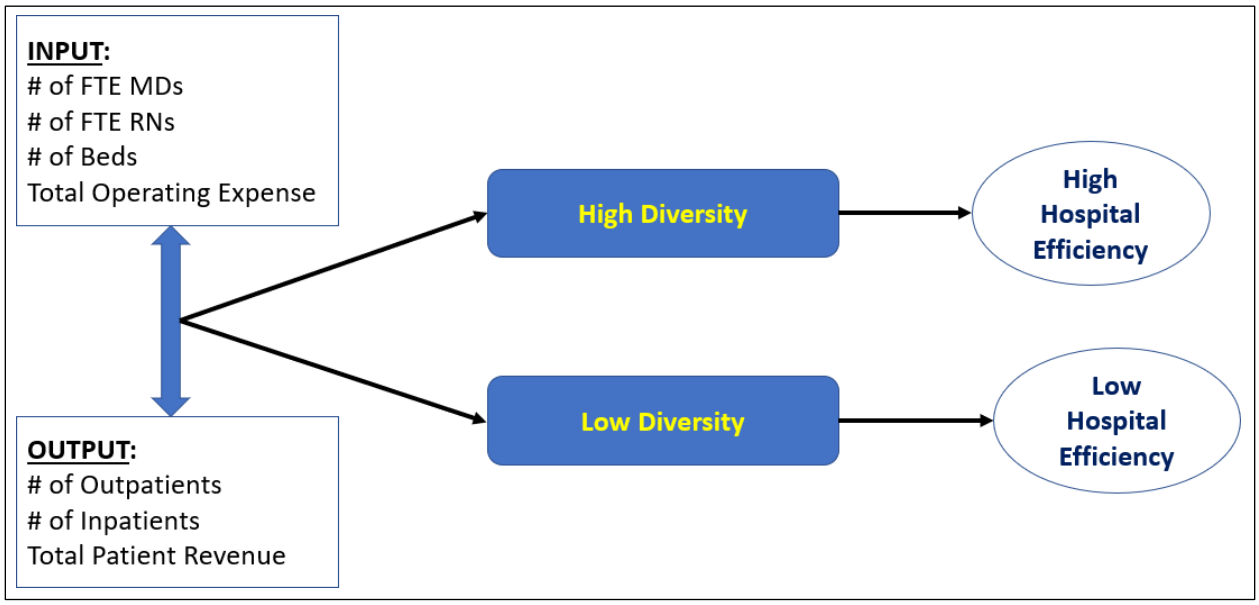
In summary, Blouch and Azeem's research (2019) underscores the importance of organizational management's robust awareness of diversity in enhancing employee engagement. Lin et al. (2019) demonstrates the potential for big data studies to inform policy changes and promote efficiency in healthcare. Dreachslin's study (2017) highlights the reciprocal relationship between diversity and patient satisfaction, emphasizing the adaptability of hospital leadership for enhanced efficiency. Lastly, Kochan's work (2003) emphasizes the positive impact of tracking and evaluating strategies for managing a diverse workforce on productivity and performance within organizations.

Research Hypothesis: If hospitals increase their diversity, hospitals will be more efficient.

METHODOLOGY

Based on the research hypothesis, this paper proposes a conceptual model in Figure 1 that describes a research framework.

Figure 1. Conceptual Model



1.1 Variables

Full-Time Equivalent Medical Doctors (FTED)

Ersoy et al (1997) introduced medical doctors as a crucial determinant of efficiency. Their study revealed a correlation between the number of doctors and hospital efficiency, with inefficient hospitals employing a higher number of doctors. This paper will use the number of full-time equivalent medical doctors (FTED) for an input variable in the proposed DEA model. Our research will delve further into the role of diversity in influencing efficiency.Full-Time Equivalent Registered Nurses (FTEN)

Previous studies have investigated the wide range of services and comparable quality offered by hospitals. Staat (2006) explored how efficiently hospitals are performing using the DEA model. Efficiency in a hospital can be affected by the organization of its staff and its diversity. Staff, including registered nurses, will be assessed in a manner akin to the evaluation of medical doctors in the research conducted by Ersoy et al. (1997). This paper will use the number of full-time equivalent registered nurses (FTEN) for an input variable in the proposed DEA model. Despite the disparity in educational levels, the staffing ratio remains a crucial factor in our analysis.

Number of Beds (BDTOT)

Another important variable used to measure efficiency in hospitals will be the number of beds. Hospitals must keep in mind how to generate higher returns on their investments.

Watcharasriroj and Tang (2004), using the contingency theory, revealed that size does influence hospital efficiency. According to this theory, three elements are highlighted: communication, coordination, and integration of effort across the organization. When hospitals increase in size, so will the number of employees or APRNs on hand. This would lead to a higher utilization of beds and a more appropriate utilization of APRNs, ultimately leading to increased hospital efficiency. Hospital bed utilization, as assessed in the study conducted by Ersoy et al. (1997), also serves as a decisive factor in determining hospital efficiency. The research revealed that inefficient hospitals were utilizing twice as many beds as efficient ones. This paper will use the number of total beds (BDTOT) for an input variable in the proposed DEA model.

Total Operating Expenses (EXPTOT)

Numerous studies have delved into the connection between financial performance and efficiency, with research by Watkins (2000) highlighting essential variables to consider when evaluating a hospital entity's profitability. Operating expenses encompass all costs incurred by a hospital in its regular operations. When assessed in relation to the total revenue generated within a given period, researchers can gain valuable insights into the performance of a unit's operations. Watson also regards this as a measure of efficiency. In

the study conducted by Lee et al. (2023), the management of group purchasing organizations by hospitals is recognized as a factor influencing expenses and, over time, their efficiency. The outcomes of the study shed light on how medical suppliers or distributors impact efficiency. This paper will use the total operating expenses (EXPTOT) for an input variable in the proposed DEA model.

Inpatients (IPDTOT)

One variable we will use to evaluate hospital efficiency is the number of inpatients that are treated based on the 2017 AHA data. The use of this variable comes from research of Gok and Sezen (2012). However, this variable is often used as a measure of output for studies pertaining to the efficiency of a hospital. Inpatient turnover measurement allows researchers to measure the number of patients admitted, treated and released, in comparison to the various inputs. When comparing the number of inpatients between hospitals of similar scale, we can better understand what variables are instrumental in creating hospital efficiency. Inpatient output is an important variable when considering hospital efficiency. The study by Lee et al (2023) used inpatient days as a variable to consider if distributors can impact hospital efficiency. The study found high correlations from the Spearman rank correlation test between inpatient days and other input and output variables. This paper will use the total inpatient days (IPDTOT) for an output variable in the proposed DEA model.

Outpatients (VTOT)

Another variable we will use to evaluate hospital efficiency is the number of outpatients that are treated, also based on the 2017 AHA data. Like the use of inpatient turnover, the use of this variable comes from the research of Gok and Sezen (2012). The measurement of outpatient services can be used to assess hospital efficiency. However, unlike inpatient services, outpatient measurements pertain to different services offered by a hospital, such as emergent care, which may not necessarily align with the procedures performed on inpatients. Drawing from the research of Caballer-Tarazona et al. (2010), who advocated for segmenting hospital services in efficiency studies, we have chosen to treat inpatients and outpatients as distinct variables in our research. Furthermore, Lin et al. (2019) examined the number of outpatients per department in Taiwanese hospitals. This approach allows for incremental analysis within the hospital in smaller units, yielding departmental efficiency rates that can be compared within a DEA model.

Consequently, this approach also provides a benchmark department when assessing diversity and efficiency within each department. This paper will use the total outpatients (VTOT) for an output variable in the proposed DEA model.

Total Patient Revenue (TPR)

Total revenue stands as another frequently employed variable when assessing hospital efficiency. In a study conducted by Watkins (2000) on hospital performance, it is proposed that total revenue serves as an indicator of efficiency. By utilizing the DEA method to identify the hospitals with the best financial performance based on total revenue and comparing inputs through variance analysis, we will ascertain the inputs and control variables that contribute to superior financial efficiency. Uncompensated care has both a direct and indirect impact on financial performance. Applying the DEA model to gauge inefficiencies within hospitals reveals an opportunity for enhancing efficiencies and revenue by accounting for the costs associated with uncompensated care and addressing technical inefficiencies (Ferrier et al., 2006). This paper will use the total patient revenue (TPR) for an output variable in the proposed DEA model.

Data Envelopment Analysis Model

The study conducted by Dreachslin (2017) will allow us to add patient pre and post care survey scores to the DEA model. Reviewing this data will help in measuring patient perception compared to efficiency. DEA models have been used to measure hospital efficiencies and provide valuable information to analyze multiple inputs to produce various outputs. The results improve the decision-making processes for planning, allocation, and utilization in hospitals (Ersoy et al., 1997). The analysis conducted by Lin et al. (2018) will enable us to interpret the actions of the inputs studied in the role they play in the output, which in the case of this article

was the outpatients per department within the hospital. These results will help us look deeper into each department of the hospital to see if diversity has a role in a department being more efficient compared to the others. Lee et al. (2023) conducted a first of its kind study that used the DEA method to incorporate inputs: total expenses, beds set up and staffed, full-time physicians and dentists, full-time registered nurses, and supply expenses, with output variables inpatient days and total outpatient visits. The study was aiming to discover if hospital efficiency for distributors can be determined by the proposed input and output variables.

In measuring comparative efficiency of diversity in the health care industry, we utilize data envelopment analysis (DEA) for Hospitals using variables related efficiency in operations. DEA is a special application of linear programming based on frontier methodology of Farrell (1957). Since Farrell, additional breakthroughs for developing DEA were achieved by Charnes et al. (1978) and by Banker et al. (1984). Data envelopment analysis is a useful approach for measuring relative efficiency among similar organizations or objects. An entity that is an object to be measured for efficiency is called a decision-making unit or DMU. Because DEA can identify relatively efficient DMU(s) among a group of given DMUs, it is a promising tool for comparative analysis or benchmarking (Mhatre et al., 2014).

To explore the mathematical property of DEA, let E_0 be an efficiency score for the base DMU *0* then,

$$\text{Maximize } E_0 = \frac{\left\{\sum_{r=1}^{R} u_{r0} y_{r0}\right\}}{\left\{\sum_{i=1}^{I} v_{i0} x_{i0}\right\}} \quad (1)$$

subject to

$$\frac{\left\{\sum_{r=1}^{R} u_{r0} y_{rk}\right\}}{\left\{\sum_{i=1}^{I} v_{i0} x_{ik}\right\}} \leq 1 \text{ for all } k \quad (2)$$

$u_{r0}, v_{i0} \geq d$ for all $r, i,$ (3)

where
y_{rk}: the observed quantity of output r generated by unit $k = 1, 2, \ldots, N$, x_{ik}: the observed quantity of input i consumed by unit $k = 1, 2, \ldots, N$, u_{r0}: the weight to be computed given to output r by the base unit 0, v_{i0}: the weight to be computed given to input i by the base unit 0,
d: a very small positive number.

The fractional programming model can very easily be converted to a common linear programming (LP) model. A major assumption of LP is a linear relationship among variables. Accordingly, an ordinary LP for solving DEA utilizes a constant returns-to-scale so that all observed production combinations can be scaled up or down proportionally (Charnes et al., 1978). However, when we use a piecewise LP, we can model a non-proportional returns-to-scale such as an increasing, decreasing or variable-returns-to-scale (Banker et al., 1984). Depending on returns-to-scales and/or various modeling approaches, different types of DEA models are available (Mhatre et al., 2014).

Sherman and Ladino (1995) summarize the capability of DEA in the following manner:

- Identifies the best practice DMU that uses the least resources to provide its products or services at or above the quality standard of other DMUs;
- Compares the less efficient DMUs to the best practice DMU;
- Identifies the amount of excess resources used by each of the less efficient DMUs;
- Identifies the amount of excess capacity or ability to increase outputs for less efficient DMUs, without requiring added resources.

This study involves comparative measures of operational efficiencies for DMUs, a Charnes-Cooper-Rhodes (CCR) model, a Banker, Charnes, and Cooper (BCC) model, and a slack-based measure of efficiency (SBM) are employed. First, we measure the efficiency of DMUs using the CCR and BCC models, respectively. Next, we apply SBM to data to evaluate the efficiency of variables with non-radial properties. Finally, we try to identify the sources of inefficiency by contrasting the results of the three models (Mhatre et al., 2014).

Sample Data Collection

The data we will be using for this analysis was from the 2017 AHA (American Hospital Association) annual survey given out to a wide range of hospitals across the United States of America. This survey will give us a deeper insight into hospital operations and allow us to conduct a detailed analysis with many outcomes. The data provided includes insights on patient engagement, prescriptions, computerized information viewing, and information reporting.
However, we will primarily focus on the inputs and outputs mentioned above for the statistical analysis of efficiency. With access to this data, we will produce DEA models that will show us the impact of diversity on efficiency within the hospital system. We will be able to collect enough information to effectively develop a series of opportunities to become efficient in hospitals.

RESULTS

Diversity Variable

The independent variable in the data sample was FORNRSA in the AHA 2017 U.S. Hospital Survey dataset. The survey question was: *Did your facility hire more foreign educated nurses to help fill RN vacancies in 2017 vs. 2016?* FORNRSA variable includes four values. We transformed the FORNRSA variable into Diversity variable e as follows:

FORNRSA		DIVERSITY	
0	Did not hire	0	Less Diversity
1	More	1	More Diversity
2	Less	1	
3	Same	1	

The sample data shows that 6284 hospitals participated in the survey. We deleted hospitals with missing data or blank values, reducing our sample data from 6284 hospitals to 2776 hospitals. So, N= 2776. Sample data shows that 2332 hospitals (84.0%) have less diversity
while 444 hospitals (16%) have more diversity between 2017 and 2016. See Table 4.1 for the sample distribution frequency of less diversity and more diversity in hospitals.

Table 4.1
Sample Data Distribution

	Frequency	%
Less Diversity	2332	84.0
More Diversity	444	16.0
Total	2776	100.0

Descriptive Statistics of Sample Data

The data had 2776 hospitals that were analyzed. We used the following inputs: Fulltime Physicians and Dentists (FTED), Fulltime registered nurses (FTEN), hospital bed totals (BDTOT) and total facility expenses (EXPTOT). We also used the following outputs: total inpatient days in facility (IPDTOT0, total outpatient visits (VTOT) and total privileged (TPR). We calculated the min, max, mean and standard deviation for each to provide us with data analysis for our hypothesis.

Table 4.2
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
DEA CCR-I Score	2776	.0677	1.00000	.4617	.1756
(I) FTED	2776	.01	2669.00	42.7123	153.54881
(I) FTEN	2776	3	7517	314.61	580.787
(I) BDTOT	2776	4	2877	162.28	219.112
(I) EXPTOT	2776	2148307	5543477948	212784828.04	410817080.265
(O) IPDTOT	2776	27	761889	38990.88	61429.285
(O) VTOT	2776	62	6297877	178386.21	297997.792

(O) TPR	2776	1068528	16863431079	717381500.73	1435457958.263

Correlation Analysis

We ran a correlation analysis using Spearman's rho. CCR-I score was significantly correlated with Diversity. Data showed that the input and output variables were significantly correlated with each other ($p < 0.01$). As diversity increases, the hospital will be more efficient. The results are shown in Table 4.3.

Table 4.3
Spearman's Rho Correlation Results

	CCR-I	(I) FTED	(I) FTEN	(I) BDTOT	(I) EXPTOT	(O) IPDTOT	(O) VTOT	(O) TPR	Diversity
CCR-I	1.000								
(I) FTED	.101**	1.000							
(I) FTEN	.316**	.694**	1.000						
(I) BDTOT	.460**	.597**	.849**	1.000					
(I) EXPTOT	.340**	.717**	.966**	.833**	1.000				
(O) IPDTOT	.617**	.586**	.834**	.962**	.820**	1.000			
(O) VTOT	.288**	.717**	.864**	.722**	.890**	.699**	1.000		
(O) TPR	.351**	.644**	.950**	.818**	.957**	.797**	.847**	1.000	
Diversity	.129**	.150**	.230**	.241**	.232**	.237**	.178**	.228**	1.000

Note: **p <0.01 Correlation is significant at the 0.01 level (one-tailed)

Mann-Whitney Test Results

Mann-Whitney Test results show that a group of hospitals with more diversity (.5041 ± .1529) is significantly more efficient than those hospitals with less diversity (.4537 ± .1785). Data shows that the statistical difference between the two groups is significant [MW test statistic = 412158.5, Z = -6.818, p < .001]. The results are presented in Table 4-4.

Table 4.4
Mann-Whitney Test Results

Diversity	N	Mean	SD	Mean Rank	MW U	Z	*p*-value
Less Diversity	2332	.4537	.1785	1343.24	412158.5	-6.818	<.001
More Diversity	444	.5041	.1529	1626.22			
Total	2776	.4617	.1756				

Note: SD stands for Standard Deviation. MW U indicates the Mann-Whitney test statistic.

DISCUSSION

Impacts of Diversity on Hospital Efficiency

Evidence fully supports that we have a strong correlation between diversity in a hospital and the hospital being more efficient compared to a hospital with less diversity ($p < 0.001$). Our CCR score was also highly correlated with diversity. This leads to a compelling case that having diversity in a hospital will improve the efficiency of that hospital. Of the 2776 hospitals in the study, 444 showed this high diversity to high efficiency results.

Blouch and Azeem (2019) state that when organizational management becomes robust in diversity awareness, employees tend to increase their work engagement, consistent with our findings.

The Mann-Whitney Test results showed hospitals with more diversity were significantly more efficient than those with less. However, our findings were not compatible with a previous study that stated that gender diversity typically increased constructive group processes while racial diversity inhibited them (Kochan, 2003). Our review of diversity was broader in range, considering various diversity traits.

The studies we reviewed and the data we sampled were in line with our hypothesis. The surveys sampled in the Blouch and Azeem (2019) study focused on perceptions. A similar trait to the surveys in our sample data. An employee who perceives himself to be in a strong diverse organization will work more productively and add efficiency to the hospital. Lin's (2019) study reported that improvements are attainable. Our sample data supported our hypothesis that a

hospital that hires diverse candidates will create the environment needed to maintain an efficient workforce.

Managerial Implications

Diversity is increasing creativity throughout the world, and it plays a vital role in the life and culture of many organizations, especially in healthcare. Organizations with wide racial diversity are associated with increased sales, revenues, more customers, and a more significant market share with relative greater profits. We embrace diversity by creating a workforce comprised of multiple races, ages, gender, ethnicities, and orientations. When you include hospitals in diversity improvements you add a few layers of enhancements. You are enhancing the work environment for doctors, nurses, and other hospital staff, therefore resulting in a direct improvement of services to patients. The efficiency created by these diverse environments assists Managers in decision making and overall management of the hospital.

CONCLUSION

While we investigated the impact of diversity on hospital efficiency, the key finding from our research and data was that hospitals with more diversity are more efficient. However, just 444 (around 16%) of the 2776 hospitals studied in our data demonstrated substantial diversity, that then lead to increased efficiency. Several of the publications examined mentioned that certain types of diversity (gender) aid efficiency, while others, such as racial diversity, did not.
The results in our data, on the other hand, reveal a high association between efficiency across all categories, not just one, proving our theory correct.

Future studies could investigate the impacts of diversity on hospital efficiency more in- depth. The depth of the investigations would be based on how detailed of a data set we would be able to acquire. First, the sample size of the data set could be larger, including hospitals from all around the world not just the US. Second, a more recent AHA data set from 2020 could be compared to our data set used in this study. Third, different dependent variables could be studied to investigate the impact diversity has on labor efficiency, or the financial performance of the hospital through operating margin, ROA, or ROE which also is an indicator of efficiency. Better quality of patient care is another indicator that could be tracked through the hospital rating, readmission rate, or even patient satisfaction. Fourth, having control variables in place such as hospital size, hospital location, or hospital network will show the controlled effect that diversity has when those variables are considered. Fifth, our study used the DEA model, but future studies could use a capacity productivity model or a manpower productivity model to analyze if the same hypothesis stands. Another future study could use the regression analysis.

Lastly, a more
in-depth analysis could be taken on the current data set to see if there are other commonalities between the 444 hospitals that showed that more diversity leads to a more efficient hospitals.

The literature provides empirical evidence on the relevance of diversity and inclusion in the healthcare industry, shedding light on the industry. One of the significant achievements is bringing innovation and effectiveness to hospital organization, resulting in a dynamic culture and an efficient system. It also helps the healthcare sector become more effective by increasing sales and revenues and attracting more clients, which substantially impact the industry. One of the study's shortcomings is the limited use of information on diversity at hospitals in the United States, including a limited number of DMUs and variables. First, we gathered data from hospitals

exclusively in the United States, which raises concerns with generalization, and secondly, the study solely looks at the hospital sector. The types of inputs and outputs in public and private healthcare sectors and other industries should be the focus of future research.

REFERENCES

Banker, R. D., Charnes, A, & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science, 30*(9), 1078- 1092.

Blouch, R. & Azeem, M. F. (2019). Effects of perceived diversity on perceived organizational performance: Mediating role of perceived organizational justice. *Employee Relations: The International Journal, 41*(5), 1079-1097. DOI:10.1108/ER-05-2018-0150

Caballer-Tarazona, M., Moya-Clemente, I., Vivas-Consuelo, D., Barrachina-Martínez, I. (2010). A model to measure the efficiency of hospital performance. *Mathematical and Computer Modeling, 52*(7-8), 1095–1102. DOI:10.1016/j.mcm.2010.03.006

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429-444.

Clapp, J. R. (2010). Diversity leadership: The rush university medical center experience. *Hospital Topics*, *88*(2), 61–66. DOI: 10.1080/00185861003768993

Cooper, W.W., Seiford, L.M., & Tone, K. (2007), *Data envelopment analysis: A comprehensive text with models, applications, references and DEA-Solver software, 2nd ed.* Springer, New York, NY.

Dreachslin, J. L., Weech-Maldonado, R., Jordan, L. R., Gail, J., Epané, J. P., & Wainio, J. A. (2017). Blueprint for sustainable change in diversity management and cultural competence: Lessons from the national center for healthcare leadership diversity demonstration project. *Journal of Healthcare Management*, *62*(3), 171–183. DOI:10.1097/JHM-D-15-00029

Ersoy, K., Kavuncubasi, S., Ozcan, Y.A. et al. Technical efficiencies of Turkish hospitals: DEA Approach. *Journal of Medical Systems,* 21, 67–74.

Ferrier, G.D., Rosko, M D., & Valdamis, V.G., (2006), Analysis of uncompensated hospital care using the DEA model of output congestion. *Healthcare Managed Science, 9*, 181-188. DOI:10.1007/S10729-006-7665-8

Gook, S. M., & Sezen, B. (2012). Capacity inefficiencies of teaching and non-teaching hospitals. *The Service Industries Journal, 32*(14), 2307-2328. DOI:10.1080/02642069.2011.582495

Jordan, A. (2020). The importance of diversity in healthcare & how to promote it | Provo

College. *Provo College.* Available at: https://www.provocollege.edu/blog/the-importance-of-diversity-in-healthcare-how-to-promote-it/

Kochan, T., Bezrukova, K., Ely, R., Jackson, S., Joshi, A., Jehn, K., Leonard, J., Levine, D., & Thoas, D. (2003). The effects of diversity on business performance: Report of the diversity research network. *Human Resource Management, 42*(1), 3-21. DOI: 10.1002/hrm.10061

Lee, C. C., Langdo, J., Hwang, D., Marques, V., Hwang, P. (2023). Impacts of distributors and group purchasing organizations on hospital efficiency and profitability: A bilateral data envelopment analysis model. *International Transactions in Operational Research, 30*(1), 476-502. DOI:10.1111/itor.12957

Lin, F., Deng, Y.-J., Lu, W.-M., & Kweh, Q. L. (2019). Impulse response function analysis of the impacts of hospital accreditations on hospital efficiency. *Health Care Management Science, 22*(3), 394–409. DOI:10.1007/s10729-019-09472-6

Ludwig, M., Van Merode, F., & Groot, W. (2010). Principal agent relationships and the efficiency of hospitals. *The European Journal of Health Economics, 11*(3), 291-304. DOI: 10.1007/s10198-009-0176-z

Mhatre, N. Joo, S. J., & Lee, C. C. (2014). Benchmarking the performance of department stores within an income elasticity of demand perspective. *Benchmarking: An International Journal, 21*(2), 205-217.

Moon, K.-K., & Christensen, R. K. (2020). Realizing the performance benefits of workforce diversity in the U.S. federal government: The moderating role of diversity climate. *Public Personnel Management, 49*(1), 141-165. DOI:10.1177/0091026019848458

Pink, G. H., Murray, M. A., & McKillop, I. (2003). Hospital efficiency and patient satisfaction. *Health Services Management Research*, *16*(1), 24-38.

Saitech (2010). *DEA solver professional release 7.1.* Saitech, Inc., Holmdel, N.J.

Sherman, H. D. & Ladino, G. (1995). Managing bank productivity using data envelopment analysis. *Interfaces, 25*(2), 60-73.

Staat, M. R. (2006). Efficiency of hospitals in Germany: A DEA-bootstrap approach. *Applied Economies, 38*(19), 2255-2263. DOI:10.1080/00036840500427502

Watcharasriroj, B., & Tang, J. C. S. (2004). The effects of size and information technology on hospital efficiency. *Journal of High Technology Management Research, 15*(1), 1-16. DOI:10.1016/j.hitech.2003.09.001

Watkins, A. L. (2000). Hospital financial ratio classification patterns revisited: Upon considering nonfinancial information. *Journal of Accounting and Public Policy, 19*, 73-95.

Mapping Domestic REE Supply Chain for the Wind Energy Market in the USA

Rajkamal Kesharwani, Mercyhurst University

Sourish Sarkar, Penn State University

Abstract

The thrust for moving to renewable energy and operating a circular economy is picking momentum. One of the critical bottlenecks in this transition is the usage of rare earth (RE) minerals in the manufacturing of permanent magnets. In this research, we have tried to map the demand and potential growth in wind energy in the United States and the corresponding RE element (REE) demand. The heavy dependence on China to fulfill this demand is a strategic bottleneck that needs to be addressed. Our findings indicate that the current and planned domestic production of REE in the US will not be able to meet the current needs of the US wind market. It is more likely that US will need to make strategic alliances with other countries to protect itself from the RE supply shocks and build a resilient supply chain that can support the projected growth in the wind energy market.

Introduction

At present, in Europe the share of wind energy is around 12.4%, where Denmark leads other countries with a share of around 50% (Wiser et al., 2023). The United States has a goal for obtaining about 300 gigawatts of its energy production through wind energy by 2030, enough to power 10 million American homes and avoid 78 million metric tons of CO_2 from being released into the atmosphere. In the year 2020, the US ranked second globally after China for annual wind energy production when it generated 8.3% of its total electricity through wind. If the US must meet its ambitions towards carbon neutrality, then this share could potentially increase up to 35% by 2050 as shown in Figure 1. This would mean that the US needs to scale up wind energy production by 25-30GW per year through new installations (Baranowski et al., 2022).

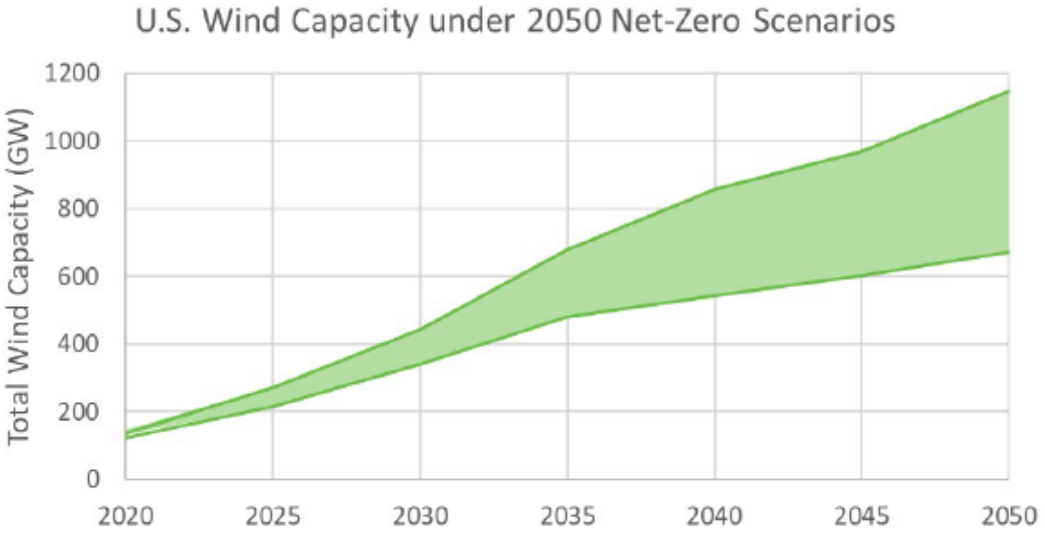


Figure 1: Project wind energy capacity increase in the US (Baranowski et al., 2022)

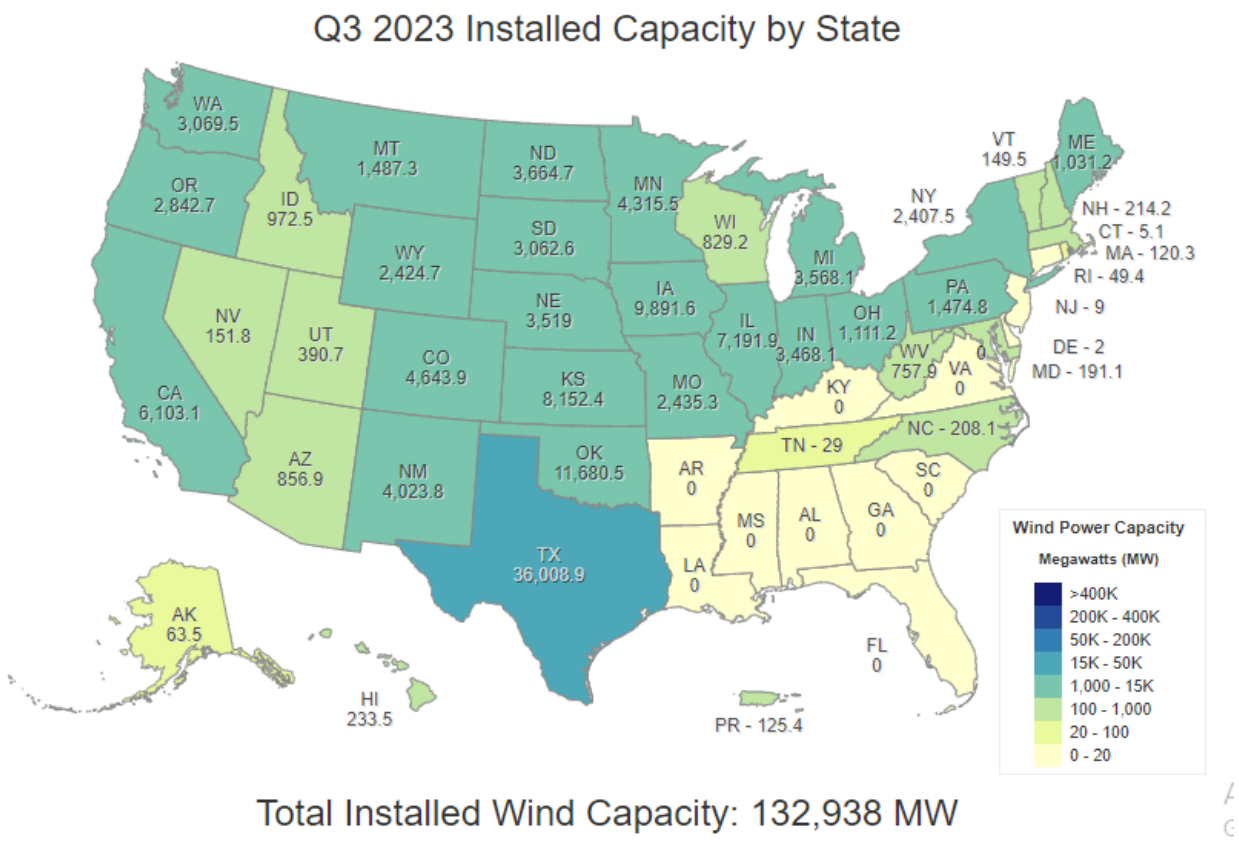


Figure 2: Top Wind Energy producing States in USA

Source: Office of Energy Efficiency and Wind Energy

https://windexchange.energy.gov/maps-data/321

Figure 2 shows the total installed wind capacity by the different states in USA. There are three principal components of a wind turbine, the tower, nacelle, and rotor as shown in Figure 3. The tower, including the supporting foundation, provides the height necessary to access the wind resource and the conduit required to transfer the turbine-generated electricity to the collection system of the wind powerplant where electricity from all wind turbines is often fed to the power grid. The nacelle compartment is connected to the rotor hub by a shaft and contains the generator, gears, and controlling mechanisms that collect and maximize rotational energy into electricity. The rotor, usually consisting of three wing-shaped blades connected to a central hub, converts the kinetic energy of the wind into rotational energy. Most land-based wind turbines have a nameplate capacity rating of 1-3 Megawatts. A 1.5 Megawatt turbine produces enough electricity to power 300 households (Wilburn, 2011).

Permanent magnets are used in the direct drive generator's rotor instead of wound copper-coiled electromagnets, reducing weight and energy required to power up the electromagnets. Sintered ferrite magnets, have lower cost and lower energy product than do rare-earth permanent magnets comprising neodymium, iron, and boron (Nd-Fe-B). Neodymium is a type of rare earth element (REE). The energy-conversion efficiency of sintered Nd-Fe-B is roughly 10 times that of sintered ferrite, but the cost per kilogram of sintered Nd-Fe-B is 30 times that of ferrite (Wilburn, 2011).

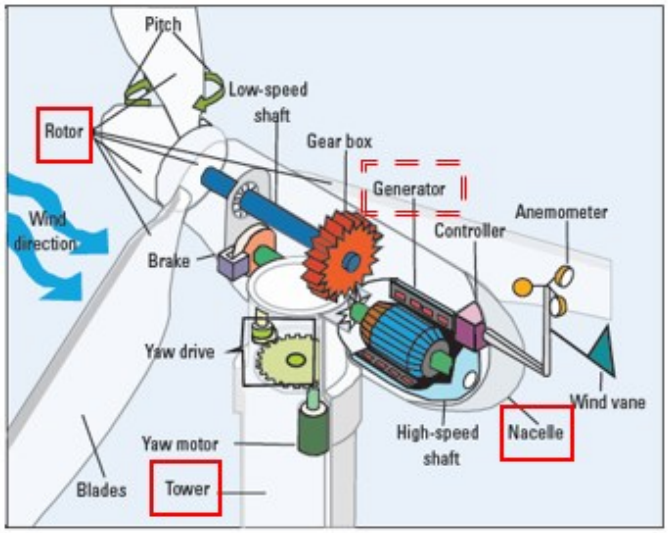


Figure 3: Parts of a Windmill (Wilburn, 2011)

The REE permanent magnet generators are common in offshore wind turbines but represent a minimal share of generators for land-based wind turbines. As turbines increase in size, they are more likely to incorporate rare earth permanent magnet generators. Nd-Fe-B magnets are the strongest magnets commercially available and are used in clean energy and defense technologies, consumer electronics, power tools, sensors, machines, and many other technologies. Within the energy sector, they are necessary components of direct drive and hybrid generators in wind turbines and of traction motors in electric and hybrid-electric vehicles. REE magnet generators are preferred for offshore wind applications for a variety of reasons, including reduced maintenance costs, overall generator efficiency, higher operating temperature, and overall generator weight (which allows for the construction of larger, higher-capacity wind turbines). The size of the permanent magnet is typically 2.7-3.2 tonnes per MW of wind turbine capacity. Sintered NdFeB magnets are composed of roughly 30% REE material, 69% iron, and 1% boron by weight (Baranowski et al., 2022).

REEs required for permanent magnet generators are not mined in the United States in sufficient quantities to meet the demand. Increasing domestic production is challenging because REEs are typically found blended in low concentrations and require extensive processing to concentrate and separate the individual elements. If demand for other rare earth elements does not increase at the same rate, there may be little economic motivation to increase production of the elements needed for wind turbine drivetrains. Global production is concentrated in China. More than 60% of 2019 rare earth production was in China, where the largest single source of REs in the world is the Bayan Obo mine in the Inner Mongolia autonomous region. In 2012, China controlled over 90 percent of global production. While the mine production of RE elements has diversified since 2012, China still accounts for an estimated 89 percent of total RE separation capacity, an estimated 90 percent of total metal refining capacity, and approximately 92 percent of global sintered NdFeB magnet manufacturing (Smith et al., 2022).

In this paper, we have searched the literature for reporting the potential for domestic REE magnet production in the USA. In section 2, we list the findings from government reports and other researchers. In section 3, we map out the current production and processing efforts in the United States. In section 4, we provide the future research directions that can be extracted from this study.

Literature Review:

The clean energy technologies sector is expected to increase demand for REEs considerably, because strong magnets are critical in the construction of direct drive wind turbines and permanent magnet motors for electric vehicles. Wilburn (2011) has done a study for listing the materials that are required by the wind industry in the US till 2030. It is concluded that as the amount of electricity generated from wind power increases, an understanding of the materials associated with the construction, transportation, installation, operation, decommissioning, and disposal of large wind powerplants is required. Faturay et al. (2020) have assessed economic and energy impacts of wind energy expansion in USA through a multi-region input output model. They note that there will be a positive indirect and induced effects in manufacturing and construction sectors due to the deployment of wind power.

Serpell et al. (2021) project that by 2035 global demand for REEs will reach close to 450,000 tons per year, compared to approximately 200,000 tons per year today. Alonso et al. (2023) have mapped mineral commodity first-use to final-use applications for REEs to estimate total requirements at the global and United States' level and report that most (∼70%) of the Nd that was mined globally in 2015 was used in magnets deemed critical for low-carbon energy transition, national defense, and economic stability. Offshore wind turbines represent one of the greatest potential applications of REE magnets as they produce around 48% less greenhouse gas emissions per kWh of produced electricity than onshore wind turbines.

Nakano (2021) has done a literature survey to identify a select set of economies whose approach to the security of critical minerals including REE supply chains is likely to be consequential in terms of geopolitics. The author identifies that there is a need for US research focus on domestic resource survey capacity; separation and processing; substitute development; and recycling technologies. It is inferred that balancing concerns on import dependence with the public acceptance of domestic mineral production is a public policy issue that requires robust research.

Regional ecosystems can be significantly altered by the presence of REE mines, both physically and chemically. Site preparation, access roads, and ancillary facilities lead to direct—and often absolute—destruction of the proximate environment, while pollution from mine processes and storage of residual tailings can lead to widespread chemical imbalances and toxic contamination. REEs are often found alongside radioactive elements such as thorium and uranium and require the separation and safe disposal of dangerous waste material. For every ton of REEs that are produced, there are 2,000 tons of mine tailings, including 1 to 1.4 tons of radioactive waste. This pollution can accumulate in surrounding areas (Filho 2016), causing respiratory issues and contaminating food sources—as plants absorb the airborne pollutants. Around the turn of the millennium, policy makers and manufacturers determined that it no longer made sense to pay for REEs mined in accordance with the relatively strict environmental protection laws in the United States. As a result, most of the REE mining related businesses have concentrated their operations in China.

By 2010 China had captured 95% of global REE production by providing the cheapest material. Following a Chinese embargo on sales of REEs to Japan in 2010, countries around the world were alerted to the economic risks inherent in having a foreign power control the supply and distribution of these critical materials. Environmental risks, regulatory costs, and low-density deposits still prevent most countries from competing directly with China. The supply of critical minerals faces the twin challenges of trade protectionism and resource nationalism from China. Global prices have remained relatively affordable in recent years only because of China's lax environmental regulations and illegal mining operations. The pressure on nations to increase domestic production at the expense of the environment will increase. Failure to avoid an increase in environmental impacts would jeopardize the sustainability of renewable energy technologies.

There is an urgent need to establish a risk assessment and monitoring system for REE supply chains to identify the hidden dangers such as geopolitical risks. Shiquan and Deyi (2022) have analyzed evolving security of critical

minerals including REE supply chains to quantify risks in global value chain. They have concluded that a chainwide macro-level theoretical guidance is lacking in literature. Mancheri et. al (2019) have studied REE supply chains to investigate number of Chinese policies that have disruptive tendencies by investigating how price of REE responds to various resilience influencing mechanisms such as diversity of supply, regulatory frameworks, and stockpiling. They believe there is a need to build on the resilience approach and analyze thoroughly the bottlenecks and disruptions in a supply chain of REE.

Leruth et al., (2022) have studied the control of the supply chains pertaining to the critical minerals such as REE required for the green energy industry. They note that periodic public policy interventions may be needed to reduce the risks to the energy transition posed by hold-ups by geopolitically intended restrictions on trade in critical minerals. These interventions need to take into consideration not only where critical minerals are produced but who controls their production (often nontransparent webs of ownership and influence which can change quickly) to shed light on the risks in value chains and to allow policy makers to craft more effective responses.

Liu et al. (2023) have mapped a global supply of REE in terms of estimated value and list some REE deposits that deserve more attention. The low success rate of REE projects over the past decade (1.5%; 275 projects are tracked in 2011, only 2 entered productions in 2021) make it quite common for most companies to fail to reach the end of the development process. Environmental degradation increases costs of the projects, which may need compensation from higher grades and larger tonnages of the REE minerals. If such issues can be solved, Greenland, Europe, and Africa would have the largest economic potentials.

One method for reducing demand for REEs in wind power and EV markets would be to reuse and recycle existing rare earth magnets. Retired wind turbines and EV motors are a source of recyclable REEs, since their magnets are relatively large and can be recovered without too much difficulty. Unfortunately, the infrastructure and systems needed to achieve REE recycling are severely underdeveloped. It will be decades before the stock of retiring magnets is sufficient to meet a considerable share of new demand.

To assure that the transition to carbon-free energy minimizes environmental costs and promotes global sustainability, policy support for clean energy solutions should be coupled with streamlined environmental regulation and sustainability incentives. Policymakers need to be able to assess the big-picture material flows and understand how REEs' supply or lack thereof can impact the domestic and global economy. There is an urgent need to establish a multi-factor, multi-objective, and multi-dimensional overseas interest protection, and risk warning and prevention system for REE supply chain. A quantitative assessment model based on four categories of criteria: affordability, availability, accessibility, and acceptability, is required to identify the risk points in the supply chain network from the perspective of the complex system and propose targeted solutions from a national strategic level.

Results:

The overall supply chain of Wind Energy is very secure, as 57% of the total monetary value of the wind turbine is made domestically in United States through three primary OEMs: GE, Siemens Gamesa Renewable Energy, and Vestas. Most of the manufacturers are concentrated close to the Great Plains region as shown in Figure 4. However, at present almost all the wind energy produced in the US is from land-based wind turbines. The offshore wind industry in the US is still very nascent and its supply chain is not domestically controlled. The potential for existing domestic suppliers to pivot to the offshore wind industry is not well understood due to differences in size and scale between these turbine types. No land-based wind supply chain is in the Northeast where most near-

term offshore opportunities exist. Offshore wind farms will require vessels that can handle components for turbines with capacities of 15 MW or more. Coastal locations can ease some of the logistical challenges of importing large components needed for these installations. As of 2020, the 12-MW Coastal Virginia Offshore Wind pilot project began generating power as the first offshore wind installation in federal waters (Baranowski et al., 2022).

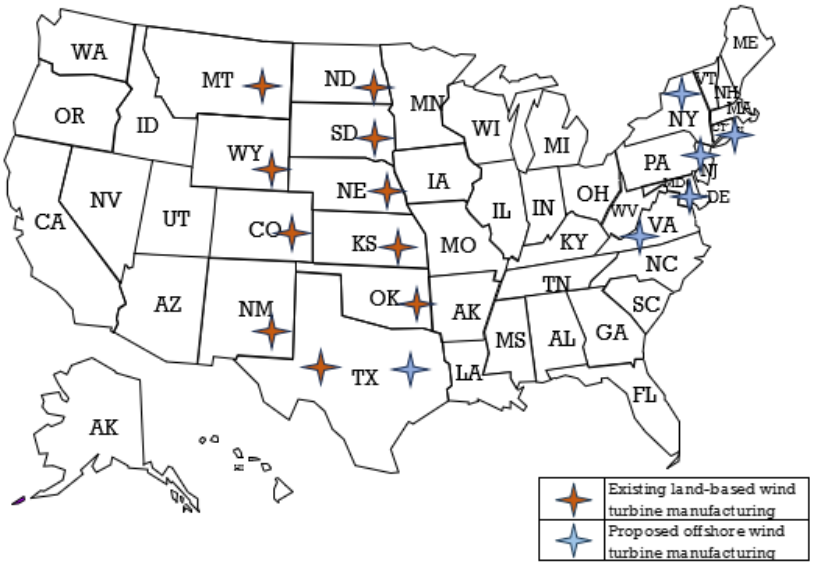


Figure 4: United States Windmill Components Market Supply

The two RE-containing mineral ores currently extracted in the United States are bastnäsite and monazite. Figure 5 shows the potential REE production and processing sites in the USA. The mines in the United States where REE can be produced are Mountain Pass in California, Round Top in Texas, Bokan Mountain in Alaska, Bear Lodge in Wyoming, and La Paz in Arizona. Recent study evaluating the potential of U.S. coal mines as domestic RE sources found that bituminous coal from the Appalachian region has the highest potential for economic RE recovery, with the most promising samples in the eastern Kentucky area. The highest-grade bastnäsite ore deposit in the world is located at Mountain Pass, California, and has been exploited since the 1950s. The mine and mill have been operated by several oil and mining companies and are currently operated by MP Materials who bought the property out of bankruptcy proceedings for former owner Molycorp (MP Materials, 2024). Monazite is found in heavy mineral sands in the southeastern United States particularly in Georgia. Around 16% of the global demand for RE for magnet manufacturing can be met by proven reserves in the USA (Smith et al., 2022).

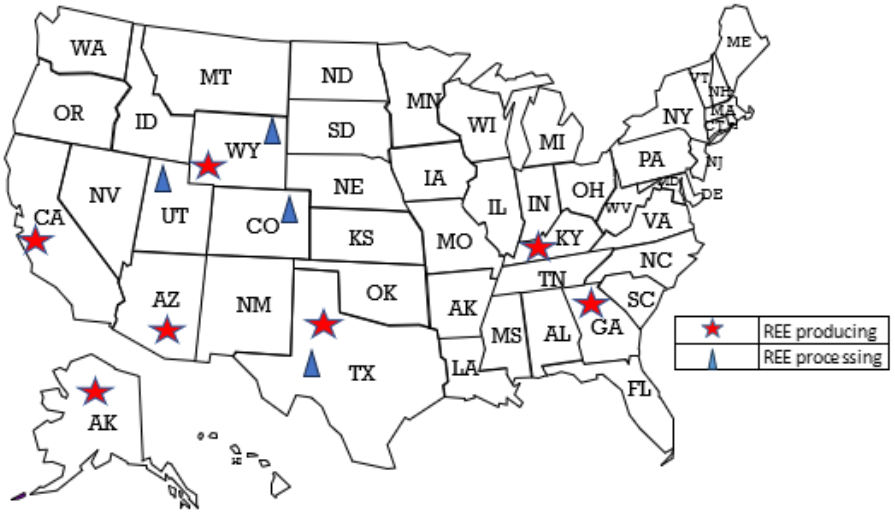


Figure 5: Potential REE production regions in USA

Rare earth metal refining currently occurs largely in China, Vietnam, Thailand with smaller amounts in Estonia and the United Kingdom, with no current metal refining in the United States though there is some potential. Figure 6 shows the regions in the US with potential for REE refining, magnet production and magnet recycling activities. Some idle metal refining capacity exists in old Mitsubishi furnaces in Ohio. MP materials has announced plans to build metal refining capacity in California. Energy Fuels, which is currently processing monazite in its Utah facility, has also studied fully separating and refining rare earth metals (MP Materials, 2024). Through a recent deal between Chemours and Energy Fuels, Chemours now separates monazite from ionic sands in Georgia and sends to its plant in Utah owned by Energy Fuels. Planned shipments from Chemours to Energy Fuels of 2500 tonnes monazite per year would be enough to generate about 0.7% of world Nd/Pr oxide production. Energy Fuels aims to increase production to 15,000 tonnes monazite/year with additional monazite from other locations, which could increase Nd/Pr production to about 4% of current world production (Energy Fuels, 2024). Lynas is planning a separation facility in Texas. This would generate about 2% of current world Dy oxide production and would be the most significant source of separated heavy REs outside of China. With the addition of the light rare earth processing facility, it was estimated that, between its plants in Texas and Malaysia, Lynas would be able to produce about 25% of the world's separated rare earth oxide. USA Rare Earths, which owns the Round Top deposit in Texas, has reportedly made progress in developing a separation facility for heavy REE in Colorado. General Atomics has received DOE funding for a demonstration facility to process and separate light REs from stockpiles of mined material from the Bear Lodge mine in Wyoming. Roughly 90 tonnes of RE oxides, including 20 tonnes of Nd/Pr oxides, would be produced from this demonstration plant over the course of a year, which would be about 0.1% of current world production. If both Bear Lodge mining and General Atomics separation were expanded to the level planned in 2014, production could increase to about 4% of current world Nd/Pr production (Smith et al., 2022).

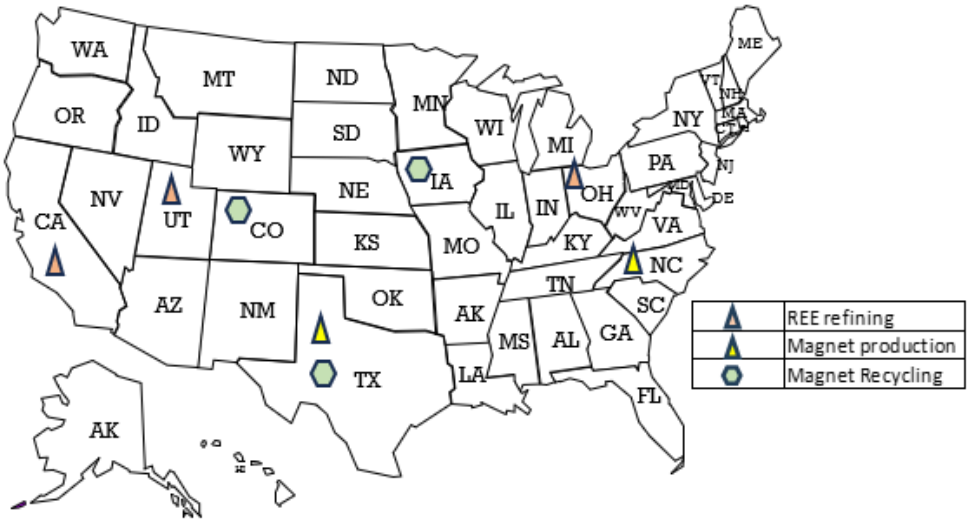


Figure 6: REE refining, magnet production and magnet recycling in USA

Permanent magnets are primarily produced in China (AMO 2020). The major producers of NdFeB magnets, alloys, and powders are China (92%), Japan (7%), Vietnam (1%), Germany (<1%) and a few other countries with relatively limited capacity. MP Materials recently announced plans to construct a magnet production facility in Fort Worth, Texas, to supply NdFeB magnets to General Motors (GM) for use in its vehicles. The facility would produce 1000 tonnes of NdFeB magnets per year, or about 1% of current worldwide production, with initial production starting in 2023 (MP Materials, 2024). Vacuumschmelze also announced plans to produce magnets for GM vehicles in the United States, though the planned size of the plant is not yet clear (Vacuumschmelze, 2021). Quadrant also recently announced plans to begin producing magnets in the U.S., with initial target production capacity of 1,500-2,000 tonnes/year in 2024. USA Rare Earths has also purchased magnet production equipment from a facility in North Carolina originally owned by Hitachi (Smith et al., 2022).

RE magnets are not typically recycled today. The high resale value and demand in turbines encourage recycling, which would contribute to the larger circular economy. RE elements used in consumer products (e.g., hard disk drives) are challenging to separate from end-of-life waste streams because they represent a small mass fraction of the total product; however, the large permanent magnets used in wind turbine generators may be easier to separate at end of life for recycling or reuse. The availability of RE permanent magnets from wind turbines for recycling is limited by their long (20+ year) service lifetime, which means that end-of-life turbines will not be a significant supply of rare earth elements through 2030 (Wilburn, 2011). Although there are currently no commercially successful processes for rare earth element recycling, ongoing research and commercial start-ups are investigating several potential processes. The recycling process occurs in two steps: the magnet recovery step (where magnets are separated from the products they are inside of) and the RE recovery step (where RE elements are separated from the rest of the magnet). Only few companies are actively recycling end-of-life magnets. The lone domestic producer, Urban Mining Company, manufactures about 2000 tons/year of NdFeB magnets from recycled material. DOE's Advanced Manufacturing Office also announced funding to Pioneer Astronautics, a Colorado-based company to recycle Dy from magnets, and to TdVib, L.L.C., an Iowa-based company developing non-toxic rare earth element recycling techniques (Smith et al., 2022).

Conclusion:

The United States has set an aggressive goal for decarbonizing its energy sector by 2050 (Baranowski et al., 2022). If it is to meet this goal, then wind energy will be a major contributor to the total energy portfolio. At present most of the wind energy is produced through land-based wind turbine farms. The major jump in wind energy production will come through offshore wind farms which are presently in pilot stage due to various challenges in setting up the supply chain for offshore wind energy. One of the critical components of offshore wind turbines will be the permanent magnets used in their generators. These magnets are made from RE elements. The availability of a consistent and flexible supply of RE magnets has the potential for becoming a severe bottleneck in the progress of wind energy.

At present China has complete dominance in the RE magnet supply chain. China's share of the different stages of the RE magnet production keeps increasing as we move more downstream in the supply chain. It is unlikely that the United States or any other country will be able to single handedly challenge China's dominance in this market. The domestic production capacity in the United States is limited and production faces significant barriers due to environmental protection laws in the United States and its allies. It is more likely that United States and its allies will form a global alliance to build their supply chains for RE magnets that will be more resilient to supply shocks from China. Future research should focus on the dynamic nature of the evolving global supply chain of RE magnets. Simulation studies, agent-based modelling and business dynamics modelling could be the ideal methods to further explore this problem.

1. References:

- Alonso, E., Pineault, D. G., Gambogi, J., & Nassar, N. T. (2023). Mapping first to final uses for rare earth elements, globally and in the United States. *Journal of Industrial Ecology*, *27*(1), 312-322.
- Baranowski, R., Cooperman, A., Gilman, P., & Lantz, E. (2022). Wind Energy-Supply Chain Deep Dive Assessment. USDOE Office of Policy (PO).
- Castillo, R., & Purdy, C. (2022). China's role in supplying critical minerals for the global energy transition: What could the future hold?
- Energy Fuels. Energy fuels engages leading consultant to support development of rare earth separation at White Mesa Mill in Utah. Press release; accessed February 18, 2024 at https://www.energyfuels.com/2021-04-27-Energy-Fuels-Engages-Leading-Consultant-to-Support-Development-of-Rare-Earth-Separation-at-White-Mesa-Mill-in-Utah.
- Faturay, F., Vunnava, V. S. G., Lenzen, M., & Singh, S. (2020). Using a new USA multi-region input output (MRIO) model for assessing economic and energy impacts of wind energy expansion in USA. Applied Energy, 261, 114141.
- Leal Filho, W. (2016). An analysis of the environmental impacts of the exploitation of rare earth metals. In *Rare Earths Industry* (pp. 269-277).
- Leruth, L., Mazarei, A., Régibeau, P., & Renneboog, L. (2022). Green energy depends on critical minerals. Who controls the supply chains?
- Liu, S. L., Fan, H. R., Liu, X., Meng, J., Butcher, A. R., Yann, L., ... & Li, X. C. (2023). Global rare earth elements projects: New developments and supply chains. *Ore Geology Reviews*, 105428.
- Mancheri, N. A., Sprecher, B., Bailey, G., Ge, J., & Tukker, A. (2019). Effect of Chinese policies on rare earth supply chain resilience. *Resources, Conservation and Recycling*, *142*, 101-112.
- MP Materials. About: Our story. https://mpmaterials.com/about/#history, February 2024.

- Nakano, J. (2021). *The geopolitics of critical minerals supply chains*. Washington, DC, USA: Center for Strategic & International Studies.
- Serpell, O., Paren, B., & Chu, W. Y. (2021). Rare Earth Elements: A Resource Constraint of the Energy Transition. *Kleiman Center for Energy Policy: Philadelphia, PA, USA*.
- Shiquan, D., & Deyi, X. (2022). The security of critical mineral supply chains. *Mineral Economics*, 1-12.
- Smith, B. J., Riddle, M. E., Earlam, M. R., Iloeje, C., & Diamond, D. (2022). *Rare earth permanent magnets-Supply chain deep dive assessment*. USDOE Office of Policy (PO).
- Technology Metals Research. TMR advanced rare-earth projects index. TMR website; accessed October 18, 2023 at https://www.techmetalsresearch.net/metrics-indices/tmr-advanced-rare-earth-projects-index/, 2015.
- Vacuumshmelze. Announcement from General Motors and VACUUMSCHMELZE. VAC News, Press release, December 9, 2021, Accessed January 21, 2022 at https://www.vacuumschmelze.com/Newsroom/announcement-from-general-motors-and-vacuumschmelze-n2195, 2021.
- Wilburn, D. R. (2011). *Wind energy in the United States and materials required for the land-based wind turbine industry from 2010 through 2030*. Washington, DC: US Department of the Interior, US Geological Survey.
- Wiser, R., Bolinger, M., Hoen, B., Millstein, D., Rand, J., Barbose, G., ... & Paulos, B. (2023). *Land-Based Wind Market Report: 2023 Edition*. Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA (United States).

Evolution of Entrepreneurial Conceptualization: Empirical Evidence from the Gravity Model

Ying-Chih Sun

Bradley University, Peoria, USA

ABSTRACT

This study attempts to employ quantitative methodologies to substantiate the temporal progression of the notion pertaining to entrepreneurship. Leveraging the renowned gravity model, which assesses essential elements including Gross Domestic Product, Gross Domestic Product Per Capita, geographic proximity, adjacency to national borders, and linguistic similarities across countries, this research further integrates variables such as infrastructure spending, foreign direct investment, public-private participation, and expenditures in research and development. These additions aim to encapsulate the diverse historical conceptualizations of entrepreneurship. The findings of this study assert that the conceptualization of entrepreneurship does not merely undergo evolution over time but also becomes increasingly complex and plays a pivotal role in shaping the dynamics of contemporary international economics.

KEYWORDS: Entrepreneurship, Gravity model, International Economics

Introduction

The conventional delineation of entrepreneurship predominantly confines itself within the realm of risk-bearing activities aimed at generating profit through the exploitation of extant opportunities (Zimmerer & Scarboroug, 2005). Nonetheless, the economist Joseph Schumpeter posits a broader vista, attributing entrepreneurship a pivotal role in propelling economic development (Kuratko, 2016). Extending the temporal perspective further into the annals of history, Marco Polo's expeditions between Italy and China epitomize early entrepreneurial endeavors, serving as intermediaries in what constitutes an embryonic form of modern trade (Hisrich, 2014). Additionally, Adam Smith's introduction of the *absolute comparative advantage* concept underscores the imperative for nations to focus on the production of goods aligned with their abundant factor endowments, thereby facilitating market exchanges that optimize social welfare. This conceptual framework suggests that our comprehension of entrepreneurship is inherently tied to the genesis and evolution of trade. Consequently, it is eminently logical to associate the essence of entrepreneurship with the advancement of trade, reflecting a deep-seated domain knowledge.

The nexus between trade and entrepreneurship can be conceptualized as a mechanism of resource allocation or redistribution (Guillen, 2000). In the realm of trade, its cardinal role is to surmount the barriers posed by asymmetric information and geographical constraints, thereby facilitating the equalization of factor endowments across disparate markets (Rauch & Casella, 2003; Vatn, 2002). Within the scholarly discourse on entrepreneurship, the focal points include the allocation of environmental resources (York & Venkataraman, 2010) and the phenomenon of market entrants motivated by objectives beyond monetary gains (Dunkelberg et al., 2013). Hence, it can be deduced that trade and entrepreneurship, particularly when considering entrepreneurship's traits as derived from trade, share a foundational linkage within the market ecosystem, potentially underpinning a symbiotic relationship.

The preponderance of scholarly inquiry appears to be disproportionately allocated, with scant attention devoted to the domain of entrepreneurship. Examination at the firm level reveals that incumbent entities perceive trade as a catalyst for innovation, rather than solely the purview of market newcomers (Fabling & Sanderson, 2010). Furthermore, the construct of entrepreneurship is intricately linked with macroeconomic concerns, encompassing economic stability, taxation, and regulatory frameworks (McQuaid, 2002).

Within the discipline of management science, the conceptualization of entrepreneurship is afforded a more stringent scrutiny. Tracing back to the era of Marco Polo's voyages between Italy and China in the thirteenth century, which introduced the archetype of the intermediary trader (Hisrich, 2014), the subsequent historical epoch, notably the Middle Ages, intimates the emergence of figures akin to large-scale production project managers. These individuals leveraged resources from their nations in manners that could be deemed entrepreneurial. By the seventeenth century, entrepreneurship had evolved to encompass contractual agreements sanctioned by state authorities to furnish specified services. The eighteenth century heralded a pivotal shift with the advent of novel technologies, precipitating an augmented demand for financial investment, thus integrating the concept of capital within the entrepreneurial paradigm. Throughout the nineteenth and twentieth centuries, the archetype of the entrepreneur as an innovator gained widespread acceptance and application. This era underscored the role of individuals and/or organizations in

orchestrating resource allocation and assuming risk, with the aim of generating profit as a recompense for their innovative endeavors.

While these endeavors persist in contemporary society, their association with the typical definition of entrepreneurship has evolved. The burgeoning expansion of international commerce has extended their functional scope well beyond their initial scope. Moreover, governmental entities continue to influence the dynamics of bilateral and multilateral trade through a comprehensive suite of policies (Acharya, 2016; Boguslavski et al., 2019; Short, 2017). The advancement of technology, notably in the realms of Information Technology (IT) and Information and Communications Technology (ICT), facilitates the global dissemination of innovation via commodity trade, heralding the potential for intriguing synergies. On one aspect, the impetus for innovation coupled with capitalist financing could bolster trade, whereas, on the alternate aspect, capitalist ventures might propel innovation. In the modern economic perspectives, venture capital emerges as a pivotal force, underwriting and invigorating startups that translate novel concepts and ideas into tangible products and services.

These interactions possess the potential to elucidate a few foundational concerns. Initially, the government frequently acts as a catalyst in the economic sphere, steadfast in its support for entrepreneurship (O'Connor, 2013) with the objectives of fostering economic expansion or sharing risk within the confines of fiscal limitations. Moreover, a symbiotic relationship between the public and private sectors often facilitates the enhancement of social welfare, particularly within the infrastructure domain (Brandao & Saraiva, 2008). Subsequently, the significance of capital has been a cornerstone in shaping the conceptual framework of entrepreneurship since the eighteenth century. The diversity of capital forms have profoundly influenced entrepreneurial operations (Anderton et al., 2004; Thanasegaran & Shanmugam, 2007). Specifically, foreign direct investment (Keller, 2010; Xu & Wang, 2000) underscores the role of substituting physical cash flows and potentially circumventing tariffs (Javorcik & Narciso, 2017), thereby becoming a central element in the discourse on international commerce. Lastly, in recent times, the advancements in technology and innovation have emerged as pivotal issues in entrepreneurship discussions. The global trade of commodities is acknowledged as a principal conduit for the diffusion of technology and the realization of profits (Qiang & Zhibiao, 2009).

The aforementioned concepts aptly facilitate the analogy of trade as emblematic of entrepreneurship (Fabling & Sanderson, 2010). Figure 1 elucidates the progression of these conceptual interconnections. Despite its foundational significance, the intermediary role evolves from its sophisticated progeny, the large-scale project manager, which, in turn, is predicated upon its descendant, the government contractor. This lineage further extends to capitalism, ultimately culminating in innovation. These successive elements not only complete the conceptual framework of entrepreneurship but also suggest that trade, within the context of this analysis, ought to be perceived as a distinct area of specialization.

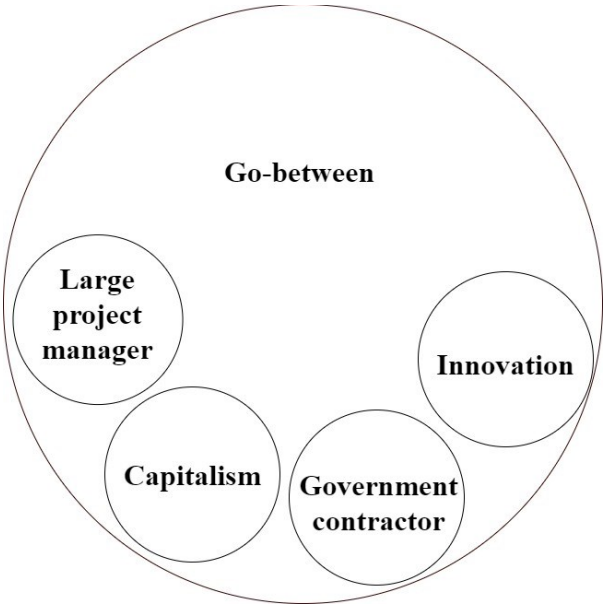


Figure 1. The evolution of entrepreneurship

The discourse surrounding international trade has garnered considerable attention within the realms of political and economic scholarship, with a predominant emphasis on theoretical contributions. Distinguished trade theories have emerged over time, encompassing nation-centric paradigms such as *Mercantilism*, *Absolute Advantage*, *Comparative Advantage* (Ricardo, 1891), and the *Heckscher-Ohlin theorem* (Jones, 1956), alongside firm-centric frameworks like the *Product Life Cycle* (Vernon, 1966) and Porter's *Theory of National Competitive Advantage* (Porter, 1990). In contrast, empirical investigations, particularly those of a quantitative nature, remained sparse until the advent of the gravity model. This model offers a robust mechanism for assessing the causative dynamics of both domestic and international trade flows. Thus, the gravity model is employed in this study to scrutinize the influence of entrepreneurial factors on the expansion of international trade. It is postulated that the maturation of entrepreneurship will align with and capitalize on the emergent opportunities within the global trade landscape.

To fulfill the objectives delineated in this research, the context is organized as follows. The second section will delve into a review of literature pertinent to the focal themes of this inquiry. The methodology employed in this study will be explicated in the third section. Given the quantitative analytical approach adopted herein, the sources of data utilized are elaborated upon in the fourth section. Subsequently, the fifth section will disclose the empirical findings derived from the analysis. Conclusions and implications of the study will be articulated in the final section.

Literature Review

The scholarly trajectory within the domain of entrepreneurship theory has accorded greater emphasis to the individual dimension (Bull & Willard, 1993; Mitchell et al., 2002), with a predominant focus on personal attributes, including familial background and educational attainment. Concurrently, the psychological perspective (Hisrich et al., 2007) has meticulously examined the impact of psychological resilience and psychotherapeutic interventions at a professional level on the sustenance of firm growth.

Within the framework of an ecosystem, entrepreneurial decisions and behavior can serve as a pivotal force to expedite the integration of research and development, manufacturing, and marketing processes (Baumol, 1993). The confluence of social justice and entrepreneurship has garnered increased attention from a lots of activists dedicated to these causes (Ebrashi, 2013). As social entrepreneurial endeavors proliferate, the lack of robust evaluation mechanisms frequently culminates in diminished efficacy within the realm of public governance. An illustrative instance of this phenomenon can be observed in the Milwaukee school voucher program (Andersson & Ford, 2015).

Within the expansive domain of management, entrepreneurship has emerged as a focal area of scholarly inquiry, attracting considerable theoretical and empirical scrutiny. Yet, the interdisciplinary amalgamation and diversification within entrepreneurship have inadvertently diluted the concentration on the discipline itself, potentially curtailing the uniqueness of scholarly contributions (Alvarez & Barney, 2017). This situation underscores the imperative for an integrated and thorough review within the field to enhance the efficacy of knowledge (Rauch, 2019). The concept of ecosystem entrepreneurship posits that methodologies akin to ecological restoration, characterized by their interventionist nature, could be effectively applied (Isenberg, 2016). Moreover, the interplay between entrepreneurship and international trade can be elucidated through a network perspective (Ahmad & Dimitratos, 2017), particularly regarding the global engagements of new ventures, as evidenced in frameworks like organizational learning, the resource-based view, and social capital. Shifts within local markets may, in turn, impinge upon entrepreneurial ventures on a global scale (Cumming & Zahra, 2016). For instance, the decision on Brexit has the potential to redirect new startups towards North American venture capital investment, propelled by the escalated levels of uncertainty.

Introduced in the 1970s (Aitken, 1973), the gravity model initially existed solely as a theoretical construct. By the 1990s, a practical empirical framework was developed (Balestra, 1992; Mátyás, 1997), leading to its widespread adoption as a quantitative tool for empirical investigations utilizing commodity trade data. Notably, the model has been extensively applied to explore the dynamics of regional currency blocks (Bergstrand & Egger, 2013; Rose & Van Wincoop, 2001), spurred by frequent trading activities. Subsequent applications have focused on regional economic integration, particularly within the context of regional trade agreements (Ullah & Inaba, 2012). Despite international trade's significance to entrepreneurship, the scholarly examination of their interrelation has been comparatively scant. More recently, the gravity model has been applied to the study of immigration (Lin & Yang, 2017), revealing that communities of low-skilled

immigrants may exhibit greater entrepreneurial ambition and a more pronounced pro-trade effect within migrant networks than their high-skilled counterparts.

Methodology and Data Sources

The initial formulation of the gravity model is derived from the fundamental principles of Newtonian physics. This theoretical framework posits that the magnitude of the attraction between two entities is principally contingent upon their respective masses and the spatial separation between them. Within this model, the relationship with mass is characterized by a direct correlation, whereas the relationship with the square of the distance between the entities exhibits an inverse correlation. Economists have adapted this model, applying it efficaciously to elucidate the underpinnings of trade dynamics. Owing to its robust theoretical underpinnings and comprehensive explanatory capacity, the gravity model has garnered widespread acclaim for its potent analytical capabilities.

The conceptual foundation of the gravity model is anchored in a microeconomic issue: the maximization of consumer utility, as delineated by (Anderson & Van Wincoop, 2003). Specifically, this involves solving for the constant elasticity substitution (CES) expenditure function, articulated by (De Benedictis & Taglioni, 2011) as:

$$x_{ij} \equiv \left(\frac{p_{ij}}{P_j}\right)^{1-\sigma} M_j, \tag{1}$$

where x_{ij} denotes the expenditure from country i to country j, p_j is the price index of country j, σ represents the elasticity of substitution, M_j is the expenditure country j, and p_{ij} is the consumer price for goods transported from country i to j. Furthermore, the equation:

$$p_{ij} = \mu_{ij} p_i \phi_{ij} \tag{2}$$

introduces μ_{ij} as the price makeup and ϕ_{ij} as transportation costs. Substituting the value of p_{ij} from equation (2) into (1) and aggregating over all x_{ij} yields:

$$X_{ij} = \sum_i x_{ij} = n_{ij}(\mu_{ij} p_i \phi_{ij})^{1-\sigma} \frac{M_j}{P_j^{1-\sigma}}, \tag{3}$$

where X_{ij} represents the total trade flow. Equation (3) means essential elements of the gravity model, encompassing trade flow, the income level of the importing country (M_j), and transportation costs (ϕ_{ij}). The income level of the exporting country is the remaining factor, which, as per existing literature, is posited to mirror the role of a competitively priced supplier, offering a diversity of products and ensuring market saturation (Tinbergen, 1962). Hence, country i's expenditure is described as:

$$M_i = \sum_j n_j x_{ij} = p^{1-\sigma} \sum_j n_{ij} \left[(\mu_{ij}\phi_{ij})^{1-\sigma} \frac{M_j}{P_j^{1-\sigma}}\right]. \tag{4}$$

If, further,

$$\Omega_i = \sum_j \left[n_j (\mu_{ij}\phi_{ij})^{1-\sigma} \frac{M_j}{P_j^{1-\sigma}}\right],$$

then

$$X_{ij} = \phi_{ij}^{1-\sigma} \frac{M_j}{P_j^{1-\sigma}} \frac{M_i}{\Omega_i}. \quad (5)$$

This formulation finalizes the necessary components for the gravity model, facilitating its application within an econometric framework. Despite the foundational efficacy of the gravity model, its scope was initially constrained. Recent scholarly endeavors have sought to infuse additional variables into the model, thereby broadening its applicability and enhancing its

relevance to a wider array of issues. In this vein, our study proposes an expanded empirical gravity model, formulated as follows:

$$\ln(X_{ij} + X_{ji}) = \beta_0 + \beta_1 \ln(GDP_i \cdot GDP_j) + \beta_2 \ln(GNIPC_i \cdot GNIPC_j) + \beta_3 \ln(DIST_{ij}) +$$

$$\beta_4 \ln(INFR_i \cdot INFR_j) + \beta_5 \ln(PPI_i \cdot PPI_j) + \beta_6 \ln(FDI_{ij}) + \beta_7 \ln(RDexp_i \cdot RDexp_j) +$$

$$\beta_8 \ln(ADJcent_{ij}) + \beta_9 \ln(ComLng_{ij}) + u_{ij}. \quad (6)$$

An elucidation of the variables introduced will be provided in the subsequent section, affording a detailed examination. Beyond the confines of the previously mentioned factors, it is imperative to incorporate a holistic perspective that acknowledges additional pertinent influences. Among these, transaction costs emerge as a significant barrier to trade, as identified in the scholarly works (Brouthers & Nakos, 2004; Hennart, 2010). Furthermore, the cultural dimension plays a supplementary role, enriching the discourse on international trade. Prior research has delineated variables such as common language (Egger & Toubal, 2016; Santana-Gallego et al., 2016), geographical contiguity (Magerman et al., 2016), and historical colonial ties. In the refined iteration of the gravity model, an endeavor is made to integrate entrepreneurial factors to scrutinize their impact on international trade.

Within equation (6), *INFR* denotes infrastructure, serving as a surrogate for the concept of large-scale project management. While the term “large project manager” typically refers to an individual operating within the governmental sphere, its implications for public welfare are significant in contemporary contexts, thus being acknowledged as a critical catalyst for economic advancement. *PPI*, representing private sector participation, is utilized to signify the role of a government contractor, embodying an entrepreneurial ethos. *FDI*, or foreign direct investment, is recognized as a pivotal element in contemporary analyses of international trade. FDI transcends the mere alleviation of capital mobility constraints, offering a strategy for tariff circumvention. Additionally, *RDexp*, indicating research and development expenditure, serves as an effective indicator of innovation.

The analytical methodology employed herein utilizes STATA version 17, a statistical software of considerable repute within the realms of economics and econometrics for its robust analytical capabilities. Furthermore, the preparatory stages of data cleaning and integration are predominantly executed using Access, leveraging the SQL syntax functionality.

A multitude of data repositories have been employed in this research, with the requisite variables being aggregated and harmonized from these sources. Initially, trade-related data were procured from the PC-TAS dataset, which ostensibly mirrors the contents found within the UN Comtrade Database. The raw dataset encompasses over 5,062,624 observations, inclusive of disaggregated data on intermediate commodity levels (spanning 2- and 3-digit levels of SITC and 4-digit levels of HS), thereby enabling industrial-level analyses. Furthermore, the dataset covers approximately 235 countries and economic entities. The dataset is confined to a data range spanning from 1995 to 2014.

In the context of this study, the variable representing geographic distance is typically operationalized through the application of the great circle distance formula, a method prevalently employed in aviation and maritime contexts. The data pertaining to distances utilized within this study were derived from extant scholarly contributions (Huang et al., 2006) and were computed using marine statistics, incorporating a weighted average based on the principal ports within each country. Analogously, the determinants of border adjacency and linguistic commonality were ascertained employing a comparable methodological approach.

The World Development Indicators (WDI) database is esteemed for its high-quality, internationally comprehensive statistical compendium, encompassing aspects of global development. This extensive repository features over 1,600 time series indicators, spanning 217 economic entities from the year 1960 through to 2019. A selection of variables from the WDI has been meticulously extracted and incorporated into the present research.

Initially, net foreign direct investment (FDI) encompasses a comprehensive aggregation, including equity capital, reinvested earnings, as well as other long-term and short-term capital flows, as delineated in the balance of payments, with values presented in current U.S. dollars. Secondly, the infrastructure metric amalgamates elements from both the transportation and communication sectors. Within transportation, this category integrates data on air freight and rail goods transport, quantified in millions of tons per kilometer, sourced from the International Civil Aviation Organization (ICAO). The communication sector encapsulates data on mobile cellular and fixed telephone subscriptions, measured per 100 individuals. Thirdly, private sector participation is gauged through a spectrum of variables encompassing investments in energy, information and communication technology (ICT), transport, and water and sanitation projects with private sector involvement, quantified in current U.S. dollars. These investments are appraised based on the project value, including lease agreements or operational management contracts that entail significant capital expenditure. Fourthly, research and development (R&D) expenditure is expressed as a percentage of Gross Domestic Product (GDP), aggregating capital and operational expenditures across business enterprises, government bodies, higher education institutions, and private non-profit organizations. Table 1 demonstrates these variables, which are earmarked for incorporation within the gravity model analysis.

Table 1. The list of variables attributes.

Variable	No. of Obs.	Sources	Type	Unit
Export value	382,153	International Trade Centre - PC-TAS	Continuous	dollar
Geographic distance	16,290	Huang et al., 2006	Continuous	KM
Boarder adjacent	13,288	Huang et al., 2006	Binary	0,1
Common language	13,288	Huang et al., 2006	Binary	0,1
Net foreign direct investment	4,160	World Development Indicator	Continuous	dollar
Infrastructure - transportation	4,160	World Development Indicator	Continuous	dollar
Private participation	4,160	World Development Indicator	Continuous	dollar
R&D expenditure	4,160	World Development Indicator	Continuous	%

Modeling Results

Table 2 presents the principal empirical findings derived from the application of a linearized gravity model. The primary distinction between the two models lies in their respective approaches to handling missing data. The result in Model 1, observations are excluded in entirety if the value in dependent variable is missing. This method, while stringent, results in a significant reduction of the dataset, albeit the total number of observations remains substantial, approaching 4,000. Conversely, in the table presented in the Model 2, missing values are addressed by imputing a nominal value of 0.0000001, which markedly enhances the sample size to exceed 151,000, representing an increase of nearly 3.8-fold compared to the sample size in the Model 1. Additionally, the R-squared value, indicative of the proportion of variance in the dependent variable that is predictable from the independent variables, achieves a notable level of 0.680. This signifies that the augmented gravity model exhibits a robust structure and possesses the requisite validity to serve as an efficacious instrument in this study.

At the heart of the gravity model lie pivotal elements such as Gross Domestic Product (GDP), GDP per capita (GDPpc), and geographic distance. Analytical outcomes elucidate that both GDP and GDPpc exert a significantly positive influence, whereas the impact of geographic distance manifests as significantly negative. This suggests that an augmentation in the GDP and GDPpc of trading nations correlates with an increase in export volume. GDP is frequently interpreted as a reflection of a country's productive capacity, implying that nations with expansive GDPs likely possess substantial natural resources and labor forces, facilitating their engagement in international trade. Similarly, GDPpc is often viewed as an indicator of a nation's purchasing power within the global marketplace, positing a conjecture that it, too, would wield a positive effect on trade dynamics.

Geographic distance, serving as a proxy for trade resistance, invariably incurs transaction costs, thereby exerting a negative influence on bilateral trade flows. An additional geographical factor within the model is the proximity of borders, which, as anticipated, demonstrates a positive and significant correlation with trade volumes. Moreover, the model's incorporation of historical and cultural dimensions, notably the presence of a common language, is found to significantly enhance trade from the literature perspectives, underscoring the multifaceted nature of trade dynamics as captured by the gravity model's estimations.

The analysis of infrastructure within the domains of transportation exhibits the anticipated positive significance. The favorable impact associated with transportation infrastructure suggests that well-developed rail and airport facilities are instrumental in facilitating the shipment of goods to both local and international markets. Hence, it is prudent to infer that transportation infrastructure holds direct relevance to the physical act of trading commodities.

The influence of Foreign Direct Investment (FDI) manifests variably across the presented tables; it is characterized as positively significant. The significance of FDI is likely to be accentuated in contexts of production specialization and outsourcing. When contemplating production within targeted local markets, the mobility of capital inherently enhances trade volume and elucidates the positive trajectory impacting international trade dynamics.

The influence of private sector participation is observed to exert a negative impact on international trade, indicating a potential detriment to global commerce. A more anticipated outcome would have been a neutral coefficient, given that private sector involvement is likely to affect international trade in a more indirect manner. This suggests that while private participation plays a role in the economic landscape, its direct correlation with international trade may not always be conducive to enhancing trade volumes.

The increase of research and development (R&D) expenditure is posited to facilitate an increase in international trade, a phenomenon underpinned by several key mechanisms. Principally, elevated R&D spending catalyzes innovation, leading to the development of new products and the enhancement of existing goods and services. This innovation not only enriches a nation's competitive edge in the global marketplace but also fosters diversification in its export portfolio. As countries innovate, they are more likely to produce unique or superior products that attract international demand, thereby expanding their trade horizons.

Table 2. The Result of Gravity Model

Dependent Variable: *Total Export*	Model 1	Model 2:
$GDP_i * GDP_j$	0.942***	0.844***
	(40.26)	(2,900)
$GDPPC_i * GDPPC_i$	0.0544***	0.0755***
	(2.751)	(110.5)
$DIST_{ij}$	-0.949***	-0.883***
	(-92.90)	(-359.4)
$Adjacent_{ij}$	1.450***	1.343***
	(19.29)	(48.62)
$Common\_lang_{ij}$	0.973***	0.827***
	(13.95)	(209.7)
$inf\_trans_i * inf\_trans_j$	0.0698***	0.100***
	(6.064)	(55.49)
$FDI_i * FDI_j$	0.0202***	0.0285***
	(4.376)	(2.701)
$Pvt\_Partic_i * Pvt\_Partic_j$	-0.0283***	-0.0298***
	(-14.84)	(-2.772)
$RDEXP_i * RDEXP_j$	0.0578**	0.00301***
	(2.251)	(2.915)
Constant	-31.21***	-27.80***
	(-120.3)	(-5,126)
Observations	3,923	151,041
R-squared	0.680	0.678
Fixed Effect	Year	Year

Note:
1. The value in parentheses means t-stat.
2. The asterisk stands for the level of significance: *** p<0.01, ** p<0.05, * p<0.1.
3. The result in Model 1 deletes observation if total export value is missing.
4. The result in Model 2 fills zero if total export value is missing.

Conclusions and Discussions

This study intends to bridge the existing scholarly gap pertaining to the exploration of entrepreneurship from a macroeconomic perspective. Specifically, the research focuses on scrutinizing the intricate dynamics between trade and entrepreneurship, aiming to elucidate the mechanisms through which entrepreneurship catalyzes the evolution of international trade patterns within the contemporary global context. Drawing upon the findings derived from gravity model, the research culminates in the articulation of a nuanced definition of entrepreneurship. This refined conceptualization underscores the pervasive role of entrepreneurship in permeating societal fabric and exerting a significant impact on the architecture of the international trade system.

Drawing from the foundational principles of the conventional gravity model, which is predicated upon the determinants of market size, purchasing power, and implicit transaction costs, this research advances the discourse by demonstrating that the geographical proximity of markets and the historical and cultural nuances relationships also significantly enhance the propensity for international trade activities. Moreover, our analysis substantiates the proposition that advancements in transportation infrastructure markedly contribute to the efficiency of commodity exchanges.

In the contemporary epoch, international capitalism, characterized by its capacity for free mobility, emerges as a salient embodiment of entrepreneurship, undeniably playing a pivotal role in the facilitation of international trade within the global marketplace. Nonetheless, the involvement of private entities within the public sector no longer appears to manifest the quintessential attributes of entrepreneurship. Furthermore, the utilization of innovation as a proxy supports the prevailing discourse, suggesting instead that the ventures associated with risky research and development activities disseminate benefits across the entire economic spectrum.

This research seeks to broaden the theoretical framework initially proposed by Hisrich by incorporating empirical evidence derived through the application of the gravity model methodology. This approach allows for a nuanced exploration of the concept of entrepreneurship, demonstrating that its evolution transcends a mere sequential progression where one development follows another over time. Instead, it reveals a complex landscape where entrepreneurial activities not only succeed each other but also engage in a dynamic, mutually inclusive interaction that exerts a profound influence on the fabric of modern international trade. By adapting gravity model to the context of entrepreneurship, this research uncovers the intricate ways in which entrepreneurial endeavors contribute to and shape the patterns of global commerce. The findings indicate that entrepreneurship acts as a catalyst, facilitating trade flows in a manner that reflects the innovative spirit and adaptability inherent to entrepreneurial ventures.

This interaction between entrepreneurship and international trade is not merely a peripheral occurrence but a core component of the modern economic landscape, embodying the realization of entrepreneurship in a global context. Such a realization suggests that the influence of entrepreneurship extends beyond traditional boundaries, impacting international trade mechanisms through innovation, strategic market entry, and the exploitation of cross-border opportunities. This research not only substantiates the theoretical constructs put forth by Hisrich but also enriches our understanding of the dynamic role of entrepreneurship in the global economy. It underscores the significance of entrepreneurial activities in shaping the pathways through which international trade

evolves, highlighting the importance of fostering an entrepreneurial ecosystem that is conducive to innovation and cross-border economic exchanges.

Reference

Acharya, R. (2016). *Regional trade agreements and the multilateral trading system*. Cambridge University Press.

Ahmad, S., & Dimitratos, P. (2017). International Entrepreneurship and Networks. *The Wiley Handbook of Entrepreneurship*, 451-483.

Aitken, N. D. (1973). The effect of the EEC and EFTA on European trade: A temporal cross-section analysis.

The American Economic Review, *63*(5), 881-892.

Alvarez, S. A., & Barney, J. B. (2017). Resource-based theory and the entrepreneurial firm. *Strategic entrepreneurship: Creating a new mindset*, 87-105.

Anderson, J. E., & Van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *American Economic Review*, *93*(1), 170-192.

Andersson, F. O., & Ford, M. (2015). Reframing social entrepreneurship impact: Productive, unproductive and destructive outputs and outcomes of the Milwaukee school voucher programme. *Journal of Social Entrepreneurship*, *6*(3), 299-319.

Anderton, R., Di Mauro, F., & Moneta, F. (2004). Understanding the impact of the external dimension on the euro area: trade, capital flows and other international macroeconomic linkages. *ECB Occasional Paper*(12).

Balestra, P. (1992). Fixed effect models and fixed coefficient models. In *The Econometrics of Panel Data*

(pp. 30-45). Springer.

Baumol, W. J. (1993). Formal entrepreneurship theory in economics: Existence and bounds. *Journal of Business Venturing*, *8*(3), 197-210.

Bergstrand, J. H., & Egger, P. (2013). Gravity equations and economic frictions in the world economy. In

Palgrave handbook of international trade (pp. 532-570). Springer.

Boguslavski, M. M., Smirnov, P. S., Levitsky, S. L., Boguslavski, M., Levitsky, S. L., & McCauley, D. (2019). *The Reorganization of Soviet Foreign Trade: Legal Aspects: Legal Aspects*. Routledge.

Brandao, L. E. T., & Saraiva, E. (2008). The option value of government guarantees in infrastructure projects. *Construction management and economics*, *26*(11), 1171-1180.

Brouthers, K. D., & Nakos, G. (2004). SME entry mode choice and performance: A transaction cost perspective. *Entrepreneurship theory and practice*, *28*(3), 229-247.

Bull, I., & Willard, G. E. (1993). Towards a theory of entrepreneurship. *Journal of Business Venturing*, *8*(3), 183-195.

Cumming, D. J., & Zahra, S. A. (2016). International business and entrepreneurship implications of Brexit.

British Journal of Management, *27*(4), 687-692.

De Benedictis, L., & Taglioni, D. (2011). The gravity model in international trade. In *The trade impact of European Union preferential policies* (pp. 55-89). Springer.

Dunkelberg, W., Moore, C., Scott, J., & Stull, W. (2013). Do entrepreneurial goals matter? Resource allocation in new owner-managed firms. Journal of Business Venturing, 28(2), 225-240.

Ebrashi, R. E. (2013). Social entrepreneurship theory and sustainable social impact. Social Responsibility Journal, 9(2), 188-209.

Egger, P. H., & Toubal, F. (2016). Common spoken languages and international trade. In The Palgrave handbook of economics and language (pp. 263-289). Springer.

Fabling, R., & Sanderson, L. (2010). Entrepreneurship and aggregate merchandise trade growth in New Zealand. Journal of International Entrepreneurship, 8(2), 182-199.

Guillen, M. F. (2000). Business groups in emerging economies: A resource-based view. academy of Management Journal, 43(3), 362-380.

Hennart, J.-F. (2010). Transaction cost theory and international business. Journal of Retailing, 86(3), 257-269.

Hisrich, R., Langan-Fox, J., & Grant, S. (2007). Entrepreneurship research and practice: a call to action for psychology. American psychologist, 62(6), 575.

Hisrich, R. D. (2014). Advanced introduction to entrepreneurship. Edward Elgar Publishing.

Huang, D.-S., Huang, Y.-Y., & Sun, Y.-C. (2006). Production specialization and trade blocs. Journal of Economic Integration, 474-495.

Isenberg, D. J. (2016). Applying the ecosystem metaphor to entrepreneurship: uses and abuses. The Antitrust Bulletin, 61(4), 564-573.

Javorcik, B. S., & Narciso, G. (2017). WTO accession and tariff evasion. Journal of Development Economics, 125, 59-71.

Jones, R. W. (1956). Factor proportions and the Heckscher-Ohlin theorem. The Review of Economic Studies, 24(1), 1-10.

Keller, W. (2010). International trade, foreign direct investment, and technology spillovers. In Handbook of the Economics of Innovation (Vol. 2, pp. 793-829). Elsevier.

Kuratko, D. F. (2016). Entrepreneurship: Theory, process, and practice. Cengage Learning.

Lin, X., & Yang, X. (2017). From human capital externality to entrepreneurial aspiration: Revisiting the migration-trade linkage. Journal of World Business, 52(3), 360-371.

Magerman, G., Studnicka, Z., & Van Hove, J. (2016). Distance and border effects in international trade: A comparison of estimation methods. Economics: The Open-Access, Open-Assessment E-Journal, 10(2016-18), 1-31.

Mátyás, L. (1997). Proper econometric specification of the gravity model. World Economy, 20(3), 363-368. McQuaid, R. W. (2002). Entrepreneurship and ICT industries: support from regional and local policies.

Regional Studies, 36(8), 909-919.

Mitchell, R. K., Busenitz, L., Lant, T., McDougall, P. P., Morse, E. A., & Smith, J. B. (2002). Toward a theory of entrepreneurial cognition: Rethinking the people side of entrepreneurship research. Entrepreneurship theory and practice, 27(2), 93-104.

O'Connor, A. (2013). A conceptual framework for entrepreneurship education policy: Meeting government and economic purposes. Journal of Business Venturing, 28(4), 546-563.

Porter, M. E. (1990). The competitive advantage of nations. Harvard business review, 68(2), 73-93. Qiang, W., & Zhibiao, L. (2009). Analysis on the Realization Mechanism of Export Miracle in Chinese

Coastal Regions [J]. Economic Research Journal, 6.

[Record #21 is using a reference type undefined in this output style.]

Rauch, J. E., & Casella, A. (2003). Overcoming informational barriers to international resource allocation: prices and ties. The Economic Journal, 113(484), 21-42.

Ricardo, D. (1891). Principles of political economy and taxation. G. Bell and sons.

Rose, A. K., & Van Wincoop, E. (2001). National money as a barrier to international trade: The real case for currency union. American Economic Review, 91(2), 386-390.

Santana-Gallego, M., Ledesma-Rodríguez, F. J., & Pérez-Rodríguez, J. V. (2016). International trade and tourism flows: An extension of the gravity model. Economic Modelling, 52, 1026-1033.

Short, J. (2017). American Business and Foreign Policy: Cases in Coffee and Cocoa Trade Regulation 1961-1974. Routledge.

Thanasegaran, H., & Shanmugam, B. (2007). International trade-based money laundering: the Malaysian perspective. Journal of Money Laundering Control.

Tinbergen, J. (1962). Shaping the world economy; suggestions for an international economic policy. Ullah, M. S., & Inaba, K. (2012). Impact of RTA and PTA on Bangladesh's Export: Application of a Gravity

Model. Journal of Industry, Competition and Trade, 12(4), 445-460.

Vatn, A. (2002). Multifunctional agriculture: some consequences for international trade regimes. European review of agricultural economics, 29(3), 309-327.

Vernon, R. (1966). International Investment and International Trade in the Product Cycle. The Quarterly Journal of Economics, 80(2), 18.

Xu, B., & Wang, J. (2000). Trade, FDI, and international technology diffusion. Journal of Economic Integration, 585-601.

York, J. G., & Venkataraman, S. (2010). The entrepreneur–environment nexus: Uncertainty, innovation, and allocation. Journal of Business Venturing, 25(5), 449-463.

Zimmerer, T. W., & Scarboroug, N. M. (2005). Essentials of entrepreneurship and small business management. Prentice-Hall.

Exploring the Relationship between Bitcoin and Altcoins in late 2018

Chulhwan Chris Bang1, Ph.D., Geogia Southern University

Fauziya Ado Yakasai, Ph.D., Auburn University

Tagbo Aroh, Ph.D. Auburn University

Yoon Sang Lee, Ph.D., Columbus State University

Donghyup Woo, Ph.D., University of Pittsburgh at Greensburg

Abstract

As a result of the increase in cash liquidity, capital has recently flooded the investment market. In addition to this phenomenon, capital tends to cause a sharp increase in the price of Cryptocurrencies. There may be investors who have realized profits as a result of Cryptocurrency's price increase, but there are also many investors who have suffered losses due to Crypto's repetitive volatility. Consequently, mitigating losses is equally as crucial as maximizing profits. Besides, so-called Altcoins' market volume is smaller than Bitcoin's, Altcoins are more speculative than Bitcoin. Moreover, since Altcoin information is very limited, investors are more sensitive to price fluctuation. Insufficient research has been conducted on Altcoins, making it difficult to predict price drops or recommend a prudent investment strategy during bear markets. Therefore, we present the most realistic prediction model by comparing several machine learning algorithms to predict what accelerates the decline of some Altcoins, namely, Zcash, Litecoin, Ripple, and Dash. In this study, we predict the price fluctuations of Altcoins by analyzing sentiments extracted from the Reddit comments of potential investors. Eventually, we suggest to minimize loss during bear market. Initially, we clarify the relationship between the price fluctuations of each Altcoin and Bitcoin as well as each Altcoin and Ethereum. Then, the model is trained with Neural Net, C&R Tree, Random Trees, and Extreme Gradient Boosting Regression Tree models (XGBoost). Using relative error, XGBoost outperforms the competition. We recommend XGBoost as a prediction model because its Root Mean Square Error is the least (RSME).

Keywords:Cryptocurrency, Altcoins, Bear Market, Reddit Sentiments, XGBoost

Introduction

[1] Corresponding author, Email: chulhwanbang@georgiasouthern.edu

There have been several "Cryptocurrency" fads, but they were all started by Bitcoin (Bartolomeu & Ferreira, 2018). The price has been held at a lower level for now, but the market for Cryptocurrencies continue to excite investors with its pattern of repeated sharp rises and falls (Burniske & Tatar, 2018). When the price of a market continues to fall for an extended period of time, this type of market is known as a bear market. The term "Crypto winter" generally refers to a scenario in which the value of Cryptocurrencies has dropped by at least 20% from their recent highs as a result of widespread pessimism and poor investor sentiment (Chohan, 2022; OECD, 2022).

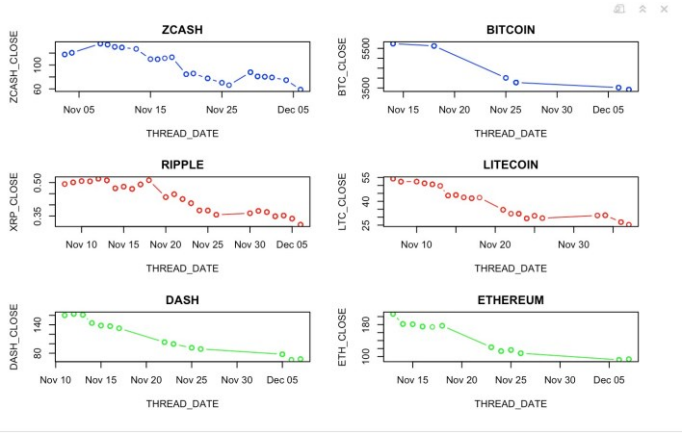


Figure 2 Price Trend of the Cryptocurrencies in a Bear Market in 2018

The market for Cryptocurrencies is extremely volatile, and so are the patterns it exhibits (Jalal, Alon, & Paltrinieri, 2021; Katsiampa, Gkillas, & Longin, 2018; McCoy & Rahimi, 2020; Vejačka, 2014). We are interested in it because they want to be able to capture its volatility and predict its behavior in the future. Investors and market analysts conduct research on the behavior of markets and develop purchase and sale strategies based on the findings of this research. Particularly during a collapse or decline, Altcoin fluctuations are much larger, making it extremely challenging to minimize losses. However, the best alternative is to make a profit even during a market downturn. Since this is difficult to achieve in practice, we began our research to suggest a method to minimize losses, which is the next best alternative.

The vast majority of investors will base their decisions on the most recent news pertaining to a specific coin. The sentiments of potential investors on Reddit and other Cryptocurrency instruments were utilized in this study in order to make a price prediction for four of the most prominent alternative Cryptocurrencies. The Cryptocurrencies, Zcash, Litecoin (LTC), Ripple (XRP), and Dash are some of the most widely used ones today. We are interested in finding out whether or not the positive or negative sentiment on Reddit regarding a specific Altcoin influences the price of that Altcoin. In other words, we study if sentiment of others at social media affects other investors' decision.

Young generation make up the majority of participants in the Cryptocurrency trading market, and most characteristic of their investment style is known as "speculator" or "aggressive trader(Iacurci, 2023; Jalal et al., 2021; McCoy & Rahimi, 2020)". They look for high returns in a short period of time, even if it means taking risks and exposing themselves to volatility, in contrast to long-term investors who look for undervalued companies or analyze long-term market trends. Recently, in the stock market, companies that specialize in machine learning have been actively introduced in an effort to maximize profits from short-term trading. When it comes to short-term trading, machine learning primarily employs natural language processing (NLP) to analyze news and social networks (Hirschberg & Manning, 2015). Alternatively, it may examine the timing and price of selling and buying by substituting a representative index for the industry along with NLP.

In this regard, our research seeks learning as a strategy for reducing our financial losses in the event that the market continues to decline. The most common cause of a bear market is a weak, declining, or sluggish economy. However, a bear market can be caused by a number of different events. It has only been relatively recently that machine learning has started to be implemented at the beginning of stock trading; however, it is not well studied whether or not machine learning is useful in the Cryptocurrency market. As a result, our research explores various machine learning methodologies in order to investigate the possibility of machine learning in bear market to minimize loss. Among them, we will discuss which machine learning technology has the most impact.

Literature Review

Blockchain technology is a distributed public ledger. It is a piece of technology that was developed with the objective of providing (or disclosing) individual and individual transactions to all Bitcoin users while also preventing security breaches and hacking. Cryptocurrencies are digital or alternative currencies that differ from traditional currencies in that they are based on the principle of decentralized control as opposed to relying on central banking systems (Dai, 1998; Nakamoto, 2008; Szabo, 2008). The most well-known of these is called Bitcoin (BTC), and it was first introduced in 2009 as the first decentralized digital currency.

Bitcoin is a decentralized digital currency that was developed by Satoshi Nakamoto on the basis of open-source software. It enables users to record peer-to-peer transactions that take place across the internet into a public ledger that is not centralized. Bitcoin's market cap is twice as large than Ethereum's, the market cap of the second largest Cryptocurrency. As of May 4, 2023, the dollar value of Bitcoin's market cap was around $559 billion, while the second largest Cryptocurrency

Ethereum was $227 billion, out of the total market capitalization of $1.19 trillion (Divine, 2023). Bitcoin's market cap is the largest of all Cryptocurrencies.

The Cryptocurrency known as Ethereum (ETH) is a digital asset that was introduced in the year 2015. It is currently the Cryptocurrency with the second largest market capitalization. Ethereum, in contrast to Bitcoin, is built on top of an existing technology referred to as blockchain. Ethereum is not only a platform but also a programming language that allows applications to be built and run on it. Bitcoin was initially developed as a currency that could be used similarly to traditional money. Transactions, the generation of new Cryptocurrencies, and the safe transfer of Cryptocurrency assets are all encrypted with the help of Cryptography, which is also used to monitor the creation of new Cryptocurrencies (Grubbs, Maram, & Paterson, 2022). The most well-known Cryptocurrency, Bitcoin and all other Cryptocurrencies, referred to as the "Altcoin", fall under alternative coins.

Reddit is a website that compiles news stories, allows users to rate and discuss various pieces of web content, and provides users with the ability to watch live stream content (Silberman & Record, 2021). Users of Reddit can start threads, and other users on the website can comment on those threads. We developed programs to collect data from the internet in a manner that was only partially automated. We gathered information pertaining to Cryptocurrencies from social networks and researched the prices of Cryptocurrencies from the past. The manner in which people use language in their day-to-day lives sheds light on their personalities, as well as their beliefs, fears, thought processes, and the social relationships they maintain (Plutchik, 1984). The word cloud shown in Figure 2 illustrates the extent to which each term appears in our datasets. When a keyword is more prominent in the graphic that is generated, this indicates that it appears more frequently in the text that is being analyzed. It should come as no surprise that Bitcoin dominates the market in terms of trading volume, market volume, and price compared to other Cryptocurrencies. Zcash has a number of threads on Reddit comparable to Bitcoin. (Securities, 2014).

Figure 3 Word Cloud of The Cryptocurrencies

Figure 4 Word Cloud of The Cryptocurrencies

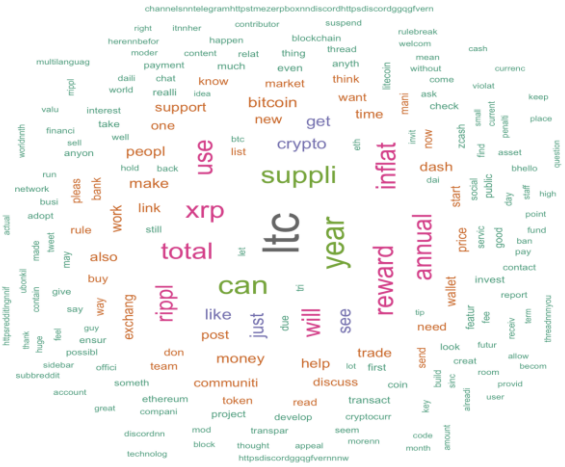


Figure 5 (continued) Word Cloud of The Cryptocurrencies

Text Processing

Text processing involves various methods to analyze and sort unstructured text data. These methods often leverage natural language processing (NLP) and machine learning, subfields of artificial intelligence, to automatically understand human language and extract value from it. Here are some of the key text processing methods:

1) Word Frequency: This statistical method identifies the most frequently used words or expressions in a specific piece of text(Rayson, 2003). Word frequency can be calculated using various algorithms, which returns a map with a key for each different string and the value being the number of times that string appears in the array(Pennebaker, Francis, & Booth, 2001).

2) Concordance: This technique provides every occurrence of a given word or phrase in a text along with some context(Rayson, 2003).

3) TF-IDF (Term Frequency-Inverse Document Frequency): This is a numerical statistic that reflects how important a word is to a document in a collection or corpus(Rayson, 2003).

4) Topic Analysis: This method identifies the main themes present in a text(Rayson, 2003).

5) Sentiment Analysis: This technique determines the emotional tone behind words to gain an understanding of the attitudes, opinions, and emotions expressed within an online mention(Rayson, 2003).

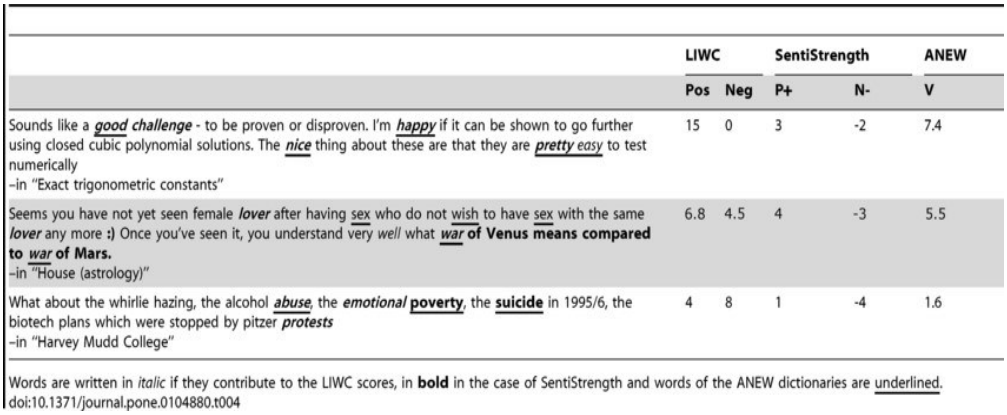
6) Intent Detection: This method predicts the user's intention behind a piece of text(Rayson, 2003).

7) Language Classification: This technique classifies text into one or more languages(Rayson, 2003).

In the context of word counting, there are several techniques and tools available. For instance, word counting can be done manually using online editors that count the number of characters and words as you type, delete, and edit them(Pennebaker et al., 2001). There are also word counting algorithms that can be implemented in various programming languages(Paice, 1996). These algorithms typically count the number of spaces or other separators to determine the word count. Some tools also provide additional features like readability, keyword density, and character count(Cohn, Mehl, & Pennebaker, 2004).

It's important to note that different word counting programs may give varying results, depending on the text segmentation rule details(Paice, 1996). For example, when converting character counts to words, a measure of 5 or 6 characters to a word is generally used for English(Paice, 1996).

We use a text analysis application called Linguistic Inquiry and Word Count (LIWC) to provide a quick and efficient method for analyzing the numerous emotional, cognitive, and structural components present in the spoken and written speech samples of Reddit commenters. LIWC extracts emotions from a text by calculating the proportion of words that belong to each sentiment category. Six italicized words are identified as positive in the first statement in figure 3, for example, whereas no negative words were detected; the total number of words is 39; hence the positive sentiment is scored as $\frac{6}{39} * 100 \approx 15$ while negative sentiment is scored $\frac{0}{39} * 100 = 0$.



	LIWC		SentiStrength		ANEW
	Pos	Neg	P+	N-	V
Sounds like a ***good challenge*** - to be proven or disproven. I'm ***happy*** if it can be shown to go further using closed cubic polynomial solutions. The ***nice*** thing about these are that they are ***pretty*** *easy* to test numerically –in "Exact trigonometric constants"	15	0	3	-2	7.4
Seems you have not yet seen female ***lover*** after having sex who do not wish to have sex with the same ***lover*** any more **:)** Once you've seen it, you understand very *well* what ***war*** **of Venus means compared to** ***war*** **of Mars.** –in "House (astrology)"	6.8	4.5	4	-3	5.5
What about the whirlie hazing, the alcohol ***abuse***, the ***emotional*** **poverty**, the **suicide** in 1995/6, the biotech plans which were stopped by pitzer ***protests*** –in "Harvey Mudd College"	4	8	1	-4	1.6

Words are written in *italic* if they contribute to the LIWC scores, in **bold** in the case of SentiStrength and words of the ANEW dictionaries are underlined.
doi:10.1371/journal.pone.0104880.t004

Figure 6 Examples of Linguistic Inquiry and Word Count (LIWC)

Table 2 Example of Reddit Comments with positive and negative sentiment scores in our datasets

Examples of Reddit comments in our dataset		
Comments	positive	Negative
Rumour, listing Zcash on Coinbase end of next week	0	0
Zcash after founders reward	3.62	0.72
Why there is huge hate against ZCash?	2.56	2.56

Machine Learning

Machine learning, a subset of artificial intelligence, is a field that uses algorithms to parse data, learn from it, and then make predictions or decisions. It's being applied across a wide range of industries and has numerous applications.

Random Forest

The Random Forest technique is extensively utilized in the field of machine learning to combine the predictions of multiple decision trees, resulting in a consolidated outcome. The algorithm was developed by Breiman (2001). The algorithm's versatility and practicality, enabling it to address both classification and regression problems, have engendered its extensive use. The Random Forest algorithm is an ensemble method that involves the training of several decision trees.

Random forests can be utilized as algorithms for regression, classification, and detection tasks, among other applications(Belgiu & Drăguţ, 2016; Biau & Scornet, 2016).

Support Vector Machine

Support Vector Machine (SVM), another acronym for representative algorithm, is a prominent algorithm utilized in artificial intelligence and data mining. SVM is a classification algorithm that demonstrates a commendable rate of classification. In a broad sense, classification algorithms include artificial neural networks and decision trees. SVM performs more effectively than the alternatives when it comes to data classification, particularly binary data. In general, linear and nonlinear algorithms are the two categories(Hearst, Dumais, Osuna, Platt, & Scholkopf, 1998; Steinwart & Christmann, 2008).

Decision Tree

The decision tree algorithm is a commonly used method in the field of machine learning for supervised learning tasks. The analysis approach under consideration is a technique that facilitates classification and prediction through the construction of decision rules in a hierarchical tree-like structure. In a simplified manner, the twenty peaks might be conceptualized as a visual representation. Hence, decision trees are frequently employed in scenarios requiring elucidation due to their inherent simplicity and comprehensibility. In the medical domain, when a patient presents with a specific ailment, it is explicated that the presence of said ailment is postulated based on the fulfillment of specific criteria. The utilization of this approach is applicable in situations where a financial institution provides a customer with an explanation regarding the restricted nature of a line, specifically due to limitations imposed on it(Myles, Feudale, Liu, Woody, & Brown, 2004; Song & Ying, 2015).

Extreme Gradient Boosting (XGBoost)

The Extreme Gradient Boosting (XGBoost) model and other tree-based models are a popular machine learning technique that has proven effective for a variety of applications. XGBoost constructs an ensemble of shallow and weak successive trees, each learning from and improving upon the previous, whereas random forests produce an ensemble of deep independent trees. When these numerous successively weak trees joins, they form a formidable "committee" that is typically difficult to overcome by other means (Chen et al., 2015; Srivastava, 2016).

The XGBoost model is particularly well-suited for use with our data for the following reasons:

- Frequent exceptional predictive precision.

- Extensive adaptability - the function fit can be optimized for a variety of loss functions and has multiple hyperparameter tuning options, making it quite versatile.
- Needlessness to preprocess data; categorical and numeric values can be utilized as-is.
- Needlessness to impute missing data.

The objective is to minimize:

$$L(\varphi) = \sum_i l(\hat{y}_i, y_i) + \sum_k \Omega(f_k) \quad (1)$$

$$\Omega(f) = \gamma \mathcal{T} + \frac{1}{2}\lambda ||w||$$

Where $l(\hat{y}_i, y_i)$ is the loss function, Ω (fk) is a regularization that penalizes each tree for having an excessive number of leaves and ensures smooth final learned weights. w represents the coefficient at each node, while T represents the number of leaves in the tree.

To minimize the above equation, the greedy Algorithm 1 is used to generate the regression tree forest F as initially implemented (Chen & Guestrin, 2016).

Algorithm 1: Greedy Algorithm for split finding used in our price prediction model.

input : I, instance set of current node **input** : d, feature dimension

$gain \rightarrow 0$
$G \leftarrow \sum_{i \in I} H \leftarrow \sum_{i \in I} hi$
for k = 1 to m **do**
$G_L \leftarrow 0, H_I \leftarrow 0$
for j in sorted (I, by x_{jk}) **do**
$G_L \leftarrow G_L + g_j, H_L \leftarrow H_l + h_j$
$G_R \leftarrow G - G_L, H_R \leftarrow H - H_l$
$Score \leftarrow max(score, \frac{G_L^2}{H_L + \lambda} + \frac{G_R^2}{H_R + \lambda} - \frac{G^2}{H + \lambda})$
end
end output : Split with max score

Model Comparison

As mentioned in the sections above, each algorithm has different strengths and weaknesses and the model performance is dependent on characteristics of the dataset. For this study, we selected five algorithms, considering their strengths and weaknesses. The five algorithms selected for our study are Linear Regression, Decision Tree, Random Forest, SVM, and XGBoost.

As the baseline model, we selected Linear Regression. Linear Regression is a popular choice in various studies when predicting numerical values because it is not only simple to apply but also

provides an easy interpretation of the result. However, it is less effective for non-linear data prediction.

Among the tree-based algorithms, we selected Decision Tree, Random Forest, and XGBoost. Decision Tree is another popular classification and regression algorithm adopted in many studies, and it is used as a foundation for decision tree ensemble algorithms such as Random Forest and XGBoost. Decision Tree can model the non-linear relationship, but it is susceptible to overfitting. For the model interpretation, Decision Tree provides good interpretability when the tree is small, but the interpretation becomes more complex as the tree grows. Random Forest is the ensemble of decision trees. By combining the decision trees, Random Forest improves the prediction accuracy and reduces the overfitting. As it uses an ensemble of decision trees, Random Forest can model the non-linear relationships, but it provides less interpretability. However, a measure of feature importance is available, so it can be used for the analysis of the result. XGBoost is another type of ensemble algorithm using decision trees and gradient boosting. Recently, it has gained popularity in academic and practical applications due to its performance and flexibility. It creates a series of weak learners to improve the prediction performance. Similar to random forest algorithms, it is less interpretable as it uses multiple trees but provides a measure of feature importance. XGBoost might be overfit for small datasets, but it includes the regularization term for overfitting.

SVM provides good performance for both classification and regression problems in high-dimensional spaces by using the hyperplane and kernel trick. SVM provides good performance for non-linear modeling, but the interpretability of the model becomes more complex due to the use of the kernel function.

As seen above, linear regression provides a simple and relatively easy modeling method and good interpretability but cannot model non-linear relationships. However, the other four algorithms can model non-linear relationships and the interpretation can be complex. In the case of SVM, it has a strength for high-dimensional spaces. As we are not clear about the type of regression algorithm that provides the best fit for our dataset, we applied the five regression algorithms in the experiment and observed the performances of the algorithms in the experiment.

Experiment

Data Source

Until the beginning of 2017, the preponderance of Cryptocurrencies, including Bitcoin, continued to rise until November 2017, when they suddenly began to fall. After maintaining a flat trajectory from the beginning of 2018 until November 2018, it began to decline again. From November 3,

2018 to December 7, 2018, we gathered data for about a month. Opening and closing prices of Cryptocurrencies were collected from Coinbase during this time period. It is believed that the decline after the box range is further from a mass hysteria than the collapse after the rise[2]. In the same vein, Baker and Wurgler (2007) found that the investor sentiment affects stock price when stocks are difficult to arbitrage or to value. In this study, a program was created to collect and combine threads and remarks posted on Reddit subreddits pertaining to Cryptocurrencies. Figure 1 depicts the price change of Cryptocurrencies during the specified time period. In addition, Table 2 details the Volume and Market Capitalization of Cryptocurrencies during the specified time frame. According to Table 2, Bitcoin's volume and market capitalization outperform those of other Cryptocurrencies.

Table 3 Cryptocurrency Description

	Range	Minimum	Maximum	Mean
BTC Volume	4,769,650K	3658,640K	8,428,290K	55,831,235K
BTC Market Cap	53,847,988K	59,547,646K	113,395,633K	83,901,561K
ETH Volume	1,827,260K	1,307,150K	3,134,410K	2,071,843K
ETH Market Cap	12,873,081K	9,510,417K	22,383,498K	15,134,765K
XRP Volume	1,262,999K	275,311K	1,538,310K	720,470K
XRP Market Cap	9,178,534K	12,359,839K	21,538,372K	16,950,825K
Zcash Volume	138,316K	85,513K	223,829K	144,692K
Zcash Market Cap	388,188K	317,226K	705,414K	485,441K
LTC Volume	296,643K	322,713K	619,356K	459,336K
LTC Market Cap	1,697,365K	1,503,109K	3,20,0474K	2,215,678K
Dash Volume	218,152K	102,231K	320,383K	176,655K
Dash Market Cap	842,859K	560,563K	1,403,422K	967,926K

Exploratory Data Analysis

For testing our model, we calculated price fluctuations by subtracting the closing price from the opening price. People who are more interested in Cryptocurrencies tend to be younger than equity investors, and we examine concerns that they may be susceptible to the sentiments of others. Thus, we trained our model with seven variables: Comment (Content of Comment) Positive,

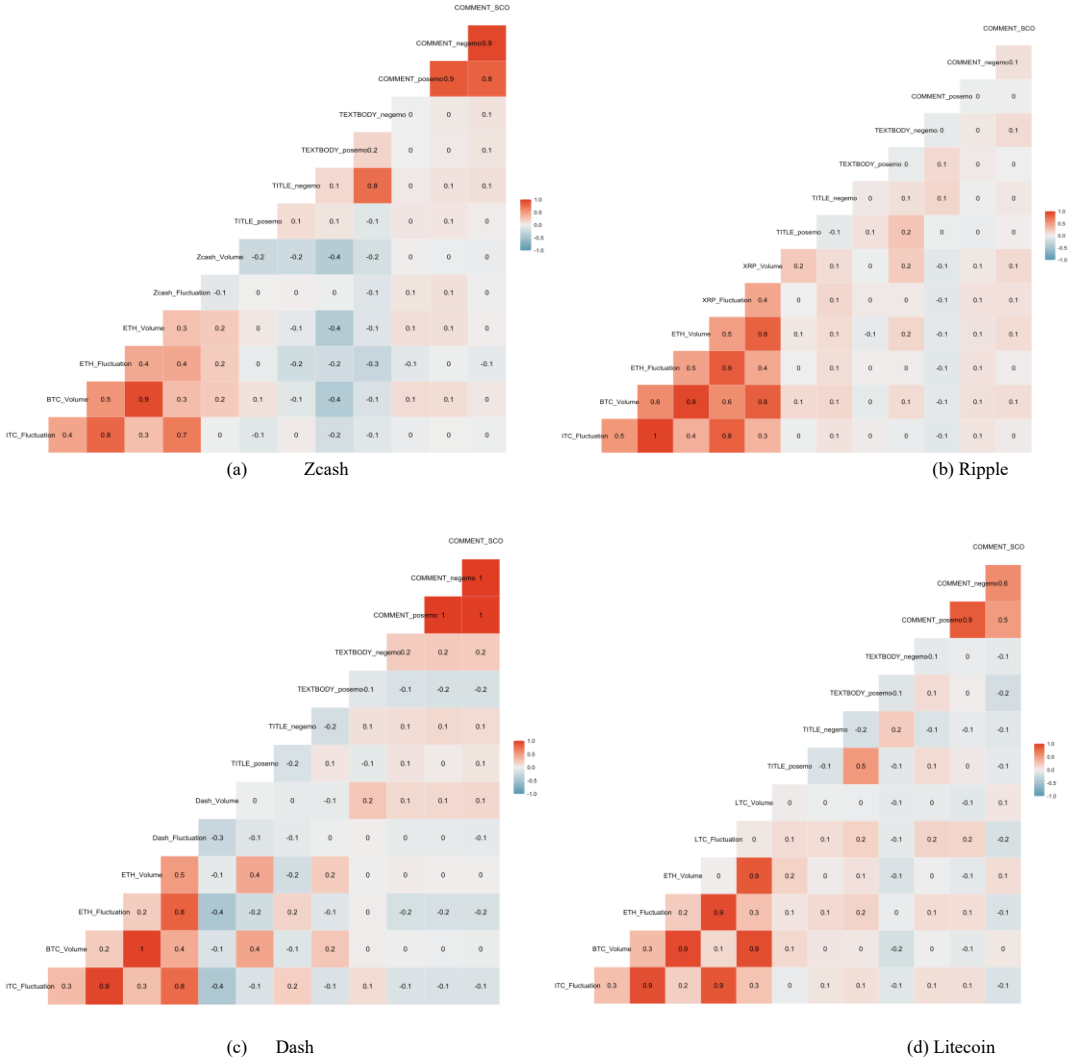
[2] On June 14, 2023, *Bankrate* reported in the "Bitcoin's Price History: 2009 to 2023" that: "After the huge melt-up of 2017, Bitcoin spent most of 2018 in a downtrend, falling throughout the year, following a brief surge to start the year. By the end of the first quarter, Bitcoin was down nearly 50 percent from where it had started the year. It spent much of the year bouncing between $6,000 and $8,000 before closing 2018 at $3,709 – down 73 percent for the year (https://www.bankrate.com/investing/Bitcoin-price-history/#j2018)."

Comment (Content of Comment) Negative, Textbody (Content of Thread) Positive, Textbody (Content of Thread) Negative, ETH Fluctuation, and BTC Fluctuation. Because the price fluctuations of Bitcoin and Ethereum affect the price fluctuations of Altcoins, both variables were included in each of our models. These six parameters were sufficiently diverse to successfully train the model on a wide array of trading options, and they also provided the most accurate overall correlation with Altcoin prices (as demonstrated by 4). We normalized the data so that each characteristic contributes roughly equally.

Our correlation analysis revealed interesting patterns among the cryptocurrency variables. Notably, we observed strong positive association between the fluctuation values of Bitcoin and Ethereum (**BTC_Fluctuation** vs. **ETH_Fluctuation**, correlation approximately 0.793), Bitcoin and Zcash (**BTC_Fluctuation** vs. **Zcash_Fluctuation**, correlation approximately 0.682), Bitcoin and Ripple (BTC Fluctuation and XRP Fluctuation, correlation approximately 0.825), Bitcoin and Dash (**BTC_Fluctuation** vs. **Dash_Fluctuation**, correlation approximately 0.776), as well as Bitcoin and Litecoin (**BTC_Fluctuation** vs. **LTC_Fluctuation**, correlation approximately 0.876). These findings suggest that when the fluctuation in Bitcoin's price increases, there is a tendency for the fluctuation in the other cryptocurrency's price to increase as well.

Furthermore, we identified a strong positive association between the trading volumes of Bitcoin, Ethereum and other Altcoins except for Dash coin (**BTC_Volume** vs. **Dash_Volume**, correlation approximately -0.130). This indicates that higher trading volumes for Bitcoin are associated with higher trading volumes for Ethereum, Zcash Ripple, and Litecoin.

However, the correlations between sentiment and negativity scores with the Cryptocurrency variables were generally low, indicating weak relationships between market indicators and sentiment scores. Additionally, the composite comment score exhibited weak correlations with other cryptocurrency variables. (See figure a-d)



(a) Zcash (b) Ripple

(c) Dash (d) Litecoin

Figure 7 Correlation Between the Chosen Features

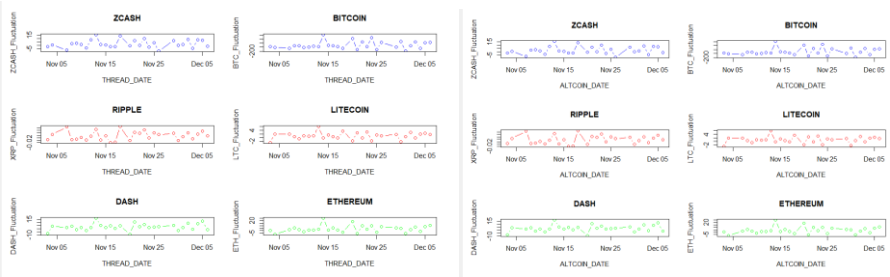


Figure 8 Price Fluctuation of Cryptocurrencies in a Bear Market in 2018

Metric Used

a. Mean Squared Error (MSE): The Mean Squared Error measures the average of the squared differences between predicted values and actual values. It penalizes larger errors more severely due to the squaring.

b. Root Mean Squared Error (RMSE): The Root Mean Squared Error is the square root of the Mean Squared Error. It provides a measure of the average magnitude of the errors in the units of the target variable.

c. Mean Absolute Error (MAE): The Mean Absolute Error computes the average of the absolute differences between predicted values and actual values. It provides a more robust measure of errors compared to MSE because it does not involve squaring the errors.

d. Mean Absolute Percentage Error (MAPE): The Mean Absolute Percentage Error computes the average percentage difference between predicted values and actual values. It's often used when you want to express the errors as a percentage of the actual values.

Experiment Results

We compared several machine learning models such as Linear Regression, Random Forest, XGBoost, Support Vector Machine and Decision Tree. We used t+1 leading variable in the prediction model. The table below demonstrates that XGBoost has the lowest errors (Mean square error, Root Mean square error, Mean Absolute Value and mean Absolute Percentage Error**)**. Therefore, we utilized the XGBoost R program to optimize our model.

Table 4 Model comparison for Zcash

	MSE	**RMSE**	**MAE**	**MAPE**
Linear Regression	22.4528200000	4.7384402884	3.9802040000	2.3191700000
Random Forest	0.0231869200	0.1522725310	0.0495758900	0.0234483300
XGBoost	0.0000000147	0.0001214153	0.0000870231	0.0000438956
SVM	12.6905700000	3.5623826065	2.0090800000	82.3686000000
Decision Tree	1.4216050000	1.1923107203	0.7526116000	0.3756775000

Table 5 Model comparison for Ripple

Model	MSE	RMSE	MAE	MAPE
Linear Regression	0.0001824687	0.0135080988	0.0108262011	2.9215481300
Random Forest	0.0000000654	0.0002557866	0.0001043464	0.0557666300
XGBoost	0.0000000300	0.0001733145	0.0001018801	0.1795528600
SVM	0.0001185129	0.0108863636	0.0063584930	0.7701965400
Decision Tree	0.0000107360	0.0032765789	0.0021920155	0.2096415500

Table 6 Model comparison for Dash

Model	MSE	RMSE	MAE	MAPE
Linear Regression	21.5580000000	4.6430595049	3.5179290772	2.5214260000
Random Forest	0.0032789110	0.0572617758	0.0265089972	0.0128582000
XGBoost	0.0000000477	0.0002183135	0.0001305378	0.0000808088
SVM	10.3417200000	3.2158547945	1.8612126616	0.5980686000
Decision Tree	1.4807740000	1.2168706553	0.7248847330	0.2782612000

Table 7 Model comparison for Litecoin

Model	MSE	RMSE	MAE	MAPE
Linear Regression	1.0635840000	1.0313021798	0.8253896000	31.6337800000
Random Forest	0.0003779815	0.0194417474	0.0070217830	0.0106011100
XGBoost	0.0000000138	0.0001176282	0.0000844597	0.0000991487
SVM	0.2706916000	0.5202802676	0.3047347000	0.8500563000
Decision Tree	0.1181724000	0.3437621240	0.2382574000	0.5580380000

Discussion

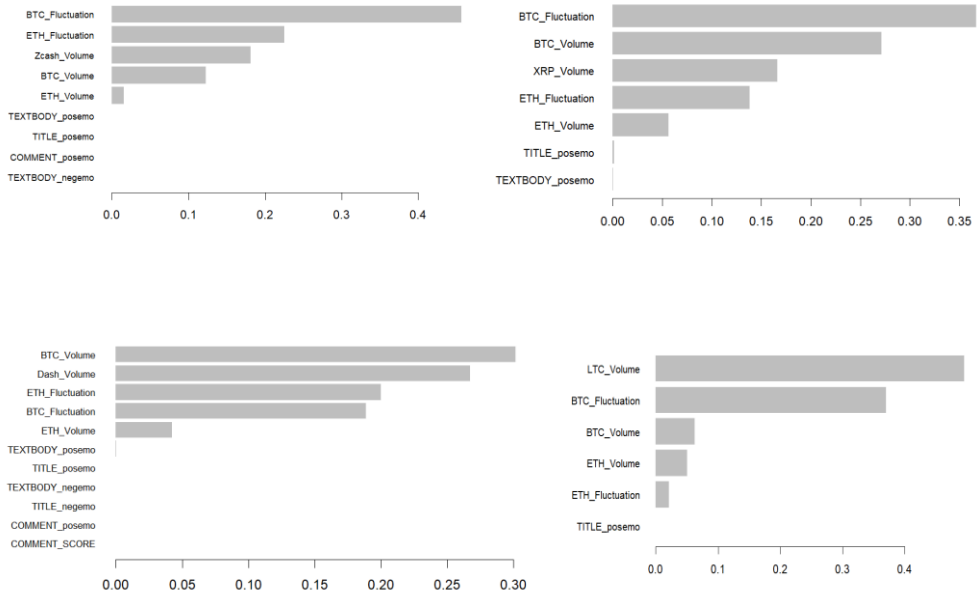
Metrics and XGBoost Decision Tree

<< XGBoost Best Parameters Used >>

When tested against the actual test data, our model has a smaller RMSE and MAE, and MAPE in all cases. As a result, our model provides a feasible method for predicting price fluctuations and demonstrates that statistical studies based on Reddit sentiment can be used to analyze price fluctuations in other Cryptocurrencies. Notably, despite the similar directionality between the price model and actual Zcash price fluctuations, there appears to be a $0.07 price difference between the two (see table 3). This could be the result of a lack of large training and testing datasets. However, the model's overall predictability remained high, indicating that it would have generated more accurate predictions if trained on larger datasets.

<< Tree and Explanation of the Results>>

Variable Importance



Conclusion

In conclusion, our findings suggest that an Extreme Gradient Boosting Regression Tree Model can be used to predict price fluctuations in the bear market for Cryptocurrencies by analyzing Reddit sentiment, Bitcoin price fluctuations, Ethereum price fluctuations, and trade volume. While Bitcoin and Ethereum prices affects Altcoins price fluctuations, sentiments are not correlated to them.

Our study serves as proof of concept, demonstrating that sentiment from social media platforms such as Reddit can be used to collect investor sentiment. Due to the paucity of research in this area, however, the effects by sentiment can be neglectable to predict future price fluctuations of Altcoins in bear market. Also, our study suggests what indexes Altcoin investors should refer to when minimizing losses. We posit that, although mostly Cryptocurrency investors are believed as younger generation(Bohr & Bashir, 2014), they have has a strong speculative tendency (Pichet, 2017). While previous studies reveal user sentiments from social media and online communities affect to Bitcoin prices (Kinderis, Bezbradica, & Crane, 2018; Kristoufek, 2013; Rahman, Hemel, Anta, Al Muhee, & Uddin, 2018), the young investors are not simply affected by the emotional states of others, nor do they engage in panic peddling. In a bear market, our analysis determines that Zcash should be most sensitive to a decline in Bitcoin's price, while Litecoin, Ripple, and Dash should be most sensitive to a decline in Ethereum's price in order to minimize losses.

Additional social media sites or data, such as Google Search results, Facebook posts, and Tweets, could further enhance our pricing model. The greatest flaw of LIWC, as the most of linguistic tools, is its inability to identify sarcasm, a common linguistic schema on social networking platforms, which it incorrectly classifies as "positive." Therefore, additional research into enhancing text analytics tools to detect sarcasm would increase the precision of our sentiment analysis and our ability to predict retail-driven price fluctuations.

Finally, it would be intriguing to train and evaluate our model over a longer time frame. Due to the limitations imposed by the date of our Cryptocurrency's fork and our processing power, our analysis was restricted to a data set that spanned only four weeks. However, our findings indicate the need for additional resources and investments to test our pricing model over a longer time period and with other Cryptocurrencies. Additionally, because our research data is limited to the Crypto market, we have been unable to determine whether the XGBoost model can predict the price of Altcoins in neutral or bull markets. Consequently, our future studies will accumulate more general data so that we can present a model that can predict prices not only in a bear market, but also in a flat market and a bull market, thereby minimizing losses and maximizing profits.

Appendix

Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
BTC_Fluctuation (1)		.429**	.932**	.316**	.720**	.205**	.850**	.082**	.931**	.401**	.782**	-.454**	-0.004	.064*	-0.032	-.060*	-0.023	.061*
BTC_Volume (2)	.429**		.451**	.933**	.434**	.748**	.392**	-0.028	.331**	.921**	.312**	-.346**	.147**	.069*	0.002	-0.003	0.011	0.046
ETH_Fluctuation (3)	.932**	.451**		.349**	.760**	.253**	.843**	.112**	.933**	.419**	.841**	-.417**	0.004	0.043	-0.047	-.081**	-0.025	.066*
ETH_Volume (4)	.316**	.933**	.349**		.370**	.709**	.340**	.072*	.221**	.858**	.259**	-.255**	.147**	0.037	0.003	-0.004	0.010	0.027
XRP_Fluctuation (5)	.720**	.434**	.760**	.370**		.256**	.649**	0.030	.703**	.367**	.586**	-.475**	-0.017	0.027	0.005	-.066*	-0.030	.063*
XRP_Volume (6)	.205**	.748**	.253**	.709**	.256**		.146**	-.396**	.073**	.774**	.065*	-.359**	.136**	0.033	-0.007	-0.014	-0.014	0.037
Zcash_Fluctuation (7)	.850**	.392**	.843**	.340**	.649**	.146**		.070*	.782**	.355**	.752**	-.315**	-0.022	-0.002	-0.039	-.067*	-0.017	.065*
Zcash_Volume (8)	.082**	-0.028	.112**	.072*	0.030	-.396**	.070*		.216**	-.204**	.298**	.153**	.064*	-0.009	-0.001	-.081**	0.045	0.007
LTC_Fluctuation (9)	.931**	.331**	.933**	.221**	.703**	.073**	.782**	.216**		.266**	.786**	-.384**	0.021	.072*	-0.026	-.090**	-0.028	.059*
LTC_Volume (10)	.401**	.921**	.419**	.858**	.367**	.774**	.355**	-.204**	.266**		.310**	-.245**	.137**	.069*	0.012	0.048	0.009	0.032
Dash_Fluctuation (11)	.782**	.312**	.841**	.259**	.586**	.065*	.752**	.298**	.786**	.310**		-.167**	.074**	-0.032	-0.013	-.067*	0.000	0.031
Dash_Volume (12)	-.454**	-.346**	-.417**	-.255**	-.475**	-.359**	-.315**	.153**	-.384**	-.245**	-.167**		0.016	-0.042	0.001	.124**	-0.010	-.074**
TITLE_posemo (13)	-0.004	.147**	0.004	.147**	-0.017	.136**	-0.022	.064*	0.021	.137**	.074**	0.016		-0.021	.064*	0.023	0.056	0.000
TITLE_negemo (14)	.064*	.069*	0.043	0.037	0.027	0.033	-0.002	-0.009	.072*	.069*	-0.032	-0.042	-0.021		-0.032	.256**	-0.005	.086**
TEXTBODY_posemo (15)	-0.032	0.002	-0.047	0.003	0.005	-0.007	-0.039	-0.001	-0.026	0.012	-0.013	0.001	.064*	-0.032		-0.004	0.027	0.016
TEXTBODY_negemo (16)	-.060*	-0.003	-.081**	-0.004	-.066*	-0.014	-.067*	-.081**	-.090**	0.048	-.067*	.124**	0.023	.256**	-0.004		-0.027	.060*

COMMENT_posemo (17)	-0.023	0.011	-0.025	0.010	-0.030	-0.014	-0.017	0.045	-0.028	0.009	0.000	-0.010	0.056	-0.005	0.027	-0.027		-0.022
COMMENT_negemo (18)	.061*	0.046	.066*	0.027	.063*	0.037	.065*	0.007	.059*	0.032	0.031	-.074**	0.000	.086**	0.016	.060*	-0.022	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Variables	BTC_Fluctuation	BTC_Volume	ETH_Fluctuation	ETH_Volume	Zcash_Fluctuation	Zcash_Volume	TITLE_posemo	TITLE_negemo	TEXTBODY_posemo	TEXTBODY_negemo	COMMENT_posemo	COMMENT_negemo	COMMENT_SCORE
BTC_Fluctuation		0.4472 ***	0.793 ***	0.2896 ***	0.682 ***	-0.0153	-0.0927	0.026	-0.1857 **	-0.0859	-0.0331	0.0022	-0.0143
Pvalue		0	0	9e-04	0	0.863	0.2963	0.7698	0.0351	0.3331	0.7096	0.9806	0.872
BTC_Volume	0.4472 ***		0.5394 ***	0.9248 ***	0.304 ***	0.2196 **	0.077	-0.0964	-0.4005 ***	-0.1463 *	0.113	0.1064	0.0431
Pvalue	0		0	0	5e-04	0.0124	0.3858	0.2772	0	0.0982	0.2022	0.2303	0.628
ETH_Fluctuation	0.793 ***	0.5394 ***		0.419 ***	0.423 ***	0.209 **	-0.04	-0.2145 **	-0.201 **	-0.2737 ***	-0.0777	-0.0122	-0.0543
Pvalue	0	0		0	0	0.0175	0.6528	0.0147	0.0224	0.0017	0.3812	0.8911	0.5408
ETH_Volume	0.2896 ***	0.9248 ***	0.419 ***		0.2794 ***	0.219 **	0.0481	-0.0675	-0.4003 ***	-0.1112	0.0962	0.091	0.0132
Pvalue	9e-04	0	0		0.0013	0.0126	0.5883	0.4473	0	0.2096	0.2782	0.3051	0.8823
Zcash_Fluctuation	0.682 ***	0.304 ***	0.423 ***	0.2794 ***		-0.0767	0.0025	0.0138	-0.0127	-0.1131	0.0665	0.0854	0.0041
Pvalue	0	5e-04	0	0.0013		0.3877	0.9772	0.8769	0.8861	0.202	0.454	0.3362	0.9632
Zcash_Volume	-0.0153	0.2196 **	0.209 **	0.219 **	-0.0767		-0.2398 ***	-0.2257 **	-0.3906 ***	-0.1768 **	0.0079	-0.0244	-0.0344
Pvalue	0.863	0.0124	0.0175	0.0126	0.3877		0.0062	0.0101	0	0.045	0.9288	0.7841	0.6987
TITLE_posemo	-0.0927	0.077	-0.04	0.0481	0.0025	-0.2398 ***		0.1101	0.0631	-0.0946	0.0493	0.0565	0.019
Pvalue	0.2963	0.3858	0.6528	0.5883	0.9772	0.0062		0.2144	0.4775	0.2861	0.5787	0.5247	0.8304
TITLE_negemo	0.026	-0.0964	-0.2145 **	-0.0675	0.0138	-0.2257 **	0.1101		0.1356	0.7543 ***	0.0331	0.0729	0.0875
Pvalue	0.7698	0.2772	0.0147	0.4473	0.8769	0.0101	0.2144		0.1254	0	0.7093	0.4113	0.3242
TEXTBODY_posemo	-0.1857 **	-0.4005 ***	-0.201 **	-0.4003 ***	-0.0127	-0.3906 ***	0.0631	0.1356		0.1546 *	-0.0024	0.0333	0.0629
Pvalue	0.0351	0	0.0224	0	0.8861	0	0.4775	0.1254		0.0802	0.9785	0.7076	0.4787
TEXTBODY_negemo	-0.0859	-0.1463 *	-0.2737 ***	-0.1112	-0.1131	-0.1768 **	-0.0946	0.7543 ***	0.1546 *		-0.0001	0.0407	0.0742
Pvalue	0.3331	0.0982	0.0017	0.2096	0.202	0.045	0.2861	0	0.0802		0.9995	0.6472	0.4031
COMMENT_posemo	-0.0331	0.113	-0.0777	0.0962	0.0665	0.0079	0.0493	0.0331	-0.0024	-0.0001		0.8587 ***	0.8155 ***
Pvalue	0.7096	0.2022	0.3812	0.2782	0.454	0.9288	0.5787	0.7093	0.9785	0.9995		0	0
COMMENT_negemo	0.0022	0.1064	-0.0122	0.091	0.0854	-0.0244	0.0565	0.0729	0.0333	0.0407	0.8587 ***		0.943 ***
Pvalue	0.9806	0.2303	0.8911	0.3051	0.3362	0.7841	0.5247	0.4113	0.7076	0.6472	0		0
COMMENT_SCORE	-0.0143	0.0431	-0.0543	0.0132	0.0041	-0.0344	0.019	0.0875	0.0629	0.0742	0.8155 ***	0.943 ***	
Pvalue	0.872	0.628	0.5408	0.8823	0.9632	0.6987	0.8304	0.3242	0.4787	0.4031	0	0	

Variables	BTC_Fluctuatior	BTC_Volum	ETH_Fluctuati	ETH_Volun	LTC_Fluctuatio	LTC_Volum	TITLE_posem	TITLE_negem	TEXTBODY_posem	TEXTBODY_negemo	COMMENT_posem	COMMENT_negem	COMMENT_SCORI
BTC_Fluctuation		0.287 ***	0.9123 ***	0.1882 ***	0.8757 ***	0.2638 ***	-0.03	0.063	0.095	-0.0927	0.0935	0.0961	-0.1407 **
Pvalue		0	0	0.0076	0	2e-04	0.6729	0.3756	0.1808	0.1918	0.1879	0.1757	0.047
BTC_Volume	0.287 ***		0.3069 ***	0.9308 ***	0.13 *	0.9186 ***	0.1353 *	0.05	0.0422	-0.1727 **	-0.0069	-0.0636	0.049
Pvalue	0		0	0	0.0665	0	0.0561	0.4823	0.5528	0.0145	0.9228	0.3708	0.491
ETH_Fluctuation	0.9123 ***	0.3069 ***		0.2059 ***	0.9235 ***	0.2702 ***	0.0567	0.1197 *	0.1636 **	-0.0316	0.1107	0.1011	-0.1348 *
Pvalue	0	0		0.0034	0	1e-04	0.4254	0.0914	0.0206	0.6567	0.1186	0.1544	0.0571
ETH_Volume	0.1882 ***	0.9308 ***	0.2059 ***		0.0139	0.8613 ***	0.1757 **	0.0219	0.0819	-0.1311 *	-0.0066	-0.0672	0.1051
Pvalue	0.0076	0	0.0034		0.845	0	0.0128	0.7579	0.2489	0.0643	0.9261	0.3443	0.1386
LTC_Fluctuation	0.8757 ***	0.13 *	0.9235 ***	0.0139		0.0464	0.1086	0.0988	0.1738 **	-0.059	0.162 **	0.1506 **	-0.1635 **
Pvalue	0	0.0665	0	0.845		0.514	0.1258	0.164	0.0138	0.407	0.0219	0.0333	0.0207
LTC_Volume	0.2638 ***	0.9186 ***	0.2702 ***	0.8613 ***	0.0464		0.0213	-0.0114	-0.0232	-0.0558	-0.0481	-0.0837	0.0585
Pvalue	2e-04	0	1e-04	0	0.514		0.7651	0.8733	0.7448	0.4323	0.4992	0.2389	0.4106
TITLE_posemo	-0.03	0.1353 *	0.0567	0.1757 **	0.1086	0.0213		-0.1307 *	0.5128 ***	-0.0773	0.1153	0.0391	-0.0542
Pvalue	0.6729	0.0561	0.4254	0.0128	0.1258	0.7651		0.065	0	0.2766	0.1039	0.5826	0.4455
TITLE_negemo	0.063	0.05	0.1197 *	0.0219	0.0988	-0.0114	-0.1307 *		-0.1544 **	0.2067 ***	-0.1226 *	-0.053	-0.0865
Pvalue	0.3756	0.4823	0.0914	0.7579	0.164	0.8733	0.065		0.0291	0.0033	0.0838	0.4562	0.223
TEXTBODY_posemo	0.095	0.0422	0.1636 **	0.0819	0.1738 **	-0.0232	0.5128 ***	-0.1544 **		-0.1015	0.113	0.0169	-0.1811 **
Pvalue	0.1808	0.5528	0.0206	0.2489	0.0138	0.7448	0	0.0291		0.1525	0.1113	0.8125	0.0103
TEXTBODY_negemo	-0.0927	-0.1727 **	-0.0316	-0.1311 *	-0.059	-0.0558	-0.0773	0.2067 ***	-0.1015		-0.0542	-0.0337	-0.0602
Pvalue	0.1918	0.0145	0.6567	0.0643	0.407	0.4323	0.2766	0.0033	0.1525		0.4458	0.636	0.3971
COMMENT_posemo	0.0935	-0.0069	0.1107	-0.0066	0.162 **	-0.0481	0.1153	-0.1226 *	0.113	-0.0542		0.8551 ***	0.4982 ***
Pvalue	0.1879	0.9228	0.1186	0.9261	0.0219	0.4992	0.1039	0.0838	0.1113	0.4458		0	0
COMMENT_negemo	0.0961	-0.0636	0.1011	-0.0672	0.1506 **	-0.0837	0.0391	-0.053	0.0169	-0.0337	0.8551 ***		0.5876 ***
Pvalue	0.1757	0.3708	0.1544	0.3443	0.0333	0.2389	0.5826	0.4562	0.8125	0.636	0		0
COMMENT_SCORE	-0.1407 **	0.049	-0.1348 *	0.1051	-0.1635 **	0.0585	-0.0542	-0.0865	-0.1811 **	-0.0602	0.4982 ***	0.5876 ***	
Pvalue	0.047	0.491	0.0571	0.1386	0.0207	0.4106	0.4455	0.223	0.0103	0.3971	0	0	

Variables	BTC_Fluctuation	BTC_Volur	ETH_Fluctuation	ETH_Volume	Dash_Fluctuatio	Dash_Volume	TITLE_posem	TITLE_negem	TEXTBODY_po	TEXTBODY_ne	COMMENT_pose	COMMENT_nege	COMMENT_SCO
BTC_Fluctuation		0.3073 ***	0.948 ***	0.2806 ***	0.7755 ***	-0.4347 ***	-0.1375 *	0.1902 **	-0.1288	0.1172	-0.1364 *	-0.1295	-0.1398 *
Pvalue		1e-04	0	5e-04	0	0	0.0935	0.0198	0.1162	0.1532	0.0959	0.1142	0.088
BTC_Volume	0.3073 ***		0.2095 **	0.9602 ***	0.4047 ***	-0.1301	0.4437 ***	-0.1036	0.2417 ***	0.0175	-0.0085	-0.0188	-0.0248
Pvalue	1e-04		0.0101	0	0	0.1125	0	0.2069	0.0029	0.8318	0.9177	0.8198	0.7636
ETH_Fluctuation	0.2095 **	0.2095 **		0.2002 **	0.8158 ***	-0.4478 ***	-0.2139 ***	0.1612 **	-0.1141	0.0164	-0.1675 **	-0.1536 *	-0.1631 **
Pvalue	0.2095 **	0.2095 **		0.014	0	0	0.0086	0.0487	0.1646	0.8417	0.0405	0.0606	0.0461
ETH_Volume	0.2806 ***	0.9602 ***	0.2002 **		0.4964 ***	-0.0582	0.4223 ***	-0.1945 **	0.2089 **	-0.0077	0.0235	0.0107	0.0062
Pvalue	5e-04	0	0.014		0	0.4794	0	0.0171	0.0103	0.9251	0.7749	0.8965	0.9398
Dash_Fluctuation	0.7755 ***	0.4047 ***	0.8158 ***	0.4964 ***		-0.2599 ***	-0.1022	-0.0615	-0.0111	0.0126	-0.0495	-0.0462	-0.0542
Pvalue	0	0	0	0		0.0013	0.2133	0.4544	0.8928	0.8779	0.5471	0.5745	0.5097
Dash_Volume	-0.4347 ***	-0.1301	-0.4478 ***	-0.0582	-0.2599 ***		-0.014	-0.0425	-0.0515	0.2431 ***	0.1281	0.1284	0.136 *
Pvalue	0	0.1125	0	0.4794	0.0013		0.8647	0.6057	0.5316	0.0027	0.1182	0.1175	0.097
TITLE_posemo	-0.1375 *	0.4437 ***	-0.2139 ***	0.4223 ***	-0.1022	-0.014		-0.1507 *	0.0587	-0.0584	0.0667	0.0288	0.0612
Pvalue	0.0935	0	0.0086	0	0.2133	0.8647		0.0657	0.4757	0.4779	0.4173	0.7269	0.4568
TITLE_negemo	0.1902 **	-0.1036	0.1612 **	-0.1945 **	-0.0615	-0.0425	-0.1507 *		-0.188 **	0.0851	0.1054	0.1288	0.114
Pvalue	0.0198	0.2069	0.0487	0.0171	0.4544	0.6057	0.0657		0.0212	0.3004	0.1991	0.1162	0.1647
TEXTBODY_posemo	-0.1288	0.2417 ***	-0.1141	0.2089 **	-0.0111	-0.0515	0.0587	-0.188 **		-0.0888	-0.1492 *	-0.1622 **	-0.1621 **
Pvalue	0.1162	0.0029	0.1646	0.0103	0.8928	0.5316	0.4757	0.0212		0.28	0.0684	0.0473	0.0475
TEXTBODY_negemo	0.1172	0.0175	0.0164	-0.0077	0.0126	0.2431 ***	-0.0584	0.0851	-0.0888		0.2056 **	0.222 ***	0.213 ***
Pvalue	0.1532	0.8318	0.8417	0.9251	0.8779	0.0027	0.4779	0.3004	0.28		0.0116	0.0063	0.0089
COMMENT_posemo	-0.1364 *	-0.0085	-0.1675 **	0.0235	-0.0495	0.1281	0.0667	0.1054	-0.1492 *	0.2056 **		0.983 ***	0.9751 ***
Pvalue	0.0959	0.9177	0.0405	0.7749	0.5471	0.1182	0.4173	0.1991	0.0684	0.0116		0	0
COMMENT_negemo	-0.1295	-0.0188	-0.1536 *	0.0107	-0.0462	0.1284	0.0288	0.1288	-0.1622 **	0.222 ***	0.983 ***		0.9894 ***
Pvalue	0.1142	0.8198	0.0606	0.8965	0.5745	0.1175	0.7269	0.1162	0.0473	0.0063	0		0
COMMENT_SCORE	-0.1398 *	-0.0248	-0.1631 **	0.0062	-0.0542	0.136 *	0.0612	0.114	-0.1621 **	0.213 ***	0.9751 ***	0.9894 ***	
Pvalue	0.088	0.7636	0.0461	0.9398	0.5097	0.097	0.4568	0.1647	0.0475	0.0089	0	0	

Variables	BTC_Fluctuation	BTC_Volume	ETH_Fluctuation	ETH_Volume	XRP_Fluctuation	XRP_Volume	TITLE_posemo	TITLE_negemo	TEXTBODY_posemo	TEXTBODY_negemo	COMMENT_posemo	COMMENT_negemo	COMMENT_SCORE
BTC_Fluctuation		0.5171 ***	0.9589 ***	0.3791 ***	0.8254 ***	0.3475 ***	-0.0135	0.0758	0.0206	-0.0313	-0.0829 *	0.0605	0.0214
Pvalue		0	0	0	0	0	0.7731	0.105	0.6598	0.5043	0.0764	0.1965	0.6483
BTC_Volume	0.5171 ***		0.588 ***	0.945 ***	0.5828 ***	0.8365 ***	0.1198 **	0.14 ***	-0.0491	0.1183 **	-0.0698	0.086 *	0.1024 **
Pvalue	0		0	0	0	0	0.0103	0.0027	0.2946	0.0113	0.1358	0.0658	0.0284
ETH_Fluctuation	0.9589 ***	0.588 ***		0.4578 ***	0.8513 ***	0.4197 ***	-0.0049	0.0979 **	0.0133	0.0153	-0.0815 *	0.0846 *	0.0156
Pvalue	0	0		0	0	0	0.9173	0.0363	0.7768	0.7443	0.0814	0.0705	0.7398
ETH_Volume	0.3791 ***	0.945 ***	0.4578 ***		0.481 ***	0.8196 ***	0.0524	0.1123 **	-0.0526	0.1518 ***	-0.0691	0.0672	0.111 **
Pvalue	0	0	0		0	0	0.2635	0.0162	0.2612	0.0011	0.1398	0.1509	0.0175
XRP_Fluctuation	0.8254 ***	0.5828 ***	0.8513 ***	0.481 ***		0.4353 ***	0.0015	0.141 ***	0.0337	0.0343	-0.0759	0.0816 *	0.0807 *
Pvalue	0	0	0	0		0	0.9737	0.0025	0.4715	0.4638	0.1047	0.0811	0.0845
XRP_Volume	0.3475 ***	0.8365 ***	0.4197 ***	0.8196 ***	0.4353 ***		0.2313 ***	0.1021 **	-0.0151	0.2056 ***	-0.0843 *	0.0516	0.1189 **
Pvalue	0	0	0	0	0		0	0.029	0.7478	0	0.0715	0.2708	0.0108
TITLE_posemo	-0.0135	0.1198 **	-0.0049	0.0524	0.0015	0.2313 ***		-0.0631	0.0813 *	0.2484 ***	-0.0166	-0.0341	0.0134
Pvalue	0.7731	0.0103	0.9173	0.2635	0.9737	0		0.1777	0.0823	0	0.7225	0.4662	0.7757
TITLE_negemo	0.0758	0.14 ***	0.0979 **	0.1123 **	0.141 ***	0.1021 **	-0.0631		0.0381	0.0866 *	0.1479 ***	-0.007	0.0433
Pvalue	0.105	0.0027	0.0363	0.0162	0.0025	0.029	0.1777		0.4156	0.064	0.0015	0.8806	0.3556
TEXTBODY_posemo	0.0206	-0.0491	0.0133	-0.0526	0.0337	-0.0151	0.0813 *	0.0381		-0.0348	0.1193 **	0.0348	-0.0051
Pvalue	0.6598	0.2946	0.7768	0.2612	0.4715	0.7478	0.0823	0.4156		0.4574	0.0106	0.4575	0.9126
TEXTBODY_negemo	-0.0313	0.1183 **	0.0153	0.1518 ***	0.0343	0.2056 ***	0.2484 ***	0.0866 *	-0.0348		-0.0472	0.0448	0.1134 **
Pvalue	0.5043	0.0113	0.7443	0.0011	0.4638	0	0	0.064	0.4574		0.3131	0.3391	0.0152
COMMENT_posemo	-0.0829 *	-0.0698	-0.0815 *	-0.0691	-0.0759	-0.0843 *	-0.0166	0.1479 ***	0.1193 **	-0.0472		-0.0146	-0.0082
Pvalue	0.0764	0.1358	0.0814	0.1398	0.1047	0.0715	0.7225	0.0015	0.0106	0.3131		0.7558	0.8617
COMMENT_negemo	0.0605	0.086 *	0.0846 *	0.0672	0.0816 *	0.0516	-0.0341	-0.007	0.0348	0.0448	-0.0146		0.0861 *
Pvalue	0.1965	0.0658	0.0705	0.1509	0.0811	0.2708	0.4662	0.8806	0.4575	0.3391	0.7558		0.0656
COMMENT_SCORE	0.0214	0.1024 **	0.0156	0.111 **	0.0807 *	0.1189 **	0.0134	0.0433	-0.0051	0.1134 **	-0.0082	0.0861 *	
Pvalue	0.6483	0.0284	0.7398	0.0175	0.0845	0.0108	0.7757	0.3556	0.9126	0.0152	0.8617	0.0656	

References

Baker, M., & Wurgler, J. (2007). Investor Sentiment in the Stock Market. *Journal of Economic Perspectives, 21*(2), 129-152. doi:10.1257/jep.21.2.129

Bartolomeu, P. C., & Ferreira, J. (2018). *Blockchain enabled vehicular communications: Fad or future?* Paper presented at the 2018 IEEE 88th Vehicular Technology Conference (VTC-Fall).

Belgiu, M., & Drăguţ, L. (2016). Random forest in remote sensing: A review of applications and future directions. *ISPRS journal of photogrammetry and remote sensing, 114*, 24-31.

Biau, G., & Scornet, E. (2016). A random forest guided tour. *Test, 25*, 197-227.

Bohr, J., & Bashir, M. (2014). *Who uses bitcoin? an exploration of the bitcoin community.* Paper presented at the 2014 Twelfth Annual International Conference on Privacy, Security and Trust.

Breiman, L. (2001). Random forests. *Machine learning, 45*, 5-32.

Burniske, C., & Tatar, J. (2018). *Cryptoassets: The innovative investor's guide to Bitcoin and beyond*.

Chen, T., & Guestrin, C. (2016). *Xgboost: A scalable tree boosting system.* Paper presented at the Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining.

Chen, T., He, T., Benesty, M., Khotilovich, V., Tang, Y., Cho, H., . . . Zhou, T. (2015). Xgboost: extreme gradient boosting. *R package version 0.4-2, 1*(4), 1-4.

Chohan, U. W. (2022). Crypto Winters. *Available at SSRN 4142885*.

Cohn, M. A., Mehl, M. R., & Pennebaker, J. W. (2004). Linguistic markers of psychological change surrounding September 11, 2001. *Psychological Science, 15*(10), 687-693.

Dai, W. (1998). B-money. *Consulted, 1*, 2012.

Divine, J. (2023, May 4). Bitcoin vs. Ethereum: Which Is the Better Buy? *U.S. News & World Report L.P.* Retrieved from https://money.usnews.com/investing/cryptocurrency/articles/bitcoin-vs-ethereum-which-is-a-better-buy

Grubbs, P., Maram, V., & Paterson, K. G. (2022). *Anonymous, robust post-quantum public key encryption.* Paper presented at the Annual International Conference on the Theory and Applications of Cryptographic Techniques.

Hearst, M. A., Dumais, S. T., Osuna, E., Platt, J., & Scholkopf, B. (1998). Support vector machines. *IEEE Intelligent Systems and their applications, 13*(4), 18-28.

Hirschberg, J., & Manning, C. D. (2015). Advances in natural language processing. *Science, 349*(6245), 261-266. doi:doi:10.1126/science.aaa8685

Iacurci, G. (2023, JUN 7). Crypto is Gen Z's most common investment. That may be risky, experts said. *CNBC*. Retrieved from https://www.cnbc.com/2023/06/07/crypto-is-gen-zs-most-common-investment-that-may-be-risky.html#:~:text=Fifty%2Dfive%20percent%20of%20Gen,the%20U.S.%20ages%2018%2D25.

Jalal, R. N.-U.-D., Alon, I., & Paltrinieri, A. (2021). A bibliometric review of cryptocurrencies as a financial asset. *Technology Analysis & Strategic Management*, 1-16.

Katsiampa, P., Gkillas, K., & Longin, F. (2018). Cryptocurrency market activity during extremely volatile periods. *Available at SSRN 3220781*.

Kinderis, M., Bezbradica, M., & Crane, M. (2018). Bitcoin currency fluctuation.

Kristoufek, L. (2013). BitCoin meets Google Trends and Wikipedia: Quantifying the relationship between phenomena of the Internet era. *Scientific reports, 3*(1), 3415.

McCoy, M., & Rahimi, S. (2020). Prediction of highly volatile cryptocurrency prices using social media. *International Journal of Computational Intelligence and Applications, 19*(04), 2050025.

Myles, A. J., Feudale, R. N., Liu, Y., Woody, N. A., & Brown, S. D. (2004). An introduction to decision tree modeling. *Journal of Chemometrics: A Journal of the Chemometrics Society, 18*(6), 275-285.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. *Decentralized Business Review*, 21260.

OECD. (2022). Lessons from the crypto winter. doi:doi:https://doi.org/10.1787/199edf4f-en

Paice, C. D. (1996). Method for evaluation of stemming algorithms based on error counting. *Journal of the American Society for Information Science, 47*(8), 632-649.

Pennebaker, J. W., Francis, M. E., & Booth, R. J. (2001). Linguistic inquiry and word count: LIWC 2001. *Mahway: Lawrence Erlbaum Associates, 71*(2001), 2001.

Pichet, E. (2017). Bitcoin: speculative bubble or future value? *Published in The Conversation (French edition), 28*.

Plutchik, R. (1984). Emotions: A General Psychoevolutionary Theory. In K. R. Scherer & P. Ekman (Eds.), *Approaches to Emotion* (pp. 197-220). New Jersey, USA: Lawrence Erlbaum Associates, Inc.

Rahman, S., Hemel, J. N., Anta, S. J. A., Al Muhee, H., & Uddin, J. (2018). *Sentiment analysis using R: An approach to correlate cryptocurrency price fluctuations with change in user sentiment using machine learning.* Paper presented at the 2018 Joint 7th International Conference on Informatics, Electronics & Vision (ICIEV) and 2018 2nd International Conference on Imaging, Vision & Pattern Recognition (icIVPR).

Rayson, P. E. (2003). *Matrix: A statistical method and software tool for linguistic analysis through corpus comparison*: Lancaster University (United Kingdom).

Securities, U. (2014). US Securities and Exchange Commission. *Retrieved from No-Action Letters: http://www. sec. gov/answers/noaction. htm*.

Silberman, W. R., & Record, R. A. (2021). We post it, u reddit: Exploring the potential of reddit for health interventions targeting college populations. *Journal of Health Communication, 26*(6), 381-390.

Song, Y.-Y., & Ying, L. (2015). Decision tree methods: applications for classification and prediction. *Shanghai archives of psychiatry, 27*(2), 130.

Srivastava, T. (2016). How to use XGBoost algorithm in R in easy steps. *Analytics Vidhya*.

Steinwart, I., & Christmann, A. (2008). *Support vector machines*: Springer Science & Business Media.

Szabo, N. (2008). Bit Gold proposal. *Decentralized Business Review*, 21449.

Vejačka, M. (2014). Basic aspects of cryptocurrencies. *Journal of Economy, Business and Financing, 2*(2), 75-83.