



Proceedings of the International Conference of Economists

at the Faculty of Economics, Kasetsart University
18 July 2025



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Program Overview

International Conference of Economists,
18th National Conference of Economists,
and Graduate Conference in Economics

“Transforming Economies for Equity, Stability, and Sustainability: The Power of Diversity”

Friday, 18 July 2025, 8.30–16.30

Faculty of Economics, Kasetsart University

08.30–09.00	Registration
09.00–09.30	Opening Ceremony
09.30–10.15	Keynote Speaker 1 (Thai) Assoc.Prof. Dr.Witsanu Attavanich, Faculty of Economics, Kasetsart University Topic: Transforming Economies for a Climate-Resilient Future: Lessons from Agriculture, Carbon Management, and Resource Conservation
10.15–10.45	Setathat Project Award Ceremony Hand over the NCE Flag to the Next Host
10.45–11.00	Coffee Break and Group Photo
11.00–11.30	Keynote Speaker 2 Prof. Dr.Ulrike Grote, Institute for Environmental Economics and World Trade, Faculty of Economics and Management, Leibniz University of Hannover Topic: Security Risks from Climate Change and Environmental Degradation: Implications for Sustainable Transformation in the Global South
11.30–12.00	Keynote Speaker 3 Prof. Dr.Nattavudh Powdthavee, Professor of Economics, Nanyang Technological University Topic: What We Think Others Think and Do About Climate Change: A Multi-Country Test of Pluralistic Ignorance and Public Consensus Messaging
12.00–13.00	Lunch
13.00–16.30	Parallel Sessions

Parallel Sessions

Friday, 18 July 2025

Session 1: Economic Growth and Development (English only)

Time: 13.00–16.30, Room: EC5302

Chair: Asst.Prof. Dr.Tirnud Paichayontvijit

Co-chair: Assoc.Prof. Dr.Kampanat Pensupar

1. Empirical Analysis of Indebtedness in Thailand
Sanha Hemvanich, Kanokwan Chancharoenchai, [Nattanicha Chairassamee](#)
2. Bank Runs and When Liquidity and Solvency Risks Interact
[Proudfong Chamornchan](#)
3. Volatility Interdependence in Emerging Market Currencies: A Study of BRICS and Thailand
[Chavis Im-aim](#), Roengchai Tansuchat
4. Impact of Pension on Children Expenditure Evidence from Thailand
[Tanetphon Phatanet](#)
5. How Digital Technology Application Positively Moderates the Impact of Electricity Cost on Labor Productivity in Cambodian Informal Enterprises
[Tung Nhu Nguyen](#)
6. The Impact of Burmese Labor in the Informal Economy on the Economic Growth of Chiang Mai
[Maytinee Wongchomphu](#)
7. Financial Openness and Productivity Growth: Theories, Experiences and Policy Implications
[Biswajit Panigrahi](#), KP Prabheesh



Session 2: Economic Growth and Development (English only)

Time: 13.00–16.00, Room: EC5303

Chair: Assoc.Prof. Dr.Roengchai Tansuchat

Co-chair: Assoc.Prof. Dr.Kanchana Sripruetkiat

1. Trade and Value Chain Upgrading in ASEAN Countries

Borworn Tanrattanaphong

2. The Impact of Digital Workforce Transformation in Human Development Index: A Conceptual Model

Olivia Fachrunnisa, Nurhidayati, Ardian Adhiatma

3. CGE Analysis of the U.S. Reciprocal Tariff and Retaliatory Scenarios

Pattawee Puangchit, Erwin L. Corong

4. Drivers of Capital Controls in Emerging Market Economies: The Role of Traditional Goals and Prudential Goals

Biswajit Panigrahi, KP Prabheesh

5. Are We Willing to Pay for Color? An Empirical Research from China

Lin Yuan



Session 3: Climate Change and Resource Economics (English only)

Time: 13.00–16.00, Room: EC5311

Chair: Assoc.Prof. Dr.Prasopchoke Mongsawad

Co-chair: Dr.Yuvaluck Setboonsrung

1. The Role of CO₂ Emissions and Energy Use in Thailand's Economic Growth: Long-Run and Short-Run Evidence from Time-Series Analysis
Aerwadee Premashthira
2. Emission Trading Scheme and Trends of Carbon Pricing
Yuvaluck Setboonsrung
3. The Role of Socioeconomic Diversity in Advancing Climate Adaptation and Technological Transformation: Evidence from Indonesia
Ernah, Eliana Wulandari
4. The Impacts of Oil Prices on the Consumption of Oil, Renewable Energy, and Nuclear Energy in the 12 European Union countries
Kunthida Jai-In, Woraphon Yamaka, Paravee Maneejuk
5. Willingness and Influencing Factors of Farmers' Forestland Management in Ethnic Minority Areas: Evidence from Southwest China
Ya Li



Session 4: Rural Development, Agricultural and Food Economics, Development Economics

(English only)

Time: 13.00–16.30, Room: EC5320

Chair: Assoc.Prof. Dr. Teerawat Charoenrat

Co-chair: Assoc.Prof. Dr. Isriya Bunyasiri

1. Remittances, Sanitation and Child Malnutrition in Middle-income Countries: A Case Study from Rural Northeast Thailand and Central Vietnam
Trung Thanh Nguyen
2. Shocks and the Dynamics of Multi- and Single-Dimensional Poverty and Subjective Well-Being: Evidence from Thailand Vietnam Socio Economic Panel (TVSEP) Data
Katsushi Imai
3. Construction of Thailand's Social Accounting Matrix and Analysis of Household Income Distribution
Mana Luksamee-Arunothai
4. Farming Efficiency and Rural Labor Transitions: Evidence from Panel Data for Thailand
Kasem Kunasri, Manh Hung Do, Trung Thanh Nguyen
5. Food Consumption Transformation and its Effect from COVID-19. Case Study: Northeast Rural Thailand
Chompunuch Nantajit
6. Energy Poverty and Health: Panel Evidence from Southeast Asia
Thi Minh Nguyet Tran



Session 5: Rural Development, Agricultural and Food Economics, Development Economics

(English only)

Time: 13.00–16.30, Room: EC5321

Chair: Prof. Dr.Poomthan Rangakulnuwat

Co-chair: Asst.Prof. Dr.Navarat Temsumrit

1. The Impact of AI on Career Readiness: The Role of Learning Goal Orientation and Digital Skills in the Industry 5.0
Khansa Nabila Zain, Olivia Fachrunnisa
2. Strategic Orientation for Competitive Advantage and Economic Sustainability in Thai Agricultural Cooperatives
Poomthan Rangakulnuwat, Auttapol Suebpongsakorn, Phat Pisitkasem
3. Impact of Aging on Structural Change: Cross-Country Analysis on Differential Income Levels
Hongsilp Sriket, Navarat Temsumrit
4. Factors Influencing Farmers' Needs for Organic Rice Production Extension in Savannakhet Province
Inta Chanthavong
5. How Do Kiwi Farmers Feel About Planting Native Species? Evidence from Canterbury, New Zealand
Waranan Tantiwat, Brad Howlett
6. Spouse Preference in China Using a Conjoint Experiment
Wenjun Fan, Yong Yoon



Session 6: Sustainable Economy, Local Communities, Environment, Agriculture, Labor, Human Resources and Industrial Economics (Thai or English)

Time: 13.00–16.30, Room: EC5402

Chair: Asst.Prof. Dr.Adul Supanut

Co-chair: Asst.Prof. Dr.Phat Pisitkasem

1. A Development Dilemma: How Does Energy Poverty Improvement Affect Fossil Fuel Energy Consumption in Southeast Asian Countries in the 21st Century?
Chanon Thongtai, Raweroj Kanchomphu
2. Predicting Informal Loans Using Machine Learning Algorithms
Pim Pinitjitsamut, Wisarat Suwanprasert
3. The Economic Impact of International Migrant Workers in Thailand
Wonlope Khumpradith, Apivee Antarasena Kwan Phetsawang
4. Job Polarisation and Its Generation Effect on Labour Market of Thailand
Kwan Phetsawang, Wonlope Khumpradith
5. The Effects of Alcohol Consumption on Human Capital: An Empirical Analysis Using Micro-Level Data
Nattapon Siwareepan, Chayanee Chawanote
6. Accuracy Comparison of Forecasting Methods for the Pork Cuts Price between SARIMA and EGARCH Models
Onjira Sarakorn, Auttapol Suebpongsakorn
7. Kinship Involvement and Early Childhood Development Outcomes in Developing Countries: Empirical Evidence from Thailand
Natthakorn Naknong, Piriya Pholphirul
8. Unemployment Duration In Thailand During COVID-19
Nutt Thaweephoke



Session 7: ASEAN, World Economy, International Trade, Investment, Political Economy,
Institutions, Governance and Behavioral Economics (Thai or English)

Time: 13.00–16.30, Room: EC5411

Chair: Asst.Prof. Dr.Panutat Satchachai

Co-chair: Dr.Lalita Chanwongpaisarn Nguitragool

1. Concentrated Wealth and Total Factor Productivity: When Does the Equality-Efficiency Tradeoff Apply?
Bordin Bordeerath
2. Foreign Direct Investment and Gender Equality
Piyaphan Changwatchai
3. The Rise of China and Primarization in Southeast Asia
Tanadej Vecksuruck, Naphon Phumma
4. The 2018 US-China Trade War and Trade Diversion: Evidence from Thai Customs Data
Nuwat Nookhwun, Jettawat Pattararangrong, Kittichai Saelee, Wisarut Suwanprasert
5. The Effect of Low-Carbon Technology Trade on GHG Performance in ASEAN
Jirapa Inthisang Trochim
6. Learning to Wait: How Financial and Numerical Literacy Influence Time Preference Decisions
Khusrav Gaibulloev, Gerel Oyun, Dina Tasneem, Ajalavat Viriyavipart
7. Digital Labor and the Critique of Political Economy: Case Study of the Labor in the Production of Payment and Lending Applications
Norachit Jirasatthumb, Naruemon Thabchumpon
8. The Logic of the Social Order in Thailand Evidence from 1932-2024
Paisit Auiyamvong, Norachit Jirasatthumb



Session 8: Political Economy, Institutions, Governance and Behavioral Economics

(Thai or English)

Time: 13.00–16.30, Room: EC5415

Chair: Asst.Prof. Dr.Nuttaporn Rochanahastin

Co-chair: Asst.Prof. Dr.Pat Pattanarangsun

1. An Experimental Analysis of Bribe-Acceptance and Bribe-Offering
Phumsith Mahasuweerachai, [Tanyamat Srungboonmee](#)
2. Creating Motivation to Save Through Experimental Economics: A Case Study of Communities in Northeastern Thailand
Siwaporn Fongthong, [Jakkrich Jearviriyaboonya](#), Norachit Jirasatthumb
3. The Effects of Taxation and Non-Taxation Measures on Unhealthy Product Consumption: Case Study of Tobacco in Thailand
[Kanokwan Chancharoenchai](#), Nattanicha Chairassamee, Wuthiya Saraithong
4. Victim and Online Financial Scam: Understanding Heterogeneity in Susceptibility to Online Financial Scam
[Nattanicha Chairassamee](#), Kanokwan Chancharoenchai, Patrapa Vejpattarasiri
5. Political Economy and Foreign Ownership Buying Condominium in Thailand
[Juthamart Limwongsakornwanit](#)
6. Unequal Capital: Exploring Social Capital and Consumer Civil Society in Thailand, Korea, and the United States
[Kamolchanok Jittrejit](#), Norachit Jirasatthumb
7. Institutions and Sustainable Pro-Poor Growth
[Ilada Su-ngoh](#)
8. Sethatat Award Paper (Undergraduate Level)
9. Sethatat Award Paper (Graduate Level)

Session 9: Monetary Policy, Fiscal Policy, Macroeconomics, Creative Economy and
Miscellaneous (Thai or English)

Time: 13.00–16.30, Room: EC5419

Chair: Asst.Prof. Dr.Teerawut Sripinit

Co-chair: Assoc.Prof. Dr.Auttapol Suebpongsakorn

1. Heterogeneity of the Labour Market Response to Inflation-Targeting Monetary Policy: An Analysis of Formal and Informal Employment in Thailand
Thi Minh Tam Bui
2. Value Added Tax: Provincial Distribution of Value Added Tax and VAT-Registered Enterprises
Direk Patmasiriwat, Pawinee Stargell
3. Do Types of Government Spending Matter for Aggregate and Sectoral Activity? Evidence from a Structural Factor-Augmented VAR for Thailand
Kittichai Saelee
4. Credit Card Interest Rates and Fees: A Comparison between Thailand and Other Countries
Jakkrich Jearviriyaboonya, Sira Nukulkit
5. The Effect of Exchange Rate Pass-through on Export Prices
Mintrapan Chaeng-lum, Jettawat Pattarangrong, Khemmakorn Srichanyanonth
6. Exploring Tourism's Economic Impact: A Simple Simulation Using National Statistics
Anan Wattanakuljarus
7. Factors Affecting the Profitability of Specialized Financial Institutions in Thailand
Sajee Thawichsri, Siwamong Dheera-aumpon
8. A Study on Members' Participation in the Business Operations of the Maharat Nakhon Ratchasima Hospital Cooperative Store Limited
Sasivimon Yuidee, Kanokon Seemanon
9. Consumer Attitudes and Behaviors Influencing the Decision to Purchase Cannabis Infused Beverages in a Commercial Context
Tanchanok Maleerungrueangkit, Piyawong Punjatewakupt

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Table of Contents

	Page
Keynote Speaker 1	
Transforming Economies for a Climate-Resilient Future: Lessons from Agriculture, Carbon Management, and Resource Conservation	1
Witsanu Attavanich	
Keynote Speaker 2	2
Security risks from climate change and environmental degradation: implications for sustainable transformation in the Global South	
Ulrike Grote	
Keynote Speaker 3	3
What We Think Others Think and Do About Climate Change: A Multi-Country Test of Pluralistic Ignorance and Public Consensus Messaging	
Nattavudh Powdthavee	
Session 1: Economic Growth and Development	
Bank Runs When Liquidity and Solvency Risks Interact	4
Proudfong Chamornchan	
Volatility Interdependence in Emerging Market Currencies: A Study of BRICS and Thailand	28
Chavis Im-aim, Roengchai Tansuchat	
Impact of Pension on Children Expenditure: Evidence from Thailand	49
Tanetphon Phatanet	
The Effect of Digital Technology Adoption on the Labor Productivity of Informal Enterprises in Cambodia	68
Tung Nhu Nguyen	
The Impact of Burmese Labor in the Informal Economy on the Economic Growth of Chiang Mai	69
Maytinee Wongchomphu, Nisit Panthamit, Chukiat Chaiboonsri	
Session 2: Economic Growth and Development	
The Impact of Digital Workforce Transformation in Human Development Index: A Conceptual Model	83
Olivia Fachrunnisa, Nurhidayati, Ardian Adhiatma, Cici Dea Permata Exsti	
Session 3: Climate Change and Resource Economics	
The Role of CO ₂ Emissions and Energy Use in Thailand's Economic Growth: Long-Run and Short-Run Evidence from Time-Series Analysis	100
Aerwadee Premashthira	

Table of Contents

	Page
The Impacts of Oil Prices on the Consumption of Oil, Renewable Energy, and Nuclear Energy in the 12 European Union countries	101
Kunthida Jai-In, Woraphon Yamaka, Paravee Maneejuk	
Session 4: Rural Development, Agricultural and Food Economics, Development Economics	
Remittances, Sanitation and Child Malnutrition in Middle-income Countries: A Case Study from Rural Northeast Thailand and Central Vietnam	122
Trung Thanh Nguyen	
Shocks and the Dynamics of Multi- and Single-dimensional Poverty and Subjective Well-being: Evidence from Thailand Vietnam Socio Economic Panel (TVSEP) Data	123
Katsushi Imai, Minh Tam Bui, Thi Thu Hien Nguyen	
Farming Efficiency and Rural Labor Transitions: Evidence from panel data for Thailand.	124
Kasem Kunasri, Manh Hung Do, Trung Thanh Nguyen	
Food Consumption Transformation and its effect from COVID-19. Case study Northeast Rural Thailand.	125
Chompunuch Nantajit	
Session 5: Rural Development, Agricultural and Food Economics, Development Economics	
The Impact of AI on Career Readiness: The Role of Learning Goal Orientation and Digital Skills in the Industry 5.0	126
Khansa Nabila Zain, Olivia Fachrunnisa	
Strategic Orientation for Competitive Advantage and Economic Sustainability in Thai Agricultural Cooperatives	130
Poomthan Rangakulnuwat, Auttapol Suebpongsakorn, Phat Pisitkasem	
Understanding Farmer Decision-Making on Native Planting in Canterbury: Economic and Attitudinal Drivers	131
Waranan Tantiwat, Crystal Felman, Melanie Walker, Brad Howlett	
Factors Influencing Farmers' Needs for Organic Rice Production Extension in Savannakhet Province, Laos.	147
Inta Chanthavong, Sitha Khemmarath, Boungheuang Ninchaleune, Bansack Xayyaphet, Daosavanh Keonamy	

Keynote Speaker 1

Transforming Economies for a Climate-Resilient Future: Lessons from Agriculture, Carbon Management, and Resource Conservation

Witsanu Attavanich^a

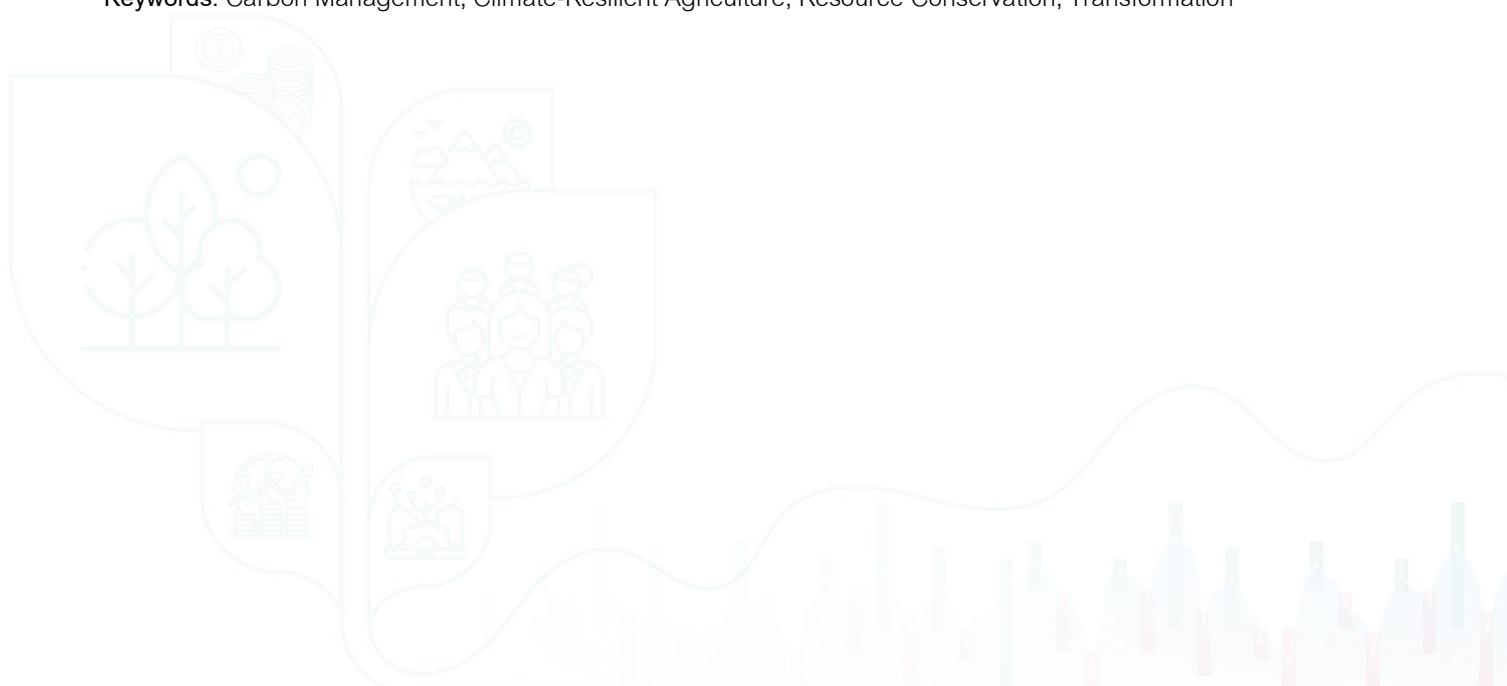
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Abstract

As the global economy confronts the converging forces of geopolitical risk, technological advancement, and climate change, economic systems must evolve to remain resilient and inclusive. This keynote explores how climate change—often viewed as an environmental issue—is fundamentally disrupting economic structures, market dynamics, and development pathways. Drawing on research from Thailand and international contexts, the presentation highlights how climate change has impacted key sectors, particularly agriculture and energy. Evidence from studies on farmers reveals how climate-smart agricultural practices can improve both productivity and resilience while also addressing environmental externalities such as air pollution. In parallel, insights from policies on carbon pricing and clean air regulation demonstrate how economic instruments can reduce greenhouse gas emissions and incentivize innovation. The presentation also synthesizes findings from a systematic review on forest and marine resource conservation, emphasizing the role of behavioral economics and policy design in enhancing management. Together, these lessons underscore the need for integrated approaches that harness technological innovation, environmental policy, and local engagement to drive climate-resilient economic transformation.

Keywords: Carbon Management, Climate-Resilient Agriculture, Resource Conservation, Transformation



Keynote Speaker 2

Security risks from climate change and environmental degradation: implications for sustainable transformation in the Global South

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Abstract

Climate change and environmental degradation remain the most complex challenges facing current and future generations of humanity and pose a range of security risks that have received relatively little attention in the literature. This presentation aims to review the evidence on the security risks posed by these challenges in the Global South and to identify forward-looking perspectives on how to increase the resilience of affected people and communities. Diversification is considered a key strategy in driving change towards greater sustainability and resilience. It is proposed that rural land use in the Global South should focus on the promotion of resource and biodiversity conservation, the development of agroforestry and tree-based farming systems, crop diversification and the use of climate-resilient crop varieties and neglected and underutilized crops. These measures would help address the security risks posed by the interlinked challenges of climate change and environmental degradation.

Keywords: Climate Change, Environment, Risks, Sustainability, Transformation



Keynote Speaker 3

What We Think Others Think and Do About Climate Change: A Multi-Country Test of Pluralistic Ignorance and Public Consensus Messaging

Nattavudh Powdthavee^a

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Abstract

Most people believe in human-caused climate change, yet this public consensus can be collectively underestimated (pluralistic ignorance). Across two studies using primary ($n = 3,653$ adult participants; 11 countries) and secondary ($n_s = 60,230$ and $22,496$ adult participants; 55 countries) data, we tested (a) the generalizability of pluralistic ignorance about climate change beliefs, (b) effects of a public consensus intervention on climate action, and (c) cultural tightness-looseness as a country-level predictor of pluralistic ignorance. In Study 1, people across 11 countries underestimated the prevalence of pro-climate views by at least 7.5% (90% CrI [5.1, 10.1]) in Indonesia and up to 20.8% (90% CrI [18.2, 23.4]) in Brazil. Providing information about this public consensus on climate change was largely ineffective, except for a slight increase in willingness to express one's pro-climate opinion ($\delta = 0.05$; 90% CrI [-0.02, 0.11]). In Study 2, pluralistic ignorance about willingness to contribute financially to fight climate change was slightly more pronounced in looser than tighter cultures, highlighting the particular need for pluralistic ignorance research in these countries.

Keywords: Climate Change, Multi-Country, Pluralistic Ignorance, Public Consensus



Bank Runs When Liquidity and Solvency Risks Interact

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Abstract

In the context of the modern banking economy, where central banks act as lenders of last resort, I examine the risk of bank runs when liquidity and solvency risks interact. Plenty of studies have demonstrated that central banks can prevent bank runs if they provide sufficient liquidity during a panic. In this model, I showed that equilibrium with bank runs exists when solvency and liquidity shocks interact. Central banks cannot prevent bank runs. The analytical solution and the Monte Carlo experiment demonstrate that the risk of bank runs increases when there is a high degree of risk aversion. With the same level of solvency risk, the chance of bank runs will increase for banks with higher numbers of depositors, which can be interpreted as the sunspots.

JEL classification: E42, E58, G21

Keywords: bank run, central bank, liquidity, solvency risk

Introduction

From the Bardi and Peruzzi family bank collapse in 1343 (Hunt 1990) to the fall of Silicon Valley Bank (SVB) in March 2023 (Cookson, Fox, Gil-Bazo, Imbet, and Schiller 2023), bank runs are the phenomena that have occurred throughout the history of banking. Several of these runs were followed by or associated with financial crises. The economic destruction of bank runs has put them in the scope of interest of economists for more than 50 years.

The work of Diamond and Dybvig (1983) is one of the most influential models of bank runs. Consumers face idiosyncratic uncertainty in preferences as they are unsure whether they will be early or late consumers. Banks in this model provide the demand-deposit contract as the risk-sharing mechanism. Depositors deposit their endowments with the banks. Diamond and Dybvig (1983) have proved that the demand-deposit system can bring about the social optimum. Nonetheless, it also has an undesired outcome, which is the bank runs.

The concept of bank runs, as described in Diamond and Dybvig (1983), involves late consumers, namely depositors withdrawing their money from banks, thereby imposing a high liquidity shock on their banks. They believe that their banks may not have enough assets left for them to withdraw, and it is self-fulfilling. In the

¹ The views expressed in this study do not necessarily reflect the views of the Bank of Thailand.

modern banking world, commercial banks face more complex problems. Nominal loans generate nominal deposits instead of consumers depositing their real endowments. When a customer uses her deposit to purchase goods from a customer of another bank, her deposits will be transferred to the seller's bank, as well as the reserves, which are used as the means of interbank transactions. These types of transactions happen every day, and banks that have negative net flows of deposits will have to borrow reserves from the central bank. Hence, in reality, banks also face the cost of managing deposits. When banks face large liquidity shocks, they may not have enough reserves to satisfy the liquidity demand. In addition, the reserve borrowing costs will also increase.

Another risk that banks are exposed to is solvency risk. Banks' operations to create loans leave them with capital lower than their level of debt. Solvency risks happen when banks may not be able to collect their loans. This can happen due to the low production as observed in Gorton (1988) or their bad monitoring and screening systems (Gupta, Lu, Simaan, and Zaki 2022).

Disasters, such as COVID-19, are other examples of events that pose solvency risk to banks. During the COVID-19 pandemic, the GDP of each country plummeted as businesses were unable to operate. Workers lost their jobs or were restricted from working. The loss of income for both businesses and households decreased the ability to pay debts, imposing the solvency risk on commercial banks. However, the solvency risk was not the only risk that banks faced during the COVID-19 pandemic. There was high demand for liquidity. Central banks around the world had to roll out emergency liquidity plans (Cantó, Cavallino, De Fiore, and Yetman 2021). While solvency shocks can cause banks to collapse, large liquidity shocks can also increase the cost of managing liquidity and exacerbate the solvency shocks.

This study aims to investigate bank runs when bank-specific solvency risk interacts with liquidity risk, using the construction of Rivero and Rodriguez (2024) to capture the environment of modern banking.

The analytical solution illustrated that the loss from low production could decrease the deposit rate, making deposits less valuable. However, the magnitude of the loss depends on the degree of liquidity shock. Different combinations of liquidity and solvency risks determine the deposit rates paid to the depositors. Due to the interaction between the two risks, an exact competitive equilibrium cannot be solved analytically. For these reasons, I introduce a Monte Carlo experiment, a simulation in which the production shock is drawn multiple times, making the realized frequency of the shock approach the actual probability from the real data-generating process.

The Monte Carlo experiment shows that bank runs exist when two shocks interact. The chance of bank runs increases with a higher degree of risk aversion. For a certain level of solvency shock, bank runs tend to happen more to banks with a higher number of depositors, indicating the sunspot of the economy. There are some explanations for these counterintuitive results. Firstly, when there is a large number of patient depositors, there are also more people who care about the value of their own deposits, and there are more people to run the banks. Secondly, the patient depositors run the banks because they are risk-averse. The patient depositors

have two options to manage solvency risk. Firstly, they can continue saving in terms of deposits, but face the risk that their deposits may lose their real value and their banks may become insolvent. Secondly, they can use their deposits to store the consumption goods for one period. This model assumes that the banks will pay locational deposit rates. The spread between deposit rates in high- and low-production areas increases with the number of impatient depositors, namely, a larger liquidity shock. In locations with larger liquidity shocks, the utility gains from high production can compensate for the utility losses. This is not the same for locations with more patient depositors. The lower spread implies greater stability, but a larger number of depositors means a larger number of people to whom the banks are indebted. The gain in the deposit rates is not high enough to compensate for the utility loss for so many depositors.

Plenty of literature such as Allen, Carletti, and Gale (2014) and Rivero and Rodriguez (2024) has emphasized the role of central banks as the lender of the last resort. As long as the central banks are willing to provide enough liquidity, there will be no bank run. This paper has demonstrated that when a solvency shock interacts with a liquidity shock, central banks are unable to prevent bank runs. The results of this study raise concerns regarding the challenges that central banks face in a world of rising uncertainties. (Jefferson 2023)

Literature review

Economists have thrived to understand bank runs, and the research in this field is still ongoing. Most studies on bank runs are also related to liquidity, central banks, and deposit insurance. Bryant (1980) studied the role of reserves and deposit insurance on bank runs. This study defined a bank run as a situation in which agents learned bad news and came to withdraw their deposits. Deposit insurance could cause complex risk redistribution and did not always have an impact on preventing the runs.

One research that is influential on the subsequent studies is Diamond and Dybvig (1983). In this model, agents face idiosyncratic uncertainty regarding their preferred time for consumption. It introduced deposit contracts as the risk-sharing mechanism. Banks act as intermediaries, gathering all resources from the consumers and offering demand deposit contracts. They have shown that demand deposits can facilitate the social optimum outcome, which is not possible with the market or autarky systems. However, demand deposits can result in an undesirable equilibrium, which is a bank run. One tool to prevent bank runs is to offer deposit insurance.

A number of theoretical studies have been built upon the structure of Diamond and Dybvig (1983). Postlewaite and Vives (1987) incorporated the Prisoner's Dilemma into the model and revealed that there was a unique equilibrium with a positive probability of bank runs, even with the deposit insurance. Allen and Gale (2004a) constructed a model with an aggregate preferences shock. In other words, the banks in their model also face the uncertainty that the whole economy will have high or low impatient agents. They discovered that the aggregate preference shock could lead to either high price volatility, bank runs, or both. Allen and Gale (2004b) explored the model that there were both banks (financial intermediaries) and the financial market that

faced aggregate shocks in asset returns and preferences. Banks may not be able to offer contingent deposit contracts, while there may be no contingent bonds for all states of shock in the financial markets. Their results have shown that an economy with both complete contracts and complete markets is incentive-efficient.

In Diamond and Dybvig (1983), Bryant (1980), and several studies, bank runs happen when depositors panic. Banks with more risk factors are more prone to runs. Having a high number of uninsured deposits is also one of the factors. The empirical model from Iyer and Puri (2012) studied micro data on depositors in the banks with runs. Though there are other factors defining the chance of a run, uninsured depositors are the most likely to run the banks. Additionally, the rise of social media has the potential to amplify these risks, as highlighted Cookson et al. (2023). Nevertheless, there are also some downsides regarding having deposits fully insured. Miller and Luangaram (1998) examined the 1997 Asian financial crisis. They found that the moral hazard caused by deposit insurance was one of the factors leading to the collapse of the financial sectors in several Asian countries. Other risk factors that can cause the runs are the business cycles and banks' insolvency. An empirical study of the National Bank Era from Gorton (1988) has shown that bank runs occurred when the perception of risks changed. Several economic downturns happened along with bank panics since banks are expected to fail more during recessions. Iyer, Puri, and Ryan (2016) used microdata from a bank in India to show that there were chances of banks' runs when the auditing authority exposed the information about banks' insolvency. Viviani and LE Hanh (2018) used the text-analysis tools to study Federal Deposit Insurance Corporation (FDIC)'s bank failure reports. They discovered that most bank failures were a result of poor management and concentrated lending, which deteriorate banks' solvency.

These models were built on real deposit contracts and real banks. In Diamond and Dybvig (1983), consumers deposit their assets in banks, then banks invest in long and short technologies. In the modern economy, loans create deposits, not the other way round (McLeay, Radia, and Thomas 2014). There exists empirical evidence supporting the notion that banks have the ability to create money from nothing (Werner 2014). Additionally, all contracts made with banks are expressed in nominal terms, not in real terms. Central banks provide reserves as a means of transaction in the interbank markets, and they use the reserves to control interest rates.

Though the banks' activities mostly happen in financial markets, and in nominal terms. The process of money creation has a real impact on real output (Berger and Sedunov 2017). The business downturns associated with financial busts are more severe and take a longer time to recover (Drehmann, Borio, and Tsatsaronis 2012). Several later works incorporate interbank markets and central banks to study bank runs. Freixas, Parigi, and Rochet (2000) created the model in which some consumers have to travel. The interbank market increases welfare by lowering the necessity to hold liquidity. However, there can be a case where the economy becomes stuck in a gridlock equilibrium. They defined "systemic risk" as the risk that spreads from banks to banks by the interbank market and identified the banks that are "too big to fail". Following the global financial crisis, the role of central banks in preventing systemic risks came into focus. Freixas, Martin, and Skeie

(2011) built a model in which there was a disparity in liquidity holding, and lowering the monetary policy rate could improve the situation. Hence, monetary policy can also have a macroprudential role. Some research also explored the role of central banks as the lender of last resort. There are some arguments that solvent banks cannot be illiquid. Rochet and Vives (2004) showed that in some circumstances, solvent banks might not be able to acquire liquidity.

Allen, Carletti, et al. (2014) replaced the real deposit contracts in Diamond and Dybvig (1983) with the nominal ones. Entrepreneurs borrow from banks to purchase capital from consumers, which they then invest in both long and short assets. Hence, deposits are created after the loans are made. Consumers use these deposits in their accounts to buy goods, and reserves are the means of transactions in the interbank market. The result illustrated that nominal deposit contracts could lead to the social planner's solution, just as real deposit contracts. Rivero and Rodriguez (2024) revisited Diamond and Dybvig (1983) with the model that incorporates the nominal deposit and debt contracts and interbank market similar to Allen, Carletti, et al. (2014). However, entrepreneurs in this economy own production technology. They borrow from banks to pay the wages to workers. Unlike entrepreneurs in other models that have to choose how much short assets to hold, they can liquidate their technology early without restrictions, except for the total amount of technology that they have. The results from Rivero and Rodriguez (2024) contradict with Allen, Carletti, et al. (2014) as the nominal deposit contracts do not lead to the welfare maximized solution.

This paper contributes to the literature by introducing a solvency shock on top of the liquidity shock in a nominal economy with an interbank market and a central bank.

The Economy with the Liquidity and Solvency Risks

The model follows the structure of Rivero and Rodriguez (2024), which incorporates a nominal economy into Diamond and Dybvig (1983). There are three time periods which are $t = 0, 1, 2$. A circular economy with unit 1 consists of continuous location $j \in [0, 1]$. A location comprises one unit of entrepreneurs, one unit of workers, and one representative commercial banks. There is only one central bank for the whole circular economy.

Commercial banks in every location face two types of idiosyncratic risks which are independent from each other; liquidity and solvency risks. Banks face liquidity risks as there is a chance that some agents in a certain location will be the early consumers. The type of preferences is denoted as $\tau \in \{1, 2\}$ according to the time of consumption. For any representative entrepreneur and worker in location j , there is a probability $\lambda(j)$, she will be impatient, preferring to consume in period 1 ($\tau = 1$). And with a probability $1 - \lambda(j)$, she will be patient, preferring to consume in period 2 ($\tau = 2$). $\lambda(j)$ is drawn from the distribution $\Phi(\lambda(j))$ with the support lying within the range $[0, 1]$ and the mean λ . The agent will get 0 utility for consuming in the period that is not her type. To be specific, the utility $U(c_1, c_2)$ is defined as,

$$U(c_1, c_2) = \{u(c_1) \text{ with probability } \lambda(j) \ u(c_2) \text{ with probability } 1 - \lambda(j)\}$$

$u(c)$ takes the form of a standard utility function, which is twice differentiable, strictly increasing, and strictly concave. It also satisfies the Inada conditions with the coefficient of relative risk aversion higher than 1.

$$\lim_{z \rightarrow 0} u'(z) \rightarrow \infty \quad , \quad \lim_{z \rightarrow \infty} u'(z) \rightarrow 0 \quad , \quad -\frac{zu''(z)}{u'(z)} > 1.$$

I assume that the preference shocks happen equally to both workers and entrepreneurs.

Another risk introduced to this model is the solvency risk, stemming from the probability that some locations will face low production in period 2. At the beginning of the economy $t = 0$, an entrepreneur in location j holds one unit of divisible production technology while a worker in the same location holds indivisible labor input of unit 1. A combination of a unit of technology and a unit of labor yields the output of 2 consumption goods if the production happens at $t = 1$ and 2ρ if the production happens at $t = 2$ where ρ is a random variable. In period 2, all entrepreneurs in location j will be able to deliver the output per capita ρ as,

$$\rho = \{R \text{ with probability } \pi \ r \text{ with probability } 1 - \pi.$$

with $0 < r < 1 < R$. I define the type $\rho = R$ as the high-production and $\rho = r$ as the low-production. Let $E\rho$ be the expected output per capita across locations, I presume that $E\rho = \pi R + (1 - \pi)r > 1$.

The efficient allocation

Before exploring further banks' and agents' actions in the nominal economy, it is worth mentioning the planner's solution. The planner gathers all resources from both entrepreneurs and workers, then chooses how much technology should be liquidated in period 1, how much technology should be left to produce in period 2, and how much each worker and entrepreneur should consume.

By the law of large numbers, a fraction π of locations will draw the high return R , and a fraction of $1 - \pi$ will draw the low return r . Since there is one unit of entrepreneurs in each location j , the gross output per capita will equal the expected output, which is $E\rho = \pi R + (1 - \pi)r$. Again, by the law of large numbers, the share of impatient agents for the whole economy is equal to the expectation, λ .

The planner chooses how much technology to liquidate, x , how much technology should be left for the production on period 2, and how much each agent consume to maximize the aggregate utility. Hence, the planner's problem is defined as,

$$\max_x \lambda u(c_1) + (1 - \lambda)u(c_2),$$

subject to the resource constraints

$$2\lambda c_1 \leq 2x, \quad [t = 1] \quad 2(1 - \lambda)c_2 \leq 2E\rho(1 - x) + 2x - 2\lambda c_1, \quad [t = 2] \quad 0 \leq x \leq 1.$$

By the assumption that $E\rho > 1$, it is not efficient for the planner to liquidate and store goods from period 1 to period 2. Hence, the storage, $2x - 2\lambda c_1$, equals zero. Solving the maximization problem, I have the optimal condition such that,

$$u'(c_1^*) = E\rho u'(c_2^*)$$

Nominal Economy

I explain the nominal economy in this section. Figure 1 summarizes the agents in the model and their actions in each period. The main assumption for this nominal economy is that entrepreneurs in location j can only borrow from a bank in the same location while the workers can buy goods from any entrepreneurs. Banks can do transactions with other banks from other locations in the interbank market.

To produce consumption goods, entrepreneurs need to combine both technology and labor input. Money is used as the means of payment, and entrepreneurs only own the production technology. With this demand to purchase labor input, the process of money creation begins. An entrepreneur asks for loans from a bank in a certain location. When the bank grants the nominal loan defined as $D_0(j)$, the deposit with the same number is generated in the entrepreneur's bank account, as illustrated in Figure 2. After the entrepreneur buys labor input from a worker in the same location, the deposit is transferred from the entrepreneur's account to the worker's. Deposits are used as a means of payments between entrepreneurs and workers. Banks also accept deposits as the means of paying debts.

Workers and entrepreneurs realize their types of preferences at the beginning of period 1. Workers who have carried deposits in their accounts from period 0 to 1 gain the interest rate i_0^d . Hence, their total deposit equals $[1 + i_0^d]D_0(j)$. The deposit rate i_0^d is the same across locations as all banks face the same uncertainty at $t = 0$. The impatient workers need to consume $c_1(j; 1)$. They withdraw their deposits to buy the consumption goods with the price P_1 . The patient workers can continue saving their deposits in the bank accounts or buy goods and store them for the next period.

Entrepreneurs choose to liquidate their technology $x(j; \tau)$ according to their types. The goods from liquidation are either consumed or sold in the market. Impatient entrepreneurs consume $z_1(j; 1)$ while patient entrepreneurs do not. Entrepreneurs accept deposits from workers as the means of payment and save their income as the deposits $D_1(j; \tau)$. Suppose a worker from location k buys a good from an entrepreneur in location j ; her bank in location k must transfer her deposit into the firm's account in location j , as shown in Figure 3.² The bank in location k will borrow the reserves from the central bank to use it as the means of the

² Since there is an infinite continuum of locations, there is zero probability that a worker will buy goods from her location.

interbank market's settlement. When it transfers the deposit of the worker to the firm's account, reserves are also transferred to the bank in location j . The bank of the worker is in the borrowing position to the central bank after the settlement. In practice, there is no need to borrow reserves every time a bank makes a payment to another bank. All payments are made, and it is the net interbank position that the central bank settles at the end of period 1.

Agents	$t=0$	$t=1$		$t=2$
		<ul style="list-style-type: none"> Liquidity shock realized Entrepreneurs and workers get the same probability of shock The share of patient agents is $\lambda(j)$ while the share of impatient agents is $1 - \lambda(j)$ 		<ul style="list-style-type: none"> Solvency shock realized. Get the same ρ for the whole location
commercial banks	<ul style="list-style-type: none"> Lend to entrepreneurs $D_0(j)$ 	<ul style="list-style-type: none"> Provide interest rate i_0^d to depositors Receive the gains of deposits and reserves for the transactions that the entrepreneur in location j sell goods Transfer deposits and reserves for transactions the workers buy food The reserve position is $M_1(j)$ 		<ul style="list-style-type: none"> Provide interest rate $i_1^d(j; \rho)$ to depositors Collect the debt from entrepreneurs $(1+i^b)D_0(j)$ Pay back the reserves with addition rate $(1+i^o)M_1(j)$ to the central bank if it is a borrower or receive $(1+i^o)M_1(j)$ if it is a net lender. Settle the interbank transaction as in $t=1$
Entrepreneurs	<ul style="list-style-type: none"> Borrow $D_0(j)$ from the bank in the same location j Pay $D_0(j)$ to workers 	Patient	<ul style="list-style-type: none"> Liquidate $x(j;2)$ to produce Sell $y_1(j; 2)$ into the market at the price P_1 Save deposits $D_1(j; 2)$ Meet the bank's expected asset constraint 	<ul style="list-style-type: none"> Produce $2\rho(1 - x(j; 2))$ Consume $z_2(j; 2; \rho)$ Sell unconsumed $y_2(j; 2; \rho)$ into the market at the price P_2 Have the debt $(1 + i^b)D_0(j)$ to pay back to the bank.
		Impatient	<ul style="list-style-type: none"> Liquidate $x(j;1)$ to produce Consume $z_1(j; 1)$ Sell unconsumed $y_1(j; 1)$ into the market at the price P_1 Save deposits $D_1(j; 1)$ Meet the bank's expected asset constraint 	<ul style="list-style-type: none"> Produce $2\rho(1 - x(j; 2))$ Sell $y_2(j; 1; \rho)$ into the market at the price P_2 Have the debt $(1 + i^b)D_0(j)$ to pay back to the bank.
workers	<ul style="list-style-type: none"> Receive $D_0(j)$ as wage Keep $D_0(j)$ in the bank accounts 	Patient	<ul style="list-style-type: none"> Withdraw $(1 + i_0^d)D_0(j)$ to buy goods at the price P_1 Consume $c_1(j; 1)$ 	
		Impatient	<ul style="list-style-type: none"> Continue saving $(1 + i_0^d)D_0(j)$ in the banks 	<ul style="list-style-type: none"> Withdraw $(1 + i_0^d)(1 + i_1^d(j; \rho))D_0(j)$ to buy goods at the price P_2 Consume $c_2(j; 2; \rho)$
the central bank		<ul style="list-style-type: none"> Provides reserves for the banks' settlement 		<ul style="list-style-type: none"> Collect the reserves debt with the policy rate $(1 + i^o)M_1(j)$ if the commercial bank is the net reserve borrower and pay the interest rate $(1 + i^o)M_1(j)$ if the commercial bank is the net lender.

Figure 1 Summary of the model

The production shock is realized at the beginning of period 2. There are risks that banks in the low production area may not be able to collect all debts. I presume that the loss from bad loans will transfer to the deposit rates. Hence, there are two deposit rates provided to the depositors; $i_1^d(j; R)$ if the location gains high production and $i_1^d(j; r)$ if the location gains low production. The deposit rates $i_1^d(j; \rho)$ are location-specific as the number of impatient agents will affect how much the banks can pay. Both entrepreneurs face the market price P_2 . Patient entrepreneurs sell the goods which are left from their consumption, while the impatient ones

sell all of their goods. All entrepreneurs use the deposits from $t = 1$ and the deposits from selling goods at $t = 2$ to pay the debt and interest rate $(1 + i^b)D_0(j)$ where i^b is the lending rate that is not location-specific. Banks gather their loans from the entrepreneurs, pay the debt to the central bank with the rate i^o if they are net reserve borrowers, and receive the gain i^o if they are the net lenders. i^o here is the monetary policy rate set by the central bank, namely, the rate that is used for reserve management.

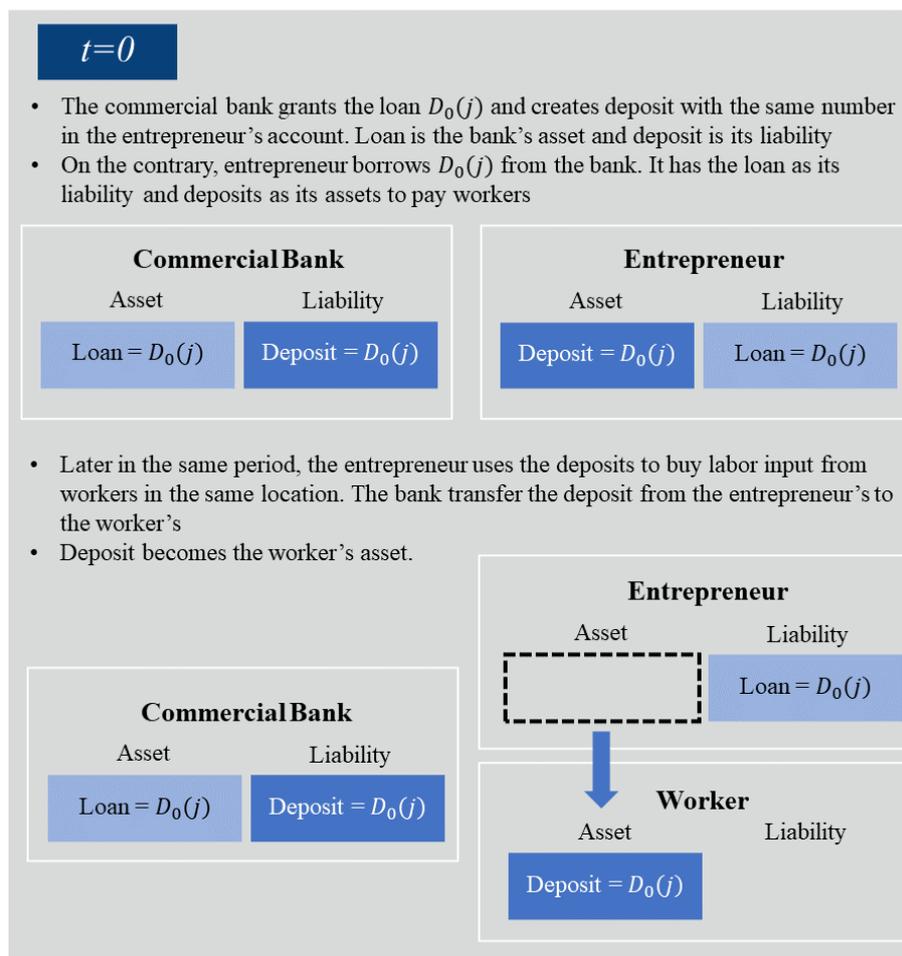
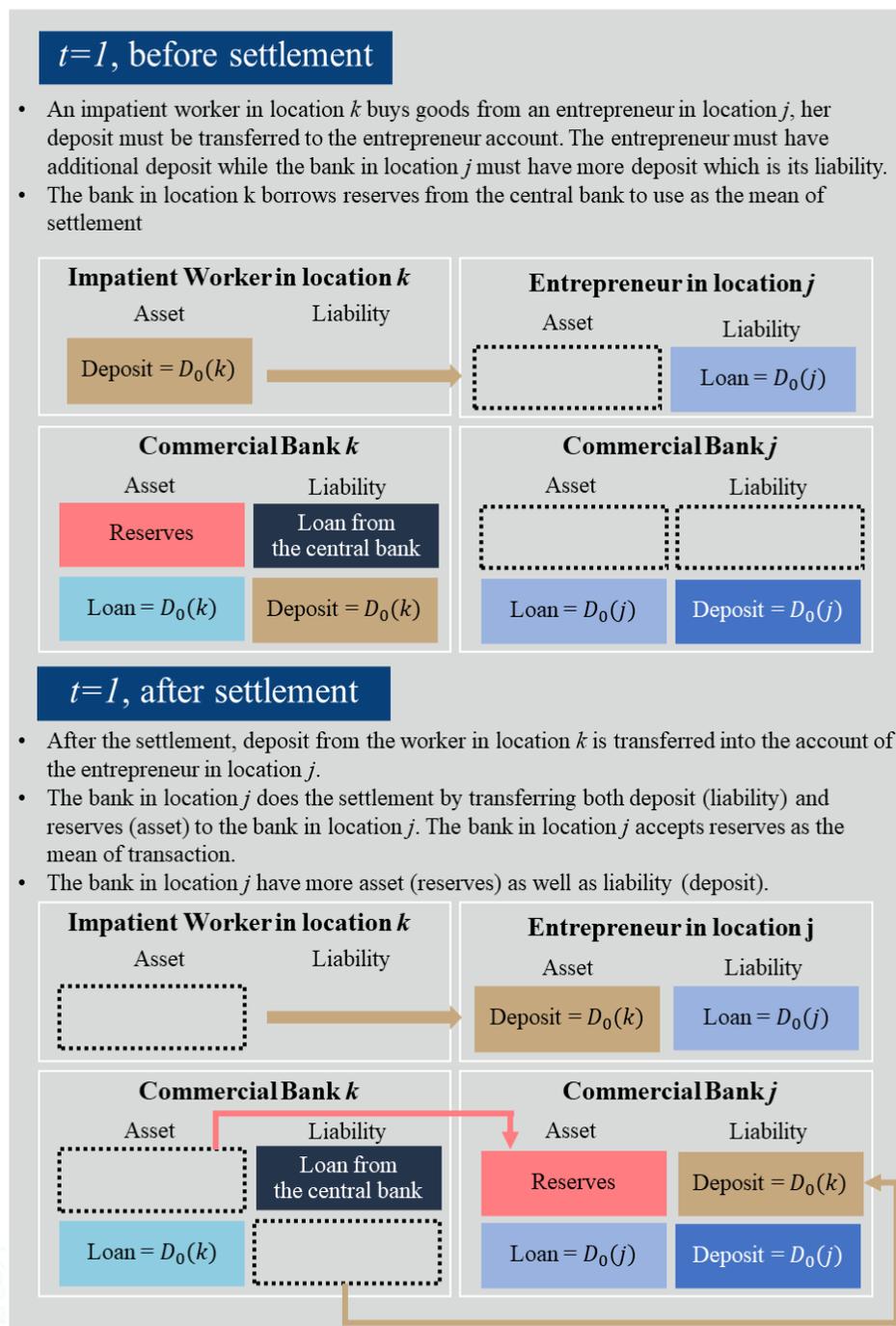


Figure 2 Balance sheets and settlements at $t = 0$

Banks' risk management

Debts are fully paid in the models with no uncertainties in production or asset return. In this model, with the uncertainty in production, there is no guarantee that entrepreneurs will pay the full amount of debt. If the representative bank constructs the condition that banks will take everything from entrepreneurs in case entrepreneurs are not able to pay the debt, only patient entrepreneurs will try to pay in order to prevent zero consumption. Without any further restrictions, impatient entrepreneurs will liquidate everything in period 1 and consume because banks' measures only affect consumption in period 2. For these reasons, the bank needs to set the requirement conditions from banks in both periods 1 and 2.

Figure 3 Balance sheets and settlements at $t = 1$

At $t = 1$, entrepreneurs gain deposits from selling goods.

$$D_1(j; \tau) = P_1[2x(j; \tau) - (2 - \tau)z_1(j; \tau)]$$

Banks require every entrepreneur to meet the nominal expected-asset constraint at $t = 1$.

$$(1 + i^b)D_0 \leq [1 + Ei_1^d(j; \rho)]D_1(j; \tau) + 2P_2E\rho(1 - x(j; \tau))$$

$Ei_1^d(j; \rho) = \pi i_1^d(j; R) + (1 - \pi)i_1^d(j; r)$ is the expected interest rate paid at $t = 1$. Hence, $[1 + Ei_1^d(j; \rho)]D_1(j; \tau)$ is the expected value from saving in deposits. $2P_2E\rho(1 - x(j; \tau))$ is the expected gain from saving in terms of real technology. Combining both nominal and real (technology) assets, the expected value should cover the debt that entrepreneurs have pay in at $t = 2$. If the entrepreneurs fail to meet the condition, the banks will take everything from them, leading the consumption to be zero.

In period 2, banks will take everything from the entrepreneur if they cannot pay the debt. I assume banks can track all assets of the entrepreneurs, so there is no entrepreneur trying to hide their asset in terms of technology. Entrepreneurs can negotiate with banks. Banks will take $(1 - n)$ of the entrepreneur's total assets in the nominal value and let the entrepreneurs have n for consumption. n can be treated as the minimum consumption for entrepreneurs. It is assumed that n is small enough that the asset after banks take $(1 - n)$ part is always smaller than the asset left after paying the full debt.

Suppose the nominal asset of an entrepreneur is 100 euros, consisting of 50 euros deposits and 50 euros of the priced value of the goods that have not yet been sold. In practice, the bank will not equally take $(1 - n)50$ from the deposits and $(1 - n)50$ of the goods as it operates only with nominal assets. Instead, it will take all the deposits and force the entrepreneur to sell goods until the deposits in the account and the inflow deposits from selling goods add up to $(1 - n)100$ euros. The goods that are not forced to sell are for the entrepreneur's consumption. I define $(1 - m)$ as the fraction of goods forced to sell and m as what is left for entrepreneurs' consumption.

$$2(1 - n)[P_1[1 + 1_1^d(j; r)]x(j; \tau) + P_2r(1 - x(j; \tau))] = 2P_1[1 + 1_1^d(j; r)]x(j; 2) + 2P_2r(1 - m)(1 - x(j; \tau))$$

The left-hand side (LHS) is $(1 - n)$ of the total assets, and the right-hand side (RHS) is the total deposits, including the gains from selling goods.

Solving the equation yields,

$$(1 - m) = (1 - n) - \frac{(n)P_1[1 + 1_1^d(j; r)]x(j; \tau)}{P_2r(1 - x(j; \tau))}$$

This method of collecting debt is crucial for the reserves and interest rates calculations, which I will mention in the later part. Notice that impatient entrepreneurs will not negotiate since the consumption in period 2 does not matter to them. They will only try to meet the nominal expected-asset constraint. Additionally, only the impatient entrepreneurs will negotiate with the banks if they are not able to pay the debt.

Impatient entrepreneurs

An impatient entrepreneur in location j liquidates $x(j; 1)$. She consumes $z_1(j; 1)$ before selling the rest of the goods in the market. The output $y_1(j; 1)$ sold to the market takes the value,

$$0 \leq y_1(j; 1) \leq 2x(j; 1) - z_1(j; 1)$$

conditionally on its limited technology resources,

$$0 \leq x(j; 1) \leq 1$$

The deposits gained from selling goods is,

$$0 \leq D_1(j; 1) \leq P_1 y_1(j; 1)$$

Without any monitoring or restriction, she has incentives to liquidate all technology and consume all the goods in $t = 1$. In this mode, impatient entrepreneurs are subject to meeting the banks' expected-asset constraint. Hence, the impatient entrepreneurs' problem is to choose how much to liquidate and maximize her consumption in period 1,

$$u(z_1(j; 1))$$

subject to the constraints stated and the expected-asset constraint.

Patient entrepreneurs

A patient entrepreneur faces uncertainty in her consumption in period 2. In period 1, she can liquidate some of the technology and save in the form of deposits. Hence, she also faces similar constraints as the impatient entrepreneurs.

$$\begin{aligned} 0 \leq y_1(j; 2) &\leq 2x(j; 2) \\ 0 \leq x(j; 1) &\leq 1 \\ 0 \leq D_1(j; 2) &\leq P_1 y_1(j; 2) \end{aligned}$$

The production shock is realized at $t = 2$. The consumption equations of the patient entrepreneur with different types of production levels $z_2(j; 2; \rho)$ are as the followings.

If the entrepreneur is in the high production area, she can consume what is left after paying debt $(1 + i^b)D_0$

$$z_2(j; 2; R) = \frac{P_1[1 + i_1^d(j; R)]D_1(j; 2) + 2P_2R(1 - x(j; 2)) - (1 + i^b)D_0}{P_2}$$

And the output sold to the market is,

$$0 \leq y_2(j; 2; R) \leq 2R(1 - x(j; 2)) - z_2(j; 2; R)$$

If she is in the low production area and fails to pay the debt, she can consume what is left after the negotiation.

$$z_2(j; 2; r) = \frac{n(2P_1[1 + i_1^d(j; r)]x(j; 2) + 2P_2r(1 - x(j; 2)))}{P_2} = 2mr(1 - x(j; 2))$$

And the output that is forced to sell by bank to the market is,

$$0 \leq y_2(j; 2; r) = 2(1 - m)r(1 - x(j; 2))$$

The only choice that the impatient entrepreneur can make is how much she should liquidate at $t = 1$ to maximize her expected utility.

$$\max_{x(j; 2)} \pi u(z_2(j; 2; R)) + (1 - \pi)u(z_2(j; 2; r))$$

subject to the constraints stated and the expected-asset constraint.

There are two main points to be noted. Firstly, the total assets in both deposits and in technology, in period 1 of patient entrepreneurs will be weakly higher than the impatient entrepreneurs' since they do not have to consume the liquidated good. Secondly, the preference and production uncertainties that are realized in different time periods make two types of entrepreneurs act differently and have different preferences even though they share the same utility function. The patient entrepreneurs maximize the utility at $t = 1$ and had to follow one restriction by the bank which is the expected-asset constraint. In contrast, patient entrepreneurs face uncertainty in production. They need to choose how much to liquidate at $t = 1$ to maximize their expected consumption.

Workers

At $t = 1$, an impatient worker in location j withdraws her deposits to buy consumption goods.

$$c_1(j; 1) = \frac{[1 + i_0^d]D_0(j)}{P_1}$$

A patient worker continues saving for another period. The return of deposits she receives depends on the production type of her location.

$$c_2(j; 2; \rho) = \frac{[1 + i_0^d][1 + i_1^d(j; \rho)]D_0(j)}{P_2}$$

If patient workers expect a high number of loan losses in period 2, it is possible for patient workers to consider storing the goods from period 1 to period 2. This is because the high loan losses will lower the deposit rates, making the patient workers able to consume less. I will discuss storing and bank runs in the competitive equilibrium part.

Balance Sheets of Commercial banks

The net worth of the representative bank in location j is,

$$NW_t^B(j) = L_t(j) + M_t(j) - D_t(j)$$

where $L_t(j)$ is the loan provided and $D_t(j)$ is the deposits. $M_t(j)$ is the net reserve position which is negative when the bank is a net reserve borrower and positive when the bank is the net lender.

Net Worth in Periods 0 and 1

All agents in every location are the same in period 0. Therefore, all banks provide the same amount of loans $D_0(j) = D_0$. With loans D_0 generated, the deposits of the same amount D_0 is also generated. There is no reserve borrowed or lent in this period. By construction, the net worth of period 0 is,

$$NW_0^B(j) = D_0(j) + 0 - D_0(j) = 0$$

In period 1, the amount of loan is still the same, which is D_0 the bank provides interest rates i_0^d for deposits that were carried across periods. Entrepreneurs liquidate, sell goods in the market, and receive income in the form of deposits. The net deposits for the bank is,

$$D_1(j) = (1 + i_0^d)D_0 - \lambda(j)P_1c_1(j; 1) + \lambda(j)D_1(j; 1) + [1 - \lambda(j)]D_1(j; 2)$$

$(1 + i_0^d)D_0$ is the old deposits of the workers plus the interest rates. $\lambda(j)P_1c_1(j; 1)$ is the outflow of the impatient workers who withdraw to buy goods. $\lambda(j)D_1(j; 1)$ and $[1 - \lambda(j)]D_1(j; 2)$ are the deposit inflows from the impatient and patient entrepreneurs, respectively. In contrast to the balance sheet in period 0, the idiosyncratic preference shock $\lambda(j)$ starts to affect banks in different locations differently.

The reserves are the net settlement to other banks. If a worker withdraws and pays to an entrepreneur in a different location, the bank has to transfer the deposit using reserves as the mean of the transaction. On the contrary, if a worker from another location pays to the entrepreneur in location j , the bank will gain the flows of deposits and reserves. Hence, the reserves is,

$$M_1(j) = -\lambda(j)P_1c_1(j; 1) + \lambda(j)D_1(j; 1) + [1 - \lambda(j)]D_1(j; 2)$$

If the reserve position is negative, it means there are more outflows than inflows. The bank is the net borrower to the central bank and vice versa.

The net worth of the bank in this period is,

$$NW_1^B(j) = L_1(j) + M_1(j) - D_1(j) = D_0 - (1 + i_0^d)D_0$$

I further assume that there is perfect competition and banks cannot make the rents from the market. Therefore, the net worth in every period must be 0. Solving the equations, we have, $i_0^d = 0$.

Loss realization and extra production

Before exploring net worth at $t = 2$, it is necessary to discuss how banks take losses into their balance sheets when the location reaches low production. On the asset side, it lowers the value it can recover from the loan, while on the liability side, the flow of deposits decreases to the same amount. Define $l(j; \tau)$ as the accounting losses banks take from the entrepreneurs of type τ . $(1 + i^b - l(j; \tau))D_0$ should equal to the deposits that it can collect. For example, suppose that an impatient entrepreneur i is indebted for 120 euros,

but all of her assets can pay only 100 euros. Her bank will take all the deposits in the account and the new deposits from selling goods. However, in the bank account, it will decrease the loan income to 100 euros and the loss $l(j; \tau)$ is 20 euros.

Impatient entrepreneurs do not need to negotiate with the bank. The bank can force them to sell all of the production goods and take all the entrepreneurs' deposits. When the location reaches low production, the low deposit rate also decreases the value of deposits that the entrepreneurs hold.

$$(1 + i^b - l(j; 1))D_0 = [1 + i_1^d(j; r)]D_1(j; 1) + 2P_2r(1 - x(j; 1)) = [1 + i_1^d(j; r)]D_1(j; 1) + P_2y_2(j; 1; r)$$

where $y_2(j; 1; r) = 2r(1 - x(j; 1))$ is the goods that the impatient entrepreneurs sell to the market in period 2 when they have low production.

Patient entrepreneurs negotiate, and banks only force them to sell some amount of consumption goods.

$$\begin{aligned} (1 + i^b - l(j; 2))D_0 &= [1 + i_1^d(j; r)]D_1(j; 2) + 2P_2r(1 - m)(1 - x(j; 2)) \\ &= [1 + i_1^d(j; r)]D_1(j; 2) + P_2y_2(j; 2; r) \end{aligned}$$

In high-production locations, banks can collect their debts. However, there is extra production from the impatient entrepreneurs. This is because, at $t = 1$, they are required to hold enough expected assets to pay the debt. The expected constraint binds with equality since there is no additional gain from decreasing the consumption at $t = 1$ to have more assets in $t = 2$.

Suppose there exists the optimal liquidation $x^*(j; 1)$, the optimal consumption at $t = 1$, $z_1^*(j; 1)$, and the optimal deposits $D_1^*(j; 1)$ satisfying the impatient entrepreneur problem; from the expected-asset constraint, the value of loans in period 2 $(1 + i^b)D_0$ equals to the expected value of the expected assets

$$(1 + i^b)D_0 = P_1[1 + E i_1^d(j; \rho)][2x^*(j; 1) - z_1^*(j; 1)] + 2P_2E\rho(1 - x^*(j; 1))$$

When the location achieves high production, the deposit rate paid will be higher than the expected rate, $i_1^d(j; R) > E i_1^d(j; \rho)$ and the production per capital will be higher than the expected value, the $R > E\rho$. With the same value of $x^*(j; 1)$, $z_1^*(j; 1)$, and $D_1^*(j; 1)$, the ex-post assets of the impatient entrepreneurs will be larger than the debts that they need to pay.

$$\begin{aligned} (1 + i^b)D_0 &= P_1[1 + E i_1^d(j; \rho)][2x^*(j; 1) - z_1^*(j; 1)] + 2P_2E\rho(1 - x^*(j; 1)) \\ &< P_1[1 + i_1^d(j; 1)]D_1^*(j; 1) + 2P_2R(1 - x^*(j; 1)) \end{aligned}$$

In this setup, the bank will take deposits from the impatient entrepreneurs up to $(1 + i^b)D_0$ and leave the rest $W(j; 1; R)$ in the entrepreneurs' accounts. This money is left for nothing as I assume that the banks cannot collect more than $(1 + i^b)D_0$.

$$\begin{aligned}(1 + i^b)D_0 &= P_1[1 + i_1^d(j; 1)]D_1^*(j; 1) + 2P_2R(1 - x^*(j; 1)) - W(j; 1; R) \\ &= P_1[1 + i_1^d(j; 1)]D_1^*(j; 1) + P_2y_2(j; 1; R) - W(j; 1; R)\end{aligned}$$

Net Worth in period 2 and the Deposit Rates

At $t = 2$, loans take different values with different states of production. For the banks in high-production locations, they can collect the loans as the following.

$$L_2(j; R) = (1 + i^b)D_0$$

In the low-production locations, the banks take the losses into their account.

$$\begin{aligned}L_2(j; r) &= \lambda(j)(1 + i^b - l(j; 1))D_0 + (1 - \lambda(j))(1 + i^b - l(j; 2))D_0 \\ &= (1 + i^b)D_0 - (\lambda(j)l(j; 1) + (1 - \lambda(j))l(j; 2))D_0\end{aligned}$$

Regarding the deposits, the bank has to pay deposit rate $i_1^d(j; \rho)$ to all deposit holders. Patient entrepreneurs will withdraw their deposits to buy goods with the value $P_2c_2(j; 2; \rho)$. All entrepreneurs in the high-production areas use deposits to pay all their debts. With low production, the entrepreneurs cannot pay all the debts. They will pay according to their production levels. Hence, the deposits with different levels of production are,

$$\begin{aligned}D_2(j; R) &= (1 - \lambda(j)) \left[(1 + i_0^d) \left((1 + i_1^d(j; R)) D_0 - P_2c_2(j; 2; R) \right) \right. \\ &\quad \left. + \lambda(j) \left[(1 + i_1^d(j; R)) D_1(j; 1) + P_2y_2(j; 1; R) - W(j; 1; R) \right] \right. \\ &\quad \left. + (1 - \lambda(j)) \left[(1 + i_1^d(j; R)) D_1(j; 2) + P_2y_2(j; 2; R) \right] \right]\end{aligned}$$

$$\begin{aligned}D_2(j; r) &= (1 - \lambda(j)) \left[(1 + i_0^d) \left((1 + i_1^d(j; r)) D_0 - P_2c_2(j; 2; r) \right) \right. \\ &\quad \left. + \lambda(j) \left[(1 + i_1^d(j; r)) D_1(j; 1) + P_2y_2(j; 1; r) \right] \right. \\ &\quad \left. + (1 - \lambda(j)) \left[(1 + i_1^d(j; r)) D_1(j; 2) + P_2y_2(j; 2; r) \right] \right]\end{aligned}$$

In both equations, the first term refers to the value of deposits that patient workers have carried from period 1 to 2 deducted by how much they withdraw for consumption. The second and the third terms represent the deposit of impatient and patient entrepreneurs, respectively.

Banks hold the reserves $M_1(j)$ from $t = 1$ with the interest rate charged or paid by the central bank $(1 + i^o)$. Hence, the reserves that the banks in the high-production locations are,

$$\begin{aligned}M_2(j; R) &= (1 + i^o)M_1(j) - (1 - \lambda(j))P_2c_2(j; 2; R) + \lambda(j)[P_2y_2(j; 1; R) - W(j; 1; R)] \\ &\quad + (1 - \lambda(j))[P_2y_2(j; 2; R)]\end{aligned}$$

And in the low-production locations,

$$\begin{aligned}M_2(j; r) &= (1 + i^o)M_1(j) - (1 - \lambda(j))P_2c_2(j; 2; r) + \lambda(j)[P_2y_2(j; 1; r)] \\ &\quad + (1 - \lambda(j))[P_2y_2(j; 2; r)]\end{aligned}$$

Hence, the bank's net worth at $t = 2$ for the high production is,

$$\begin{aligned} NW_2^B(j; R) = L_2(j) + M_2(j) - D_2(j; R) = & \left[1 + i^b - (1 + i_0^d) (1 + i_1^d(j; R)) \right] D_0 \\ & - \lambda(j) \left[1 + i^o - (1 + i_0^d) (1 + i_1^d(j; R)) \right] D_0 \\ & + \lambda(j) [i^o - i_1^d(j; R)] D_1(j; 1) + (1 - \lambda(j)) [i^o - i_1^d(j; R)] D_1(j; 2) \end{aligned}$$

The first term is the revenues from generating loans. The other terms are the costs and the revenues associated with the banks' transactions with the central bank.

Net worth for the low production is almost similar, but with the losses from entrepreneurs that are not able to pay the debts.

$$\begin{aligned} NW_2^B(j; R) = L_2(j) + M_2(j) - D_2(j; r) = & \left[1 + i^b - (1 + i_0^d) (1 + i_1^d(j; r)) \right] D_0 \\ & - [\lambda(j)l(j; 1) + (1 - \lambda(j))l(j; 2)] D_0 - \lambda(j) \left[1 + i^o - (1 + i_0^d) (1 + i_1^d(j; R)) \right] D_0 \\ & + \lambda(j) [i^o - i_1^d(j; r)] D_1(j; 1) + (1 - \lambda(j)) [i^o - i_1^d(j; r)] D_1(j; 2) \end{aligned}$$

With perfect competition and equating the net worth to 0, the deposit rates for the high and low-production locations are,

$$\begin{aligned} i_1^d(j; R) = i^o + & \frac{(i^b - i^o) D_0}{[1 - \lambda(j)] D_0 + \lambda(j) D_1(j; 1) + [1 - \lambda(j)] D_1(j; 2)} \\ i_1^d(j; r) = i^o + & \frac{[i^b - i^o - (\lambda(j)l(j; 1) + (1 - \lambda(j))l(j; 2))] D_0}{[1 - \lambda(j)] D_0 + \lambda(j) D_1(j; 1) + [1 - \lambda(j)] D_1(j; 2)} \end{aligned}$$

The losses make the interest rate weakly lower if the location reaches low production. Allen, Carletti, et al. (2014) studied the idiosyncratic preference shock and the production (in their paper, asset returns) shock separately. In this model, I combine both shocks and find that the idiosyncratic shock also has an impact on the losses from production shock. How much the loss from low production will also depend on the number of impatient agents in that location.

The Central Bank

The central bank provides reserves for banks to use as the means of transaction in the interbank market. It also charges the monetary policy rate to those who are the net reserve borrowers. At $t = 1$, banks are still not subject to high and low production. Therefore, banks are only different to each other by the number of impatient agents in their location. The central bank balance sheet at $t = 1$ equals,

$$NW_1^{CB} = \int_0^1 M_1(j) d\Phi(\lambda(j))$$

And in the second period, it gains the interest rate.

$$NW_2^{CB} = (1 + i^b) \int_0^1 M_1(j) d\Phi(\lambda(j))$$

Results of the Competitive Equilibrium and the Monte Carlo Experiment

The interest rate equations in period 2 are the most important equations in this study as they illustrate that the production losses deteriorate the interest rate and the gain from holding deposits. In the literature without uncertainty in period 1, a bank run happens when patient workers expect that $c_1 > c_2$. In this model with production uncertainty, bank runs occur when the value of withdrawing at $t = 1$ and storing the good for one period is higher than the expected utility of continuing saving in deposits and accepting the risk of receiving low interest rates.

$$u\left(\frac{D_0}{P_1}\right) \geq \pi u\left(\frac{[1 + i_1^d(j; R)]D_0}{P_2}\right) + (1 - \pi)u\left(\frac{[1 + i_1^d(j; r)]D_0}{P_2}\right)$$

The LHS is the utility from buying good in period 1 and storing, while the RHS is the expected utility from saving in terms of deposits. When a patient worker realizes $\lambda(j)$ and see that her expected utility is lower than the utility from storing, she will withdraw from the bank store the goods.

To make the reference easier, I define $\phi(j)$ as the difference between the expected utility from saving in the deposits and the utility from withdrawing at $t = 1$ and storing the goods. Locations with $\phi(j) < 0$ are facing bank runs.

$$\phi(j) = \pi u\left(\frac{[1 + i_1^d(j; R)]D_0}{P_2}\right) + (1 - \pi)u\left(\frac{[1 + i_1^d(j; r)]D_0}{P_2}\right) - u\left(\frac{D_0}{P_1}\right)$$

The value of $\phi(j)$ depends on the prices in the competitive equilibrium as well as other parameters, such as the CRRA coefficients. The prices are also subject to which locations received the low production shock. It is almost impossible to find analytical solutions or inferences. One solution is to simulate the economy and draw the shock for each location. Nevertheless, one round of shock drawing still makes the equilibrium subject to the specific locations that have low production. For these reasons, I construct a Monte Carlo experiment by simulating the economy and drawing the shock for many rounds. By the law of large numbers, the realized frequencies of shock for each location should converge to the probability. Hence, I should be able to make some inferences. The algorithm to solve for the competitive equilibrium is discussed in the online appendix.

The competitive equilibrium used in the algorithm is defined as the followings,

Definition 1 (Competitive Equilibrium). The competitive equilibrium is, $\forall j$ and $\forall \rho$

- The workers' allocation $w^w = \{c_1(j; \tau), c_2(j; \tau; \rho)\}$
- The entrepreneurs' allocation
 $w^f = \{z_1(j; \tau), z_2(j; \tau; \rho), y_1(j; \tau), y_2(j; \tau; \rho), x(j; \tau)\}$
- The nominal allocation $w^n = \{D_0(j), D_1(j; \tau), M_1(j), M_2(j)\}$
- The price $w^p = \{P_1, P_2\}$
- The market interest rates $w^i = \{i_0^d, i_1^d(j; \rho), i^b\}$
- The monetary policy i^o

such that

- Given w^p , i_0^d , $i_1^d(j; \rho)$, and $D_0(j)$; w^w satisfies workers' problem.
- Given w^p and w^i ; w^f satisfies entrepreneurs' problem.
- Given w^p , w^n , w^i , and i^o ; The banks' net worth is zero $\forall t = 0, 1, 2$.
- Let $l\{\text{condition} = \text{true}\}$ be the index function, all good markets clear

$$\int_0^1 [y_1(j; 1) + y_1(j; 2) - c_1(j; 1)] d\Phi(\lambda(j)) = 0$$

$$\int_0^1 \left[l\{\rho = R\} \sum_{\tau=1,2} y_2(j; \tau; R) + l\{\rho = r\} \sum_{\tau=1,2} y_2(j; \tau; R) \right] d\Phi(\lambda(j))$$

$$= \int_0^1 [l\{\rho = R\} c_2(j; \tau; R) + l\{\rho = r\} c_2(j; \tau; R)] d\Phi(\lambda(j))$$

The utility function in the Monte Carlo experiment takes the form as,

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}$$

where γ is the constant relative risk aversion (CRRA) coefficients

Results from the Monte Carlo Experiment

In this session, I discuss the results of the Monte Carlo experiment, which satisfy the definition of the competitive equilibrium. I focus on changing two parameters which are CRRA coefficient and the π , probability of receiving low production. The details about parameters that remain the same across the experiment are described in Table 1. It is worth noting that all of the cases illustrated have $E\rho > 1$, implying that there is no storing the planner's solutions, and it is optimal to produce at $t = 2$.

Table 1: Details about parameters

Parameter	Description	Value
R	high production level	1.4
r	low production level	0.3
$E\rho$	expected per capita output at $t = 2$	1.29
λ	expectation of $\lambda(j)$	0.5
n	share of assets the entrepreneurs can negotiate with banks	0.05
i^o	the monetary policy rate	0.05

Figure 4 shows the results from the different CRRA coefficients, namely, the economies with different levels of risk aversions. One variable that I focus on is $\phi(j)$, which is on the top-left corner. The x-axis represents locations and $\lambda(j)$. From equation $\phi(j)$, a location is facing a bank run if $\phi(j)$ is below zero.

It can be counterintuitive that $\phi(j)$ is increasing in $\lambda(j)$, across different CRRA coefficients. I can draw the interpretation from two reasons.

Firstly, there are more patient workers to run the banks. Unlike impatient workers who have already consume in period 1, these workers have to monitor how much the interest rate their banks can pay in period 2. The second reason is the degree of risk aversion. A location with a higher number of impatient agents has a higher deposit rate in period 1 when there is high production and a lower deposit rate where there is low production. In locations with larger liquidity shocks, the utility gains from high production can compensate for the utility. This is not the same for locations with more patient consumers.

I also examine the chance of bank runs when the economy has a lower probability of high production, namely, when there is a higher widespread of low production. Figure 5 shows the result when I lower π from 0.85 to 0.9. It revealed that the economy is sensitive to higher probability of production losses. With more locations facing low production, the banks can provide lower deposit rates to the depositors. The low return on deposits also makes patient entrepreneurs save lower in terms of deposits. When more entrepreneurs save on

technology, the banks are more prone to production losses. This is feed-backed to the deposit rates, making the rates lower.

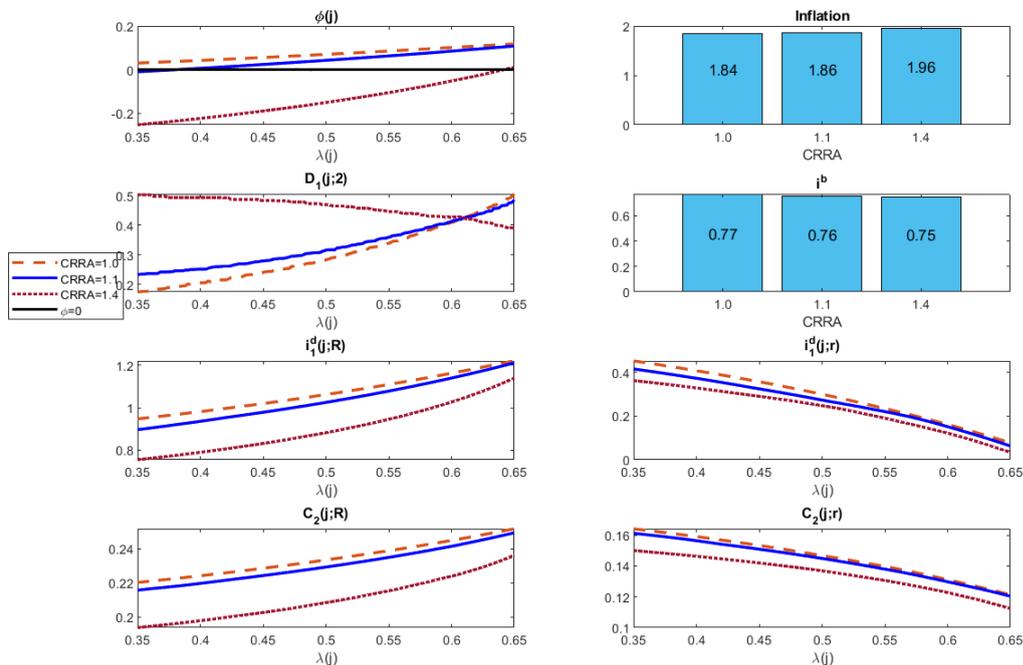


Figure 4 Allocations with different CRRA coefficients

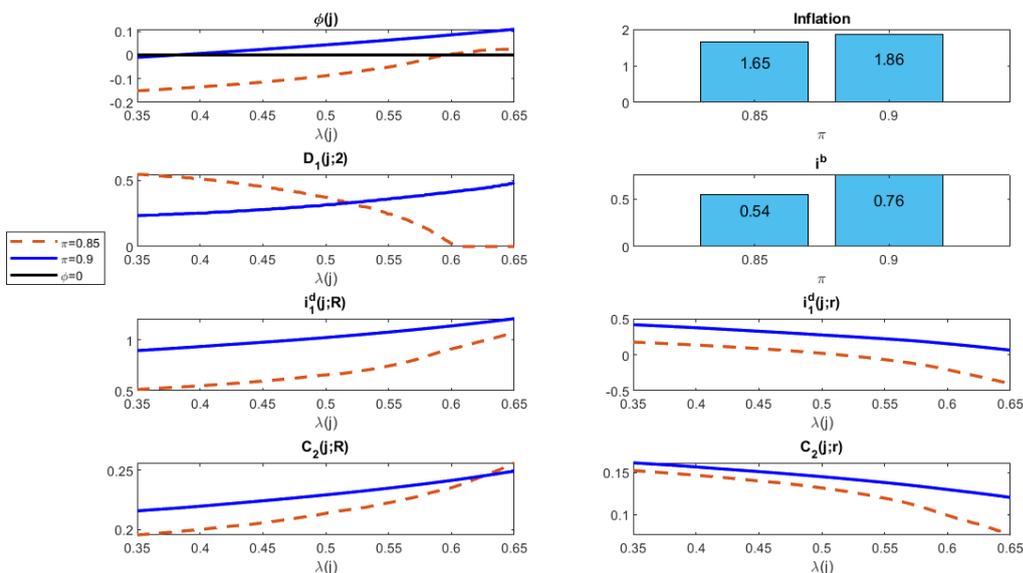


Figure 5 Allocations with different probability of high production

Conclusions

In this model, I examine the risks of bank runs when the solvency and liquidity shocks interact in the context of the complicated modern banking system. When the production shock is absent, leaving only the preference shock, the reserve system managed by the central bank can maintain economic stability by supplying liquidity (Allen, Carletti, et al. 2014; Rivero and Rodriguez 2024). There is no bank run, and the prices will absorb the shock. The nominal variables, such as the number of loans provided to each bank, the monetary policy rate, or the lending rate, do not have a real impact on the economy. When the economy experiences a combination of locational production shock and idiosyncratic preference shocks, the number of depositors affects the deposit rates paid by the bank of that particular location. There is a probability of bank runs, especially when highly risk-averse agents populate the economy.

Though the conclusions of this model are crucial, this study has some limitations. Firstly, it assumes that workers can only hold nominal assets in the form of deposits. In reality, a worker can also invest in technology or other types of assets. Incorporating the models of a family consisting of workers and managers can provide more insight (Lucas 1978; Guner, Ventura, and Xu 2008). Secondly, it has not yet tested the cases in which banks are more optimistic or pessimistic about the shocks. Having more prudent banks that require entrepreneurs to hold enough assets even during the low-production time can stabilize the economy too. Such aspects are open to future studies.

One final observation is that we obtained such results because the central bank in this model acts fully and rationally as the lender of last resort. Namely, it provides enough reserves to meet the demand. In practice, central banks may not be able to assess the magnitude of the liquidity shock accurately, or there may be delays or legal frictions that prevent banks from receiving the liquidity on time. Additionally, there is the issue of trust and credibility (Duggal and Rojas 2023), which can be a topic for further study (Chamornchan 2025). Although it is not within the scope of this paper, it is trivial to conclude that if the central bank cannot act fully as the lender of the last resort, the whole economy is at risk of bank runs.

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Volatility Interdependence in Emerging Market Currencies: A Study of BRICS and Thailand

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Abstract: This study investigates the volatility interdependence among the exchange rates of BRICS countries, Brazil, Russia, India, China, South Africa, and Thailand against the U.S. dollar over the period from 2013 to 2023. By employing the ARMA-EGARCH model, the research captures key features of exchange rate dynamics, including volatility clustering, persistence, and asymmetric responses to shocks. To further explore the complex and nonlinear dependence structure among these currencies, the study utilizes both Canonical Vine (C-Vine) and Drawable Vine (D-Vine) copula models. The results reveal significantly lower tail dependence, particularly involving the ZAR/USD and INR/USD exchange rates, indicating strong co-movement risks during financial stress. The C-Vine model anchored by ZAR/USD as the root node provides a superior fit based on AIC and BIC criteria, suggesting that most systemic dependence is concentrated in the first two vine layers. These findings underscore the systemic relevance of certain currencies in regional risk propagation and provide critical insights for policymakers and investors in managing exchange rate risks, especially during episodes of geopolitical and economic uncertainty.

Keywords: Exchange rate, Volatility, Dependence structure, BRICS, Thailand



Introduction

The global foreign exchange (FX) market is fundamental to international trade, investment, and financial stability, facilitating economic transactions across borders. As financial markets become increasingly interconnected, exchange rate volatility has emerged as a critical area of economic research (Diebold and Yilmaz 2009). Fluctuations in exchange rates significantly affect macroeconomic stability, trade competitiveness, and cross-border capital flows (IMF, 2023), particularly for emerging economies where resilience in managing currency risks effectively (Aizenman and Hutchison, 2012). Among these economies, the BRICS nations, namely Brazil, Russia, India, China, and South Africa and Thailand stand out due to their dynamic trade activities, growing economic integration, and influence on international financial trends (World Bank, 2023; IMF, 2022).

Exchange rate volatility stems from a complex interplay of domestic and international factors, including geopolitical tensions, inflationary pressures, trade imbalances, and monetary policy shifts. The Russia-Ukraine conflict, for example, has intensified global financial instability, disrupted trade flows, and reshaped currency dependencies (Sharma et al., 2024; Xu & Cao, 2023). Sanctions on Russia have further amplified volatility, generating ripple effects in emerging markets, including BRICS and Thailand (Hamza et al. 2024; Thapa 2024). Similarly, the U.S.-China trade war has restructured global trade patterns, exposing BRICS currencies to heightened uncertainty and risk (Murthy and Kalsie 2019; Cepni et al. 2023).

Thailand, as one of Southeast Asia's leading export-driven economies, is particularly sensitive to exchange rate fluctuations. Stable and predictable exchange rate dynamics are crucial for sustaining Thailand's international trade relationships, which form a significant pillar of its economic growth. In 2023, Thailand's exports to BRICS countries were valued at \$57,211.0 million, accounting for 20.1 percent of its total exports and reflecting a modest growth of 0.4 percent (Bangkokbiz, June 1, 2024). Among these exports, China represented the largest trading partner within BRICS, contributing 12 percent of Thailand's total exports, followed by India (3.6%) and South Africa (1.2%). These figures underscore the critical importance of maintaining competitive trade conditions and managing exchange rate risks to ensure sustained economic performance.

Exchange rate volatility presents both opportunities and challenges for Thailand and BRICS nations. A depreciation of the Thai Baht relative to BRICS currencies can make Thai exports more affordable, potentially boosting demand and trade flows. Conversely, excessive volatility or an appreciation of the Baht can undermine export competitiveness, leading to reduced trade volumes, economic imbalances, and diminished foreign direct investment. Additionally, heightened exchange rate uncertainty complicates financial planning for businesses, impacting profit margins, pricing strategies, and investment decisions.

Amid intensifying global uncertainties, BRICS countries have increasingly sought to reduce their reliance on the U.S. dollar by promoting the use of local currencies, particularly the Chinese yuan, in international trade (Cheung 2023). This strategic shift has been further accelerated by geopolitical tensions, notably the Russia-Ukraine conflict, which disrupted financial flows and altered currency dependencies. However, despite these efforts, challenges persist due to the limited global liquidity of non-dollar currencies

and the entrenched dominance of the dollar in global trade and finance. As BRICS nations navigate these disruptions, the intricacies of exchange rate dynamics have become even more critical for managing financial stability and sustaining international trade relationships (Liu and Papa 2022; Bharat et al. 2024; Arnold 2025).

Despite the growing significance of BRICS economies and Thailand in global trade and finance, there remains limited understanding of how their exchange rate volatilities are interrelated, especially during periods of geopolitical and economic uncertainty. Traditional models often fail to capture the complex, asymmetric, and nonlinear dependence structures characterizing currency markets under stress, particularly in emerging economies. This gap in the literature is especially critical given the intensified currency fluctuations driven by events such as the Russia–Ukraine conflict and evolving global financial dynamics. Addressing this research gap, the central research question of this study is: How are the exchange rate volatilities among BRICS currencies and the Thai baht against the U.S. dollar interdependent, and how can advanced econometric models such as EGARCH and Vine Copulas effectively capture these dependencies for risk management purposes?

This study investigates the interdependencies among BRICS currencies and the Thai baht by analyzing their exchange rate volatility against the U.S. dollar. To achieve this, it employs the EGARCH (Exponential Generalized Autoregressive Conditional Heteroskedasticity) model to estimate conditional volatility, capturing both persistence and the asymmetric impact of positive and negative shocks. The ARMA(1,1) and EGARCH(1,1) models are adopted to effectively capture short-term autocorrelations in exchange rate returns and to model asymmetric volatility without imposing parameter constraints. The ARMA(1,1) specification ensures that the residuals are well-behaved before volatility modeling, while EGARCH(1,1) provides a robust framework for capturing persistence and asymmetric responses to shocks, particularly relevant in emerging markets where positive shocks may drive higher uncertainty. Compared to GJR-GARCH and APARCH, EGARCH offers greater flexibility, numerical stability, and compatibility with copula-based dependence modeling.

In addition, the study applies both C-Vine and D-Vine copula models to examine the nonlinear and tail-dependent structures in the co-movements of exchange rate volatilities. The joint use of these copula frameworks allows for a comprehensive and comparative analysis of dependence structures in emerging market currencies. Specifically, the C-Vine model captures hierarchical dependencies centered around a key variable, while the D-Vine model uncovers sequential linkages without the assumption of a central node.

Estimating both structures serves several important purposes. First, it ensures model robustness by validating that observed dependence patterns are not artifacts of a specific copula configuration. Second, it enables structural flexibility, as C-Vine copulas are well-suited for systems dominated by one influential currency, while D-Vine copulas better reflect chain-like or evenly distributed dependencies. Third, the dual approach accommodates the complexity and asymmetry of currency co-movements during periods of financial stress, capturing both centralized and pairwise interactions. Fourth, it allows for formal model comparison using

statistical criteria such as AIC and BIC, ensuring the selection of the most suitable model. Finally, the comparative insights from both models support more robust conclusions for policymakers and investors, particularly in assessing systemic contagion channels and designing risk-sensitive strategies. This dual approach not only enhances statistical rigor but also ensures that the final conclusions are not model-dependent, thereby providing a richer and more resilient understanding of systemic risk in exchange rate dynamics.

The motivation for this analysis stems from the urgent need to better understand currency co-movements in emerging markets, especially in the context of heightened geopolitical tensions and global financial instability, such as the Russia–Ukraine conflict and the shifting economic landscape. Such understanding is crucial for policymakers, investors, and multinational corporations in managing exchange rate risks, designing effective hedging strategies, and ensuring macroeconomic and financial stability.

This study contributes to the literature by offering a comprehensive analysis of exchange rate volatility and dependence among emerging market currencies, with a specific focus on BRICS and Thailand. Unlike previous research that largely centers on developed economies, this study highlights the structural dynamics of emerging currencies under global financial stress. For instance, Patton (2001) used copulas to model asymmetric exchange rate dependence among developed currencies such as the U.S. dollar, euro, and yen, finding strong upper tail dependence during financial crises. Engle and Manganelli (2004) applied the CAViaR model to G7 currencies to capture tail risk behavior in mature markets. Similarly, Diebold and Yilmaz (2009) investigated volatility spillovers in developed stock and FX markets, revealing strong inter-market linkages but offering limited insights into emerging markets. In contrast, the present study addresses this gap by examining nonlinear and tail-dependent interdependencies among BRICS currencies and the Thai baht using ARMA-EGARCH and Vine Copula models. The results provide critical insights into contagion channels and support the design of targeted policy responses to enhance exchange rate resilience in the face of global uncertainty.

Literature review

Exchange rate volatility

Research on exchange rate volatility has evolved significantly, particularly for emerging markets where financial systems are highly susceptible to external shocks. Ruzima and Boachie (2017) studied the impact of exchange rate uncertainty on private sector investment in BRICS countries using an ARCH model and cross-country time series data. Their findings revealed that heightened volatility negatively affects private sector investment, emphasizing the importance of maintaining exchange rate stability. Similarly, Sbeiti et al. (2025) examined the dynamics of exchange rates within BRICS countries from 2000 to 2022, finding significant interconnections among currencies despite cross-country variations influenced by macroeconomic factors.

Further comparative analysis by Zerihun et al. (2019) highlighted the structural relationships and causes of relative volatility among BRICS currencies. Their results showed that Brazil, India, and China generally exhibited higher competitiveness than South Africa and Russia, with the South African rand

displaying greater volatility relative to the Brazilian real and Russian ruble but lower than the Chinese yuan and Indian rupee. Meanwhile, Diniz-Maganini et al. (2023) investigated long-term exchange rate efficiency in BRICS nations using the Multifractal Detrended Fluctuation Analysis (MFDFA) method, finding varying levels of market efficiency and supporting the Adaptive Market Hypothesis (AMH) rather than the traditional Efficient Market Hypothesis (EMH).

More recently, Das and Roy (2023) employed a Multivariate GARCH Dynamic Conditional Correlation (MGARCH-DCC) model to assess return and volatility spillovers among BRICS currencies and major developed markets between 2006 and 2019. Their findings confirmed significant co-movement and spillover effects, with the Russian ruble and Chinese yuan exhibiting particularly high volatility. Importantly, while developed countries acted as volatility transmitters to BRICS markets, the direction and intensity of spillovers varied across individual countries. These studies collectively underscore the persistent, asymmetric, and evolving nature of exchange rate volatility in emerging markets, highlighting the need for advanced econometric models to capture complex volatility dynamics under conditions of global uncertainty.

Dependence Structure Modeling with Vine Copulas

Traditional correlation-based methods often fail to capture the nonlinear and asymmetric dependencies among financial variables, especially under conditions of market stress. Vine Copula models, including C-Vine and D-Vine structures, have become increasingly popular for modeling these complex interdependencies. Praprom and Sriboonchitta (2014) investigated the multivariate relationship between Thailand's international trade and the USD/THB exchange rate using C-Vine and D-Vine copulas, finding that both structures effectively modeled dependency patterns, with time-varying Gaussian copulas proving more appropriate than static forms. Their findings provided valuable insights into managing exchange rate volatility in emerging economies.

Building on this approach, Dai et al. (2020) utilized a time-varying trivariate vine copula model combined with wavelet analysis to examine the dynamic interdependence among the oil market, gold market, and the U.S. dollar foreign exchange market. They demonstrated that dependencies between these assets are stronger in the medium-run than in the short-run, with the U.S. dollar serving as an intermediary in the short term and gold assuming a dominant role in the medium term. Similarly, Hamza et al. (2024) applied a SETAR-GARCH C-Vine Copula model to assess the linkages among energy commodities, bonds, and stocks during the period of heightened inflation caused by the Russia-Ukraine conflict. Their findings highlighted that WTI crude oil prices played a leading role in driving financial market volatility, significantly impacting global assets.

Chkir et al. (2020) extended the application of vine copulas to examine the interdependence among oil prices, stock markets, and exchange rates across oil-exporting and oil-importing countries. Their results revealed nonlinear relationships, notably a negative correlation between oil prices and exchange rates, except for currencies like the British pound and Japanese yen. Positive correlations between stock markets and oil prices emerged post-2014, reflecting changing dynamics in energy and equity markets. Finally, Yangheling Li

et al. (2020) explored the relationship between exchange rates and energy prices, specifically gas, coal, and LNG, using a C-Vine copula approach. They found that gas exhibited the highest degree of interdependence with exchange rates, underlining the critical role of exchange rates in energy market dynamics. Together, these studies confirm that Vine Copula models offer a robust and flexible framework for understanding complex financial dependencies, particularly under conditions of volatility and structural change.

Methodology

Volatility Modeling: EGARCH Model

To capture the volatility dynamics of BRICS currencies and the Thai baht against the U.S. dollar, this study employs the Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model, originally proposed by Nelson (1991). Unlike standard GARCH models, the EGARCH specification captures asymmetric volatility effects, allowing positive and negative shocks to have differential impacts on future volatility. The ARMA(1,1)-EGARCH(1,1) model is specified as:

$$\text{Mean equation: } r_t = \mu + \phi_1 r_{t-1} + \theta_1 \varepsilon_{t-1} + \varepsilon_t \quad (1)$$

$$\text{Variance equation: } \log(\sigma_t^2) = \omega + \beta \log(\sigma_{t-1}^2) + \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \quad (2)$$

In the mean equation, r_t denotes the log return of the exchange rate at time t , where μ is a constant, ϕ_1 is the autoregressive (AR) coefficient, θ_1 is the moving average (MA) coefficient, and ε_t represents the residual term with conditional variance σ_t^2 . In the variance equation, σ_t^2 denotes the conditional variance of ε_t , ω is constant, β captures the persistence of volatility (GARCH effect), α reflects the magnitude effect (response to the size of shocks). In the EGARCH framework, a negative and statistically significant γ parameter indicates the presence of the leverage effect, where negative shocks increase volatility more than positive shocks of the same magnitude.

The ARMA(1,1)-EGARCH(1,1) framework is employed to capture both the mean and volatility dynamics of exchange rate returns. The ARMA(1,1) specification effectively accounts for short-term autocorrelation and moving average components, ensuring that the residuals are well-behaved prior to volatility modeling. For the variance equation, the EGARCH(1,1) model is selected due to its ability to capture asymmetric volatility without requiring non-negativity constraints on parameters, which improves numerical stability and estimation efficiency. Unlike GJR-GARCH and APARCH, EGARCH models conditional variance in an exponential form, guaranteeing positive forecasts while accommodating the persistent and asymmetric nature of exchange rate volatility, particularly relevant for emerging markets. Moreover, EGARCH is well-suited for integration with copula-based dependence modeling, enhancing the overall robustness of the analysis.

The copula concept

The concept of the copula was first introduced by Sklar (1959) through Sklar's Theorem. This theorem shows that any joint distribution can be separated into its marginal distributions and a copula that models the dependence structure. According to the theorem, any continuous joint distribution function $F_{X,Y}(x,y)$ with marginals $F_X(x)$ and $F_Y(y)$ can be expressed as

$$F_{X,Y}(x,y) = C(F_X(x), F_Y(y)) = C(u,v) \quad (3)$$

where $C(\cdot, \cdot)$ denotes the copula function that joins the marginals F_X and F_Y into the joint distribution, and $u = F_X(x), v = F_Y(y)$ are uniform $[0,1]$ variables obtained by the probability integral transform (PIT). Let X_1, \dots, X_d be a set of continuous random variables with joint distribution $F(x_1, \dots, x_d)$ and marginals $F_1(x_1), \dots, F_d(x_d)$. The copula function $C : [0,1]^d \rightarrow [0,1]$ captures the dependence structure such that

$$F_{X_1, \dots, X_d}(x_1, \dots, x_d) = C(F_{X_1}(x_1), \dots, F_{X_d}(x_d)) = C(u_1, \dots, u_d) \quad (4)$$

The copula density, when all marginals are continuous, is given by:

$$c(u_1, \dots, u_d) = \frac{\partial^d C(u_1, \dots, u_d)}{\partial u_1 \cdots \partial u_d}$$

In this study, the marginal distribution of each exchange rate return is modeled and standardized using the ARMA(1,1)-GJR-GARCH(1,1) model. The standardized residuals are transformed into uniform margins via empirical cumulative distribution functions (ECDF) to form pseudo-observations suitable for copula modeling.

C-D Vine copula for research methodology

The Vine Copula, also known as pair-copula construction (PCC), is a flexible and powerful method for modeling multivariate dependence structures by decomposing high-dimensional joint distributions into cascades of bivariate copulas. The Vine Copula, introduced by Joe (1996) and formalized by Bedford and Cooke (2001, 2002), addresses the limitations of traditional multivariate copulas by allowing different copula families across variable pairs and modeling conditional dependencies. This study employs Canonical Vine (C-Vine) and Drawable Vine (D-Vine) structures to capture complex, nonlinear, and asymmetric dependencies among exchange rate volatilities in BRICS countries and Thailand.

In a Canonical Vine Copula (C-Vine copula), the dependence structure is centered around one key variable that acts as a "root node" in each level of the vine. This central variable is conditionally dependent on all others, and subsequent dependencies are built conditionally upon previous variables. Let X_1, \dots, X_d be continuous random variables. The joint density of a C-vine copula can be written as

$$C(u_1, \dots, u_d) = \prod_{j=1}^{d-1} \prod_{i=1}^{d-j} c_{j, j+i|1, \dots, j-1}(u_{j|1, \dots, j-1}, u_{j+i|1, \dots, j-1}) \quad (5)$$

where $C(u_1, \dots, u_d)$ is Joint copula density function for d variables, $\prod_{j=1}^{d-1} \prod_{i=1}^{d-j} (\cdot)$ is product of all conditional pair copulas across the full C-Vine structure. $c_{j, j+i|1, \dots, j-1}$ is conditional copula density function for the variable pair j and $j+i$ given preceding variables $1, \dots, j-1$. u_k is uniform-transformed variable $u_k = F_k(x_k)$ obtained via the

cumulative distribution function (CDF) of variable X_k . $u_{j|1,\dots,j-1}$ is conditional value of u_j given variables u_1, \dots, u_{j-1} represents conditional probability and d Number of dimensions or number of random variables in the system

In contrast, a D -Vine constructs the dependence structure sequentially, modeling relationships primarily between neighboring variables. The first level involves adjacent variable pairs $(X_1, X_2, X_2, X_3, \dots)$, while higher-order trees model conditional dependencies $(X_1, X_3 | X_2)$

$$C(u_1, \dots, u_d) = \prod_{j=1}^{d-1} \prod_{i=1}^{d-j} c_{i,i+j|1,\dots,i+j-1}(u_{i|1,\dots,i+j-1}, u_{i+j|1,\dots,i+j-1}) \quad (6)$$

where $C(u_1, \dots, u_d)$ is copula density function of all d variables transformed to uniform margins, $\prod_{j=1}^{d-1} \prod_{i=1}^{d-j} (\cdot)$ is the product of all copulas in the D -Vine structure across all tree levels, from bottom to top, $c_{i,i+j|1,\dots,i+j-1}$ is the conditional copula density for the variable pair i and $i+j$ given the intermediate variables $i+j|i+1, \dots, i+j-1$. $u_{i|1,\dots,i+j-1}$ is conditional value of u_i given $u_{i+1}, \dots, u_{i+j-1}$ represents conditional probability, $u_{i+j|1,\dots,i+j-1}$ is conditional value of $u_{i+j}, \dots, u_{i+j-1}$ and d is the total number of variables (dimensions) in the system.

The selection of copula families in this study followed a two-step approach that combines theoretical reasoning with empirical model evaluation. First, theoretical characteristics of each copula were considered to ensure alignment with the observed dependence structures in financial data. For instance, Survival Joe and Clayton copulas were selected to capture strong lower tail dependence, which is a common feature in financial contagion during periods of stress. Gumbel and Joe copulas, in contrast, were suited for modeling upper tail dependence. More flexible families, such as BB1 and BB7, were employed in higher-order trees to allow for asymmetric and mixed tail dependencies, especially where directional relationships were less dominant.

Second, a data-driven model selection procedure was employed to identify the best-fitting copula family for each bivariate pair within the vine structure. Multiple copula candidates were estimated, and the selection was based on standard information criteria, including the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log-likelihood values. The copula with the lowest AIC/BIC and highest log-likelihood was chosen, ensuring data-driven selection and robustness of the dependence modeling. This combined approach guarantees that the final vine copula construction reflects both the theoretical properties of tail behavior in currency returns and empirical goodness-of-fit. It also enhances the credibility of tail risk estimation and systemic dependence analysis across the BRICS and Thailand currency network.

Data

This study employs daily secondary data on exchange rates of the BRICS countries Brazil (BRL), Russia (RUB), India (INR), China (CNY), and South Africa (ZAR), as well as Thailand (THB), all quoted against the U.S. dollar (USD). The daily dataset spans from January 2, 2013, to December 28, 2023, covering 10 years. This timeframe captures key geopolitical events, most notably the escalation of the Russia-Ukraine

conflict, which contributed to elevated financial market uncertainty and currency volatility across emerging economies. To ensure stationarity and facilitate volatility modeling, the exchange rate data are transformed into continuously compounded log-returns, calculated as $r_t = \log\left(\frac{P_t}{P_{t-1}}\right)$, where P_t and P_{t-1} denotes the exchange rate at time t and $t - 1$, respectively. The fig 1 illustrates the daily log-returns of BRICS and Thai exchange rates against the U.S. dollar from 2013 to 2023. All series exhibit volatility clustering, which is periods of relative calm followed by sharp fluctuations. The RUB/USD series shows the highest volatility, especially during geopolitical shocks, while CNY/USD and THB/USD display relatively lower and more stable return variations.

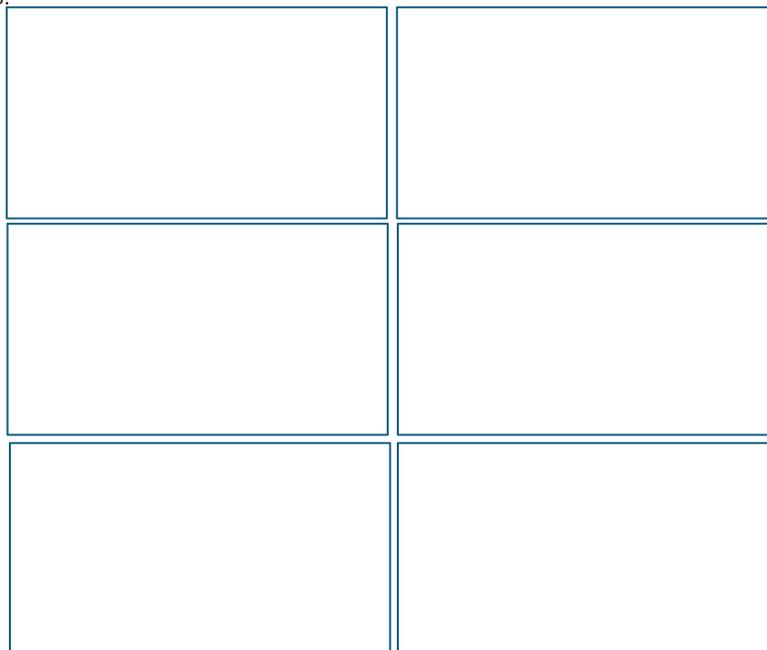


Figure 1 Daily Log-Returns of BRICS and Thai Exchange Rates Against the U.S. Dollar (2013–2023)

Table 1 presents the descriptive statistics for the monthly log-returns of six exchange rates. All series exhibit near-zero means, consistent with typical return behavior. The standard deviation (SD) values indicate that RUB/USD has the highest volatility, while CNY/USD is the least volatile. Kurtosis values for all series exceed 3, suggesting leptokurtic distributions with fat tails, especially for RUB/USD (52.03), indicating a higher likelihood of extreme returns. Skewness values show mild asymmetry, with RUB/USD notably right-skewed (2.49). The Jarque-Bera test results are highly significant across all series (at the 1% level), confirming deviations from normality. The Augmented Dickey-Fuller (ADF) test statistics strongly reject the null hypothesis of a unit root for all currencies, implying that the return series are stationary and suitable for time series modeling.

Table 1 Descriptive Statistics

Variavles	Mean	Min.	Max	SD	Kurt.	Skew.	Jarque-Bera	ADF Test
ZAR/USD	0.0002	-0.0498	0.0489	0.0096	4.0366	0.2085	148.98***	53.85***
BLR/USD	0.0003	-0.0594	0.0716	0.0101	5.3134	0.0455	639.65***	56.92***
THB/USD	0.0001	-0.0206	0.0169	0.0035	5.3951	-0.0742	687.20***	-49.82***
RUB/USD	0.0003	-0.1147	0.2251	0.0130	52.0252	2.4879	289,769.5***	-18.79***
INR/USD	0.0001	-0.0332	0.0369	0.0038	13.0381	0.4881	12,138.23***	-26.79***
CNY/USD	0.0001	-0.0162	0.0183	0.0023	9.5527	-0.0392	5,124.68***	-53.69***

Note: *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Estimation results of EGARCH

Table 2 Estimated EGARCH

Variable	μ	ϕ_1	θ_1	ω	α	γ	β	AIC	BIC	ARCH Test
ZAR/ USD	0.0004** (.0081)	-0.397 (.613)	0.380 (.632)	-0.122*** (.000)	0.033*** (.000)	0.064*** (.000)	0.992*** (.000)	-6.489	-6.484	2.708* (.0999)
BRL/ USD	0.0003* (.0428)	-0.158 (.555)	0.086 (.750)	-0.171*** (.000)	0.041*** (.000)	0.073*** (.000)	0.987*** (.000)	-6.455	-6.440	6.526** (.0106)
THB/ USD	-0.0000 (.5304)	-0.323* (.075)	0.400* (.023)	-0.208*** (.000)	0.009* (.090)	0.105*** (.000)	0.989*** (.000)	-8.617	-8.603	8.460*** (.0000)
RUB/ USD	0.0003* (.0162)	0.575* (.044)	-0.541* (.068)	-0.325*** (.000)	0.078*** (.000)	0.239*** (.000)	0.984*** (.000)	-6.644	-6.630	0.232 (.6300)
INR/ USD	0.0001** (.0028)	-0.521* (.090)	0.5472* (.071)	-0.351*** (.000)	0.056*** (.000)	0.128*** (.000)	0.978*** (.000)	-8.535	-8.520	8.046*** (.0045)
CNY/ USD	0.0000 (.3404)	-0.962*** (.000)	0.978*** (.000)	-0.047*** (.000)	0.013*** (.000)	0.012*** (.000)	0.997*** (.000)	-9.500	-9.486	78.525*** (.0000)

Note: *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 2 presents the estimated parameters of the ARMA(1,1)-EGARCH(1,1) model for six exchange rate series: ZAR/USD, BRL/USD, THB/USD, RUB/USD, INR/USD, and CNY/USD. The mean equation includes an autoregressive term (ϕ_1) and a moving average term (θ_1), while the variance equation models the log of conditional variance, capturing asymmetric and persistent volatility using the EGARCH framework. In the mean equation, the constant term c is statistically significant for most currency pairs, with ZAR/USD, BRL/USD, RUB/USD, and INR/USD showing significance at the 1 percent or 5 percent levels, suggesting a consistent mean component in these return series. The AR coefficient ϕ_1 is significant for THB/USD, RUB/USD, INR/USD, and especially CNY/USD (-0.9625, significant at 1%), indicating that past returns strongly influence current returns for these currencies. The MA coefficient θ_1 is positive and statistically significant in THB/USD, RUB/USD, INR/USD, and CNY/USD, suggesting that past shocks have a persistent effect on returns.

In the variance equation, all currencies exhibit statistically significant negative values for ω , the constant term in the log variance equation, consistent with the EGARCH model's flexibility in capturing volatility without requiring positivity constraints. The α coefficient, which reflects the symmetric effect (magnitude of shocks), is positive and significant for all currencies, implying that larger shocks—regardless of sign—lead to increased volatility. Although all estimated γ coefficients are statistically significant, their positive signs indicate the absence of the traditional leverage effect, while still reflecting asymmetric volatility behavior. This suggests that in these exchange rate series, positive shocks tend to increase volatility more than negative shocks of the same magnitude, which deviates from typical financial market behavior. The β parameter, which measures volatility persistence, is close to 1 for all currencies, consistent with strong GARCH effects. CNY/USD exhibits the highest persistence ($\beta = 0.9967$), followed by ZAR/USD (0.9922), indicating that volatility shocks decay slowly and have long-lasting impacts. From a model fit perspective, CNY/USD has the lowest AIC (-9.5001) and BIC (-9.4855), suggesting it is best captured by the EGARCH specification among the six currencies. THB/USD and INR/USD also show favorable fit statistics.

The ARCH LM test results in Table 2 reveal statistically significant ARCH effects for most currencies at lag 1 validating the use of EGARCH models. Notably, for THB/USD significant ARCH effects were only detected at lag 3 suggesting that volatility clustering in the Thai baht may manifest over a longer horizon compared to other BRICS currencies. This reinforces the importance of testing multiple lag lengths when assessing conditional heteroskedasticity and highlights structural differences in how volatility evolves across emerging market currencies.

Table 3 presents the results of the estimated C-Vine copula structure which models the dependence among the exchange rate volatilities of BRICS currencies and the THB/USD. The structure is organized hierarchically into five trees, with each tree representing a different level of conditional dependence. ZAR/USD is selected as the root node based on both statistical and economic considerations. Statistically, ZAR/USD exhibits the highest volatility persistence among the six currencies as indicated by a β coefficient of 0.9922 in the EGARCH estimation. Furthermore, it shows strong pairwise lower tail dependence (LTD = 0.95) and Kendall's tau = 0.86 with all other exchange rates in the first tree layer. These characteristics make ZAR/USD the most interconnected currency in terms of joint extreme movement risks thereby satisfying the technical criteria for root node selection in C-Vine modeling, which requires the central variable to maximize dependence with others. Economically, the South African rand (ZAR) plays a unique role within the BRICS bloc and the broader emerging market landscape. South Africa maintains one of the most liquid and internationally accessible capital markets among the BRICS countries operating under relatively liberalized exchange rate and capital flow regimes. Its currency is heavily influenced by global commodity cycles particularly due to the country's reliance on the export of precious metals such as gold and platinum. As a result, the rand is highly sensitive to external shocks global risk sentiment, and geopolitical tensions. These factors often lead to the ZAR acting as a "proxy currency" for broader emerging market risk responding swiftly and intensely during episodes

of financial stress. Moreover, fluctuations in ZAR/USD often precede or coincide with broader market corrections, making it a bellwether for global investor sentiment. Prior studies (e.g., Zerihun et al., 2019; Diniz-Maganini et al., 2023) have also identified ZAR as a conduit for volatility spillovers transmitting shocks to other BRICS currencies via trade and capital market linkages. These empirical findings, combined with theoretical rationale, support the designation of ZAR/USD as the optimal root node in the C-Vine structure.

Table 3 Estimated C-Vine Copula

Tree	Edge	Family Cop.	Par1	Par2	Tau	Utd	Ltd
1	1,2	Survival Joe	13.37	-	0.86	-	0.95
1	1,5	Survival Joe	13.37	-	0.86	-	0.95
1	1,4	Survival Joe	13.37	-	0.86	-	0.95
1	1,3	Survival Joe	13.38	-	0.86	-	0.95
1	6,1	Joe cop.	13.37	-	0.86	0.95	-
2	3,2;1	t	0.25	4.90	0.16	0.11	0.11
2	3,5;1	t	0.33	4.42	0.21	0.15	0.15
2	3,4;1	t	0.25	4.91	0.16	0.11	0.11
2	6,3;1	t	0.04	9.81	0.02	0.01	0.01
3	4,2;3,1	BB1	0.11	1.02	0.07	0.03	0.00
3	4,5;3,1	BB1	0.10	1.02	0.06	0.02	0.00
3	6,4;3,1	t	-0.01	10.70	-0.00	0.01	0.01
4	5,2;4,3,1	BB1	0.07	1.02	0.05	0.02	0.00
4	6,5;4,3,1	t	0.02	12.88	0.01	0.00	0.00
5	6,2;5,4,3,1	t	-0.03	12.09	-0.02	0.00	0.00

Note: 1= ZAR/USD, 2=BRL/USD, 3=THB/USD, 4=RUB/USD, 5=INR/USD, 6=CNY/USD.

Within this structure, ZAR/USD is directly linked to BRL/USD (2), INR/USD (5), THB/USD (4), RUB/USD (3) and CNY/USD (6) in the first tree layer. All pairwise dependencies in this layer are modeled using the Survival Joe copula except for CNY/USD which uses the Joe copula. These copulas capture strong lower tail dependence and high Kendall's tau reinforcing the central role of ZAR/USD in propagating systemic risk. The presence of LTD = 0.95 and Kendall's tau = 0.86 across these pairs reflects a high likelihood of joint extreme depreciation during financial stress. Tree 2 captures the first-order conditional dependencies, modeling pairs such as (3,2;1), (3,5;1), (3,4;1), and (6,3;1) using the t-copula which accommodates symmetric tail dependence. Kendall's tau values in this layer decrease to the 0.02–0.21 range, and LTD falls to 0.01–0.15 indicating weaker but still relevant co-movements once conditioned on ZAR/USD. Tree 3 introduces dependencies conditioned on both ZAR/USD and THB/USD employing BB1 and t copulas to reflect more

flexible and asymmetric structures. Here, Kendall's tau drops below 0.07 and LTD approaches 0.00 implying marginal systemic interconnection. In Trees 4 and 5, which condition on multiple nodes the dependence becomes negligible. Most Kendall's tau values fall below 0.05 and both upper and lower tail dependencies converge to zero, suggesting that deeper layers contribute little to systemic co-movement.

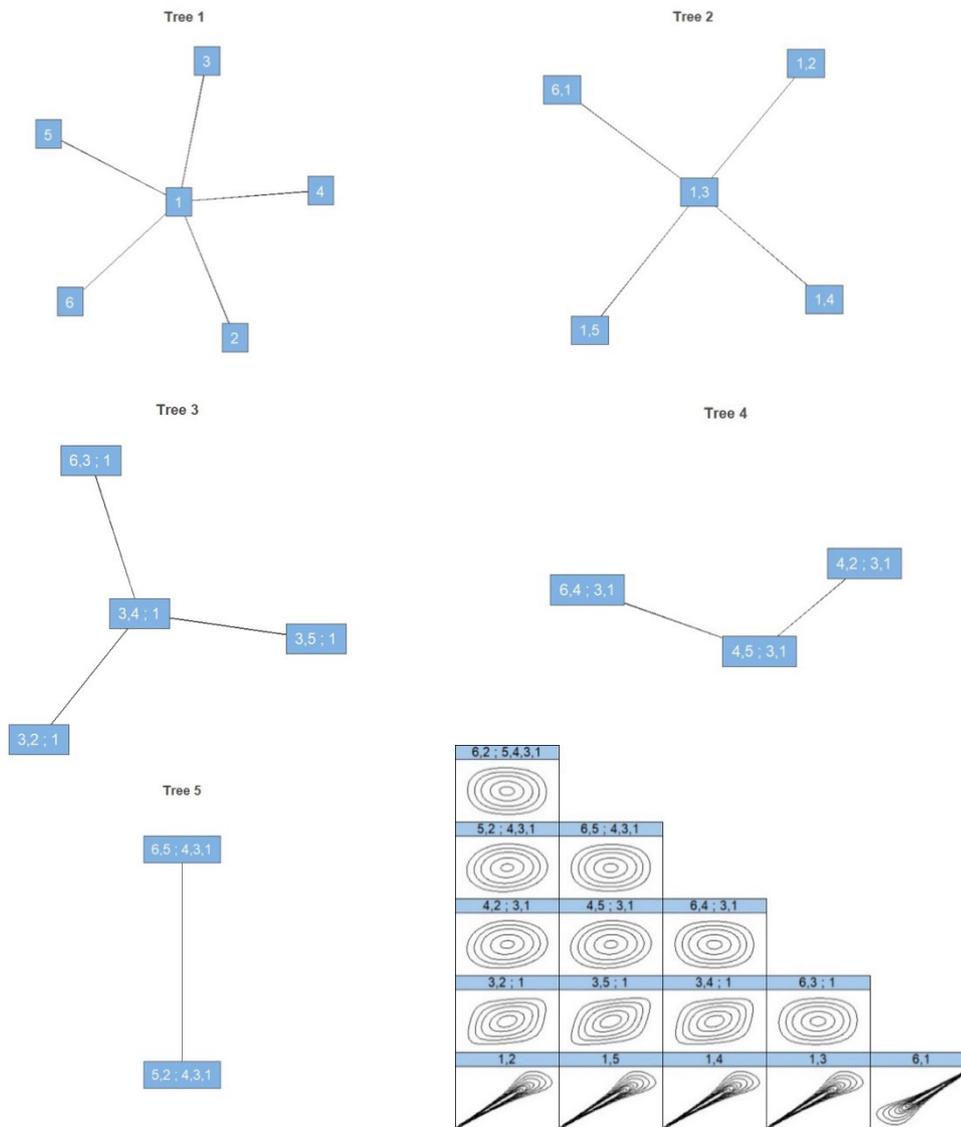


Figure 2 C-Vine copula structure

These results position ZAR/USD as the most interconnected currency in the sample acting as the root of extreme co-movement risk among BRICS and ASEAN currencies. The tail dependence structure captured through the copulas confirms that most systemic risk information is concentrated in the first two layers of the vine. This has important implications for regional financial risk monitoring especially for policymakers and financial institutions exposed to BRICS-ASEAN exchange rate dynamics. Recognizing the role of ZAR/USD as a systemic node can enhance early-warning systems stress-testing protocols, and overall macro-financial resilience in the face of global shocks.

Figure 2 illustrates the C-Vine copula structure that models the multivariate dependence among exchange rate volatilities of BRICS currencies and the THB/USD. This hierarchical diagram is composed of five trees, each representing successive layers of conditional dependencies. The structure is centered around node 5, which corresponds to INR/USD, confirming the results from Table 3 that identify INR/USD as the most influential node in the dependence network. In Tree 1, INR/USD (node 5) forms direct connections with RUB/USD (1), ZAR/USD (2), BRL/USD (3), THB/USD (4), and CNY/USD (6). These connections represent the strongest pairwise dependencies in the copula structure, with all pairs exhibiting high Kendall's tau values of 0.86 and strong lower tail dependence ($LTD = 0.95$), as discussed in the estimation results. These links indicate that exchange rate volatilities of these currencies tend to co-move significantly with INR/USD, especially during market downturns. Tree 2 captures the second level of dependence, conditional on INR/USD. Here, the node 1 (RUB/USD) becomes central, and additional relationships emerge, such as RUB/USD with ZAR/USD (2), BRL/USD (3), THB/USD (4), and CNY/USD (6). These edges reflect how currency co-movements are conditioned on the central node from the previous tree. Although weaker than the dependencies in Tree 1, these relationships still exhibit moderate tail dependence and highlight the role of RUB/USD in explaining residual dependencies.

Tree 3 further refines these relationships by introducing third-order conditional dependencies. It includes edges such as 3.2;1 (BRL/USD and ZAR/USD, conditioned on RUB/USD), 3.4;1 (THB/USD and ZAR/USD, conditioned on RUB/USD), and so on. The labels denote which variables are connected and the conditioning sets used. These connections reflect weaker but still structured dependencies that add depth to the overall modeling of the joint distribution. Trees 4 and 5 continue this decomposition process, adding higher-order conditional copulas such as 4.2;5,3,1 and 6.4;5,3,1. These trees typically capture more nuanced, lower-strength dependencies that become increasingly less impactful. As noted in Table 3, the Kendall's tau values at these levels drop significantly (to around 0.04 or less), and the tail dependence measures approach zero, indicating minimal residual dependence after conditioning on earlier variables.

The diagram also includes a lower-triangle contour matrix visualization, which provides a visual summary of the copula densities and pairwise dependencies. Each contour plot reflects the shape of dependence between specific pairs, showing whether relationships are symmetric or exhibit tail dependence (e.g., UTD or LTD). Together with the vine trees, this visual format enhances understanding of the complex dependence structure across multiple dimensions.

Estimation results of the D-Vine Copula

Table 4 displays the estimated results from the D-Vine Copula model, which captures the complex dependence structure among the exchange rate volatilities of BRICS currencies and the Thai Baht (THB) relative to the U.S. dollar (USD). In Tree 1, the initial and strongest dependencies are modeled using the Survival Joe copula family, which is particularly adept at capturing upper and lower tail dependencies. All five primary edges INR/USD with CNY/USD (5,6), BRL/USD (3,5), ZAR/USD (2,3), RUB/USD (1,2), and THB/USD

(4,1) exhibit a Kendall's tau of 0.86, indicating very strong positive dependence. Moreover, these pairs demonstrate substantially lower tail dependence (LTD = 0.95), implying that these currency pairs tend to co-move strongly during extreme market downturns. This pattern suggests a high level of vulnerability to joint depreciation events, which is critical for assessing systemic currency risk under stress.

Table 4 Estimated *D*-Vine Copula

Tree	Edge	Family Cop.	Par1	Par2	Tau	Utd	Ltd
1	5,6	Survival Joe	13.37	-	0.86	-	0.95
1	3,5	Survival Joe	13.37	-	0.86	-	0.95
1	2,3	Survival Joe	13.37	-	0.86	-	0.95
1	1,2	Survival Joe	13.37	-	0.86	-	0.95
1	4,1	Survival Joe	13.37	-	0.86	-	0.95
2	3,6;5	<i>t</i>	0.31	4.61	0.20	0.14	0.14
2	2,5;3	<i>t</i>	0.23	4.83	0.15	0.11	0.11
2	1,3;2	Survival Joe	13.37	0.00	0.86	-	0.95
2	4,2;1	<i>t</i>	0.27	5.04	0.17	0.11	0.11
3	2,6;3,5	BB7	1.01	0.07	0.04	0.02	0.00
3	1,5;2,3	<i>t</i>	0.06	22.36	0.04	0.00	0.00
3	4,3;1,2	<i>t</i>	0.06	21.57	0.04	0.00	0.00
4	1,6;2,3,5	<i>t</i>	0.02	29.12	0.01	0.00	0.00
4	4,5;1,2,3	BB7	1.01	0.11	0.06	0.01	0.00
5	4,6;1,2,3,5	BB7	1.01	0.00	0.01	0.01	0.00

Note: 1= ZAR/USD, 2=BRL/USD, 3=THB/USD, 4=RUB/USD, 5=INR/USD, 6=CNY/USD.

In Tree 2, the model introduces the second level of conditional dependencies. Most of the edges in this layer are modeled using the *t*-copula, which can capture symmetric tail behavior. The dependencies here are notably weaker than those in Tree 1, with Kendall's tau values ranging from 0.15 to 0.20. For instance, the pair (3,6;5) shows moderate upper and lower tail dependencies of 0.14, reflecting continued but diminishing co-movement under conditional settings. The only edge in Tree 2 using the Survival Joe copula is (1,3;2), maintaining a strong tau of 0.86, confirming a robust conditional dependency even after accounting for previous nodes.

As the model progresses into Tree 3 and beyond, the dependencies become increasingly weak. The BB7 copula is used for several of these deeper conditional relationships, such as (2,6;3,5), (1,5;2,3), and (4,5;1,2,3), capturing more complex, asymmetric dependencies. However, Kendall's tau values in Trees 3 to 5 are generally below 0.06, and in many cases approach 0.01 or even zero, indicating that conditional

dependence nearly vanishes in higher-order trees. For example, the pair (4,6;1,2,3,5) in Tree 5 has a tau of only 0.01, with negligible upper and lower tail dependence, suggesting minimal interaction once the primary and secondary dependencies are accounted for.

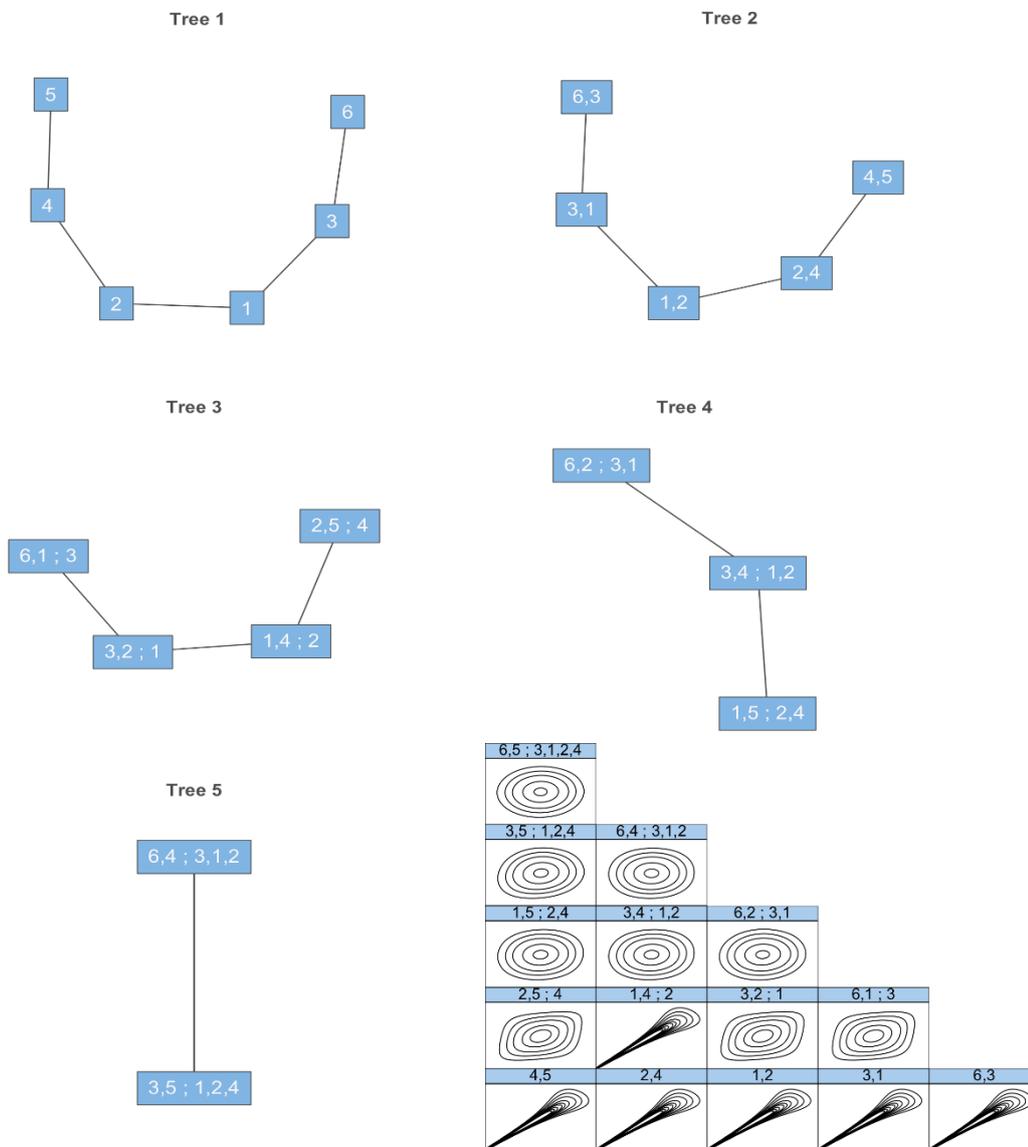


Figure 3 D-Vine copula structure

Table 5 AIC, BIC, and Loglikelihood value of C-D vine Copula

	C-Vine	D-Vine
AIC	-2,908,668	-2,771,529
BIC	-2,908,519	-2,771,386
Loglikelihood	1,454,359	1,385,789

Note: Bold numbers indicate the lowest value of AIC, BIC, and the highest value of Log-likelihood

Table 5 presents two model selection criteria, namely Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), which are used to evaluate and compare the performance of the *C*-Vine and *D*-Vine Copula models applied to exchange rate volatility among BRICS currencies and the Thai Baht against the U.S. dollar. In this table, the *C*-Vine Copula model yields lower AIC (-2,908,668) and BIC (-2,908,519) values compared to the *D*-Vine model, which has AIC and BIC values of -2,771,529 and -2,771,386, respectively. Lower values of AIC and BIC indicate a better trade-off between model fit and parsimony, suggesting that the *C*-Vine model offers a more efficient and accurate representation of the underlying dependence structure.

Discussion

The empirical findings of this study offer critical insights into the dynamics of exchange rate volatility and interdependence among BRICS currencies and the Thai baht. The results from the ARMA-EGARCH(1,1) model confirm the presence of volatility clustering, persistence, and asymmetric responses across all six currency pairs. Notably, the positive and significant asymmetric coefficients (γ) across the board indicate that positive shocks tend to generate greater volatility than negative shocks of similar magnitude, a departure from the traditional leverage effect seen in equity markets. This behavior underscores the distinct nature of foreign exchange markets in emerging economies, where unexpected appreciations often triggered by capital inflows or policy shocks may exacerbate uncertainty, particularly in financially open systems such as Thailand (Diniz-Maganini et al., 2023; Ruzima & Boachie, 2018). Among all currencies analyzed, CNY/USD and ZAR/USD exhibit the highest volatility persistence with β values nearing unity, suggesting that volatility shocks have long-lasting impacts. This is in line with Das and Roy (2023), who identified the Chinese yuan and South African rand as key contributors to regional volatility spillovers. For Thailand, the THB/USD pair displayed relatively lower volatility. Overall, the significant EGARCH coefficients reflect its sensitivity to external shocks, likely due to Thailand's high trade exposure to BRICS economies.

The copula-based analysis reveals more nuanced patterns of nonlinear and tail-dependent interdependencies. The *C*-Vine model with ZAR/USD as the root node captures strong lower tail dependence (LTD = 0.95) across first-layer edges, particularly with BRL/USD, RUB/USD, INR/USD, and THB/USD. This indicates a high probability of joint extreme depreciations during periods of financial stress, positioning ZAR/USD as a systemically important currency in the BRICS-ASEAN currency network. These findings echo the work of Zerihun et al. (2019), who reported that the South African rand displayed volatile and contagion-prone behavior in comparison to other BRICS currencies. The comparative superiority of the *C*-Vine over *D*-Vine, evidenced by lower AIC/BIC and higher log-likelihood, also reflects the hierarchical nature of currency dependencies, where a single dominant node (ZAR/USD) transmits volatility to other currencies. This aligns with theoretical expectations from the Vine Copula literature (Joe, 1996; Brechmann & Schepsmeier, 2013) and supports the policy relevance of identifying "shock hubs" in currency markets for early-warning purposes.

The findings of this study hold significant implications for understanding volatility transmission in the context of international trade and financial integration among BRICS countries and Thailand. These economies were selected not only for their emerging market status but also for their increasing interconnectivity through bilateral and multilateral trade agreements, commodity flows and capital market exposure. For instance China and India are among Thailand's top trade partners while South Africa plays a critical role in global commodity supply chains particularly in precious metals which directly affects export revenues and exchange rate behavior. Moreover, Brazil and Russia as major energy and agricultural exporters exert indirect influence on inflation and exchange rate stability across trading partners, including ASEAN economies. The observed volatility spillovers and asymmetric dependencies suggest that exchange rate risk in one country can propagate to others through trade linkages and investment channels. Policymakers and firms engaged in cross-border trade and investment should thus monitor not only domestic volatility but also systemic nodes like ZAR/USD and CNY/USD which act as early signals of broader financial stress in the region. These insights are particularly relevant in the post-pandemic era where supply chain fragility and global financial tightening amplify the interconnectedness of currency markets.

Overall, these results provide robust evidence that the exchange rate volatilities of BRICS currencies and the Thai baht are interdependent in an asymmetric and nonlinear fashion with strong systemic linkages concentrated in the lower tails of their joint distributions. The findings validate the use of advanced econometric tools such as EGARCH and Vine Copulas in capturing the complexity of emerging market dynamics, particularly under conditions of geopolitical uncertainty and global financial fragmentation (Arnold, 2024; Liu & Papa, 2022).

Conclusion

This study investigates the interdependence of exchange rate volatilities among BRICS currencies, Brazilian real, Russian ruble, Indian rupee, Chinese yuan, and South African rand, and the Thai baht against the U.S. dollar over the 2013–2023 period using ARMA-EGARCH and both Canonical and Drawable Vine copula models. The results highlight strong volatility persistence and asymmetric responses, especially in ZAR/USD and CNY/USD, alongside significantly lower tail dependence captured through vine copulas. ZAR and INR emerge as systemic hubs of financial contagion, underscoring the vulnerability of emerging markets to joint shocks during episodes of geopolitical and economic stress. Thailand, while exhibiting more stable return behavior, remains exposed to volatility spillovers from BRICS through trade and macro-financial linkages. These dynamics signal the need for more robust risk management approaches. Policymakers in Thailand and ASEAN should adopt tail-risk-sensitive models to enhance reserve adequacy and early-warning systems. Monitoring of systemically important currencies like ZAR is essential for timely intervention and stress-testing. Regional mechanisms such as the BRICS CRA or the ASEAN+3 Chiang Mai Initiative should incorporate contagion-aware frameworks in their design.

For practitioners, the study suggests implementing dynamic hedging strategies and copula-based stress testing to account for nonlinear and asymmetric dependencies, especially in firms with multi-currency exposure. Financial institutions may also improve risk assessment by integrating these models into value-at-risk and scenario analysis frameworks. However, the study is subject to certain limitations. The use of static copula models may not capture time-varying dependencies across different market regimes. Additionally, macroeconomic drivers of volatility are not explicitly modeled, which could limit explanatory power. Future research should explore time-varying copulas that include macro-financial covariates and extend the framework to cross-asset volatility spillovers for a more comprehensive view of systemic risk. In conclusion, exchange rate volatility in BRICS and Thailand is deeply interlinked, structurally asymmetric, and sensitive to tail risks. Understanding these complex dependencies is vital for policymakers and market participants aiming to safeguard financial stability in an increasingly interconnected and uncertain global landscape.

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Impact of Pension on Children Expenditure: Evidence from Thailand

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Abstract

This study examines the impact of elderly pension reforms in Thailand on household-level expenditures for children, focusing on the changes introduced by the Old Age Allowance (OAA) program reforms in 2009 and 2011. The analysis is based on panel data from the Socioeconomic Status Surveys conducted in Thailand in 2007, 2010, and 2012, using the difference-in-differences (DID) method. The results show significant positive causal effects of the 2009 and 2011 pension reforms on household expenditures for children. In particular, after the 2009 and 2011 reform, OAA beneficiaries have higher expenditures for children by 1,421.17 and 1,021 baht per month, respectively, compare to those that did not receive pension benefits. The findings also highlight how these additional expenditures are distributed across key categories, including food, housing, travel, entertainment, and personal expenses for children.

Keywords: children expenditure, Old Age Allowance (OAA), pension

Introduction

Thailand is experiencing a demographic shift, with those aged 60 and over comprising 18% of the population in 2020, projected to reach 28% by 2030 (National Statistical Office of Thailand, 2021). The Old Age Allowance (OAA), covering 82.6% of the elderly in 2019, offers a benefit below the poverty line (International Labour Organization, 2022; National Economic and Social Development Council, 2021). In 2023, the Thai government announced plans to reduce OAA coverage due to fiscal constraints, raising concerns about the program's adequacy and the broader impacts on household welfare. In Thailand, where intergenerational living is common, financial strain on elderly family members can have ripple effects on household budgets, potentially limiting investments in children's education, health, and development. In 2015, 21% of Thai children lived with their grandparents, with 5.82% in skipped-generation households (Kirdruang, 2019).

Pension benefits that fall short of basic living costs often lead to increased financial dependency within families. Studies from other countries (Fan & Hua, 2023; Kaufmann et al., 2022; Zheng et al., 2023) show that pension programs can significantly affect children's outcomes. In Thailand, Herrmann et al. (2021) found that pension reforms reduced child labor and improved literacy among older girls in the Northeastern region, although no significant impact was observed on school enrollment.

Despite these insights, limited OAA benefits restrict households' ability to invest in children's needs, and with 51% of elderly Thais relying mainly on the OAA for income (International Labour Organization, 2022),

reductions in coverage could worsen this strain. However, there is still little national evidence on how pension benefits affect household spending on children's education, health, and development. By exploring this relationship, one can justify the need for OAA program as well as to inform policies that promote intergenerational well-being in Thailand's rapidly aging society. Hence, this study aims to examine the impact of pension on children expenditure by using SES Panel data. The households included in the study are households with elderly and children with two types of households, namely three-generation households and skipped-generation households.

This paper includes a literature review covering relevant studies, policy background, and the conceptual framework. The data and methodology section details the research design. Results from a difference-in-differences analysis examine the OAA reform's impact on household expenditure and household expenditure on children. The paper concludes with discussion, key insights, and policy recommendations

Literature Review

This section provides an overview of Thailand's pension policies and reviews relevant literature on the effects of pension benefits. Thailand's Old Age Allowance (OAA) program, established under Article 11(11) of the Old Age Act, is the country's only universal welfare scheme for the elderly. Initially introduced in 2005 for disadvantaged individuals aged 60 or above, it operated under a strict quota system. In 2009, the program was expanded to cover all seniors not receiving other pension benefits, offering a flat 500-baht monthly payment. By October 2011, the scheme adopted a tiered structure based on age, ranging from 600 baht for those aged 60–69 to 1,000 baht for individuals aged 90 and above.

Pension programs, while primarily aimed at supporting the elderly, also produce significant intergenerational effects. Studies from Brazil, Mexico, and China show pensions can improve children's educational outcomes by increasing household income and reducing child labor (Mu & Du, 2015; Ponczek, 2011; Gutierrez et al., 2017; Zheng et al., 2023). For instance, pension transfers in rural China raised school attendance and literacy, particularly among disadvantaged boys.

Evidence on health impacts is mixed. While Ponczek (2011) found no clear link in Brazil, Zheng et al. (2023) observed improved physical and mental health among children in pension-receiving households in China. Pensions also influence financial and time investments in children. Increased income from pensions raises educational spending, especially in low- and middle-income households (Dong et al., 2023; Fan & Hua, 2023). Additionally, pension-related labor adjustments allow family members, particularly grandmothers, to provide more childcare (Kaufmann et al., 2022).

In Thailand, Herrmann et al. (2021) found that pension reforms reduced child labor and improved literacy, especially for girls in agricultural households, though no significant effect was found on school enrollment. While studies from countries like China, Brazil, and Mexico show that pension schemes positively impact children's education and household spending, evidence from Thailand remains limited. Existing

research, such as Herrmann et al. (2021), finds only regional effects, with little insight into national-level trends or household education expenditures. This gap is critical as Thailand considers reducing Old Age Allowance (OAA) coverage. A deeper understanding of how pensions influence household education spending is needed to assess potential intergenerational benefits. This study addresses these gaps, offering new evidence on the broader effects of pension programs like the OAA in Thailand.

Conceptual framework

The conceptual framework for this study is adapted from Fan and Hua (2023), illustrating how pension transfers influence household investment in human capital, measured by children's education expenditures. Pension transfers can impact investment through two channels. First, on the material side, receiving pensions reduces the need for family financial support to the elderly, alleviating the household's overall economic burden and allowing more resources to be allocated toward education. Second, on the non-material side, pensions can enhance the well-being of elder family members, fostering positive expectations for intergenerational investment in education and leading to qualitative improvements in human capital. This framework is applied to analyze Thailand's Old Age Allowance (OAA) reforms of 2009 and 2011, using nationally representative SES panel data. By focusing on detailed expenditure categories, the study moves beyond existing literature that emphasizes education or labor outcomes, offering broader insight into child welfare. Based on this framework, the study hypothesizes that reforming Thailand's Old Age Allowance (OAA) program would significantly increase household spending on children.

Data and Methods

Data

The primary dataset for this study comes from Thailand's 2007, 2010, and 2012 Survey of Household Socio-Economic, obtained from the National Statistics Office. It includes panel data on household characteristics such as gender, education, income, expenditure, and savings, along with information on government transfers like the Old Age Allowance (OAA) and Civil Service Pension. According to the survey question, respondents were asked, "How much do you spend on the following items on average per month?" They were required to report monthly spending across 11 specific categories, excluding total expenditure. These categories included education-related expenses such as tuition fees, books, and educational supplies. The dataset includes 4,434 elderly individuals and 9,447 children under the age of 23 (representing the typical age before completing a bachelor's degree). It focuses on 404 households with both elderly and children observed between 2007 and 2010, and 381 such households tracked between 2007 and 2012. It tracks changes in households receiving pensions from 2007 to 2012, highlighting increases in pension recipients after the 2009 and 2011 reforms.

Research Methodology

Following Wing, Simon, and Bello-Gomez (2018) and Glewwe et al. (2022), this study uses a Difference-in-Differences (DID) approach to compare changes in household expenditure on children between OAA-recipient and non-recipient households across 2010 and 2012, capturing the effects of the 2009 and 2011 OAA reforms. Equation 1 presents the estimation.

$$expenditure_c_{igt} = \beta_0 + \beta_1 T_g + \beta_2 After_t + \beta_3 + \varepsilon_{igt}, \quad (1)$$

This study investigates the average treatment on the treated of the Old Age Allowance (OAA) on children's household-level expenditures, considering various categories of spending, including education, food, housing, health, travel, and others. Where β_3 is the outcome of interest, estimates the average treatment on the treated of the OAA reforms on household expenditure on children, assuming a common trend. T_g a dummy variable identifying households that began receiving benefits in 2010 or 2012. And $After_t$ be a dummy variable for households in the second period (2010, 2012). The treatment variable (D_{gt}) identifies households exposed to treatment or control conditions and equals $T_g \times After_t$. For both groups in the first period, $D_{gt} = 0$, while in the second period, $D_{gt} = 1$ only for households that received benefits, indicating exposure to treatment. X_{igt} is a vector of household characteristics, including income, head of household's characteristics, household location, child-to-elderly ratio, household type, schooling members, and household assets. The base household is an urban household in the Bangkok Metropolitan Region, with three generations, no schooling members, a working-age head with below secondary education, ε_{igt} is the error term. The expected value of the average treatment on the treated is positive, as the increased allowance should enhance household income and spending, particularly on children's needs.

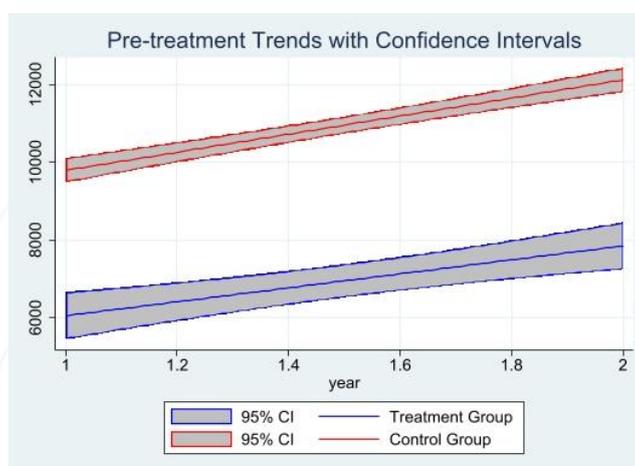


Figure 1 Pre-treatment trends with confidence intervals

Note: Author's calculations.

To ensure the reliability of the estimated effects, the study conducts robustness checks. All regressions employ cluster-robust standard errors at the household level. This adjustment accounts for potential intra-household correlation over time, a critical consideration given the panel structure of the SES dataset (2007, 2010, 2012). Additionally, the Parallel Trends Assumption holds as shown in figure 1. The pre-treatment trends with confidence intervals indicate a similar slope for the treatment and control groups during the period from 2005 (year 1) to 2007 (year 2), before the Old Age Allowance reform. This is consistent with the statistical test results. Applying the Difference-in-Differences design to households between 2005 and 2007, the variable of interest yields insignificant results.

Results and Discussion

This section presents difference-in-differences results assessing the impact of the 2009 and 2011 OAA reforms on household expenditure and household expenditure on children. Using 2007 as the baseline, the analysis compares changes from 2007–2010 and 2007–2012, distinguishing between effects from expanded coverage and increased benefits across household and children expenditure.

Coverage Change (Based on the Comparison Between 2007 and 2010)

This analysis examines how the expansion of the Old Age Allowance (OAA) program in 2009 affects household expenditure between 2007 and 2010. Initially, OAA benefits were limited to economically disadvantaged individuals aged 60 or older without family support. The 2009 reform broadened eligibility to all individuals aged 60 or older who had not received other pension benefits, resulting in a sharp rise in the number of elderly beneficiaries. Using a difference-in-differences (*DiD*) design, the key variable is the interaction term (*D*), capturing the additional impact of the OAA program on treated households in 2010. To isolate the impact of OAA on household's expenditure for children from household expenditure, hence the following results will be separated into two sets, the impact of OAA on household expenditure and on household expenditure on children. The findings reveal that the reform significantly improved household resource allocation, especially in food and housing categories.

Impact of OAA on household expenditure (2007-2010 data)

According to Table 1, following the 2009 expansion in eligibility, the results indicate a significant increase in total household expenditures among treated households. The interaction term (*D*) is statistically significant and positive, since expenditure outcome is measured in 1,000 baht, so with coefficient equal to 5.959 mean that an increase of 5,958.75 baht per month, indicating that the OAA reform enhanced household consumption. Before the reform, treated households spent significantly less than non-treated ones, as reflected by the negative treatment coefficient (*T*). The time coefficient (*After*) also shows a general decline in household

spending post-2007, likely due to macroeconomic conditions, but the *DiD* estimate isolates a clear net benefit of the reform.

Expenditure increases among treated households are concentrated on essential items. Food expenditure rose by 1,938.30 baht per month (the largest increase) followed by travel (1,704.43 baht) and housing (574.18 baht) compared to those didn't have received benefits. These shifts suggest that the additional income helped households meet basic needs and improve their living standards.

Control variables show that higher household head income and education were linked to greater spending. Urban and Bangkok households spent more overall. Households with children had slightly higher, but insignificant, education spending. More elderly members reduced non-essential spending. Private-sector households spend more on food and travel than agricultural ones.

Impact of OAA on household expenditure on children (2007-2010 data)

Household expenditure on children (for household members under 23 years old) also rose significantly as a result of 2009 reform. The interaction term (*D*) is positive and statistically significant, showing that households with increasing income by pension spent more on children after the reform compared to those didn't. Increases are evident in food (485.61 baht), housing (268.72 baht), and travel (288.47 baht) as presented in Table 2. These changes suggest improved living conditions for children resulting from enhanced household income. Spending increased on entertainment (39.68 baht) and personal care (130.78 baht), indicating more discretionary consumption for children. This improvement may enhance child well-being and psychosocial outcomes.

However, education expenditure for the treated group did not change significantly as a result of the reform. Households with school-aged children tended to spend more on education, but the effect was weak—potentially due to trade-offs in budget allocation or structural barriers to education access.

Urban households spent more across all categories than rural ones, and households with higher child-to-member ratios tended to prioritize education. Households with more elderly members reduced discretionary spending for children, highlighting potential intergenerational trade-offs. Occupational differences also influenced spending: non-agricultural households spent more on food and travel for children. Income and education of the household head were not statistically significant in explaining household expenditure on children, underscoring the greater impact of household composition and region.

Coverage and Benefits Change (Based on the Comparison Between 2007 and 2012)

This section examines the combined effects of expanded eligibility and increased benefits of the OAA program between the baseline year of 2007 and the comparison year of 2012. The eligibility criteria were expanded in 2009, leading to a significant increase in the number of elderly individuals receiving benefits. In 2011, the program further increased benefits, building on the eligibility expansion from 2009. This continuous

expansion of both eligibility and benefits led to a shift in household resource allocation, with treated households demonstrating higher expenditures across essential categories. The interaction term D for the coverage and benefit expansions in 2012 shows a significant increase in total household expenditures, particularly in food and housing. These ongoing adjustments to the program reflect the cumulative impact of the eligibility expansion in 2009 and the benefit increase in 2011 on household spending patterns. The following results are divided into two parts: the effect of the OAA reform on overall household expenditure and on household expenditure on children.

Impact of OAA household expenditure (2007-2012 data)

According to Table 3, When examining the combined effect of the 2009 coverage expansion and the 2011 benefit increase, the results reveal a continued positive impact on household expenditures. The DiD interaction term (D) is again positive and statistically significant, since expenditure outcome is measured in 1,000 baht, so with coefficient equal to 3.974 means that with an average increase of 3,973.65 baht per month for treated households. Although the treatment coefficient (T) remains negative, reflecting lower spending for OAA recipients, the reform's net effect is beneficial. The *After* term again captures a general decline in consumption post-2007.

The reform enabled increased spending on both essentials and discretionary items among treated groups. Compared to non-OAA recipients, the OAA recipients have higher food expenditure by 1,556.17 baht per month, while housing expenditure rise by 461.01 baht per month. These shifts indicate that households used the allowance primarily for improving nutrition and living conditions. The tiered benefit system introduced in 2011 provided more substantial financial support, allowing households to engage in discretionary spending on decoration, entertainment, and personal expenses.

These findings are consistent with earlier studies on pension programs that document increases in both essential and non-essential spending following benefit expansions (Cheng et al., 2018; Gutierrez et al., 2017; Herrmann et al., 2021; Fan & Hua, 2023; Dong et al., 2023).

Coefficients of control variables show that income and education levels were again positively associated with spending, and urban households continued to spend more than rural ones. Bangkok residents reported the highest expenditure. Households with more elderly members spent more on health and external social expenses, while those with children allocated more to education and food. Private-sector households, compared to agricultural ones, spent more on food and travel, reflecting occupational differences in income and consumption habits.

Impact of OAA household expenditure on children (2007-2012 data)

According to Table 4, household expenditure on children remained positively influenced by the reform through 2012. The interaction term (D) shows increased spending in food (468.34 baht), housing (218.99 baht),

and travel (200.13 baht) among OAA recipients, compared to non-recipients. These categories reflect improved basic living conditions for children in treated households.

Discretionary spending also increased slightly among treated group compared to control group. Entertainment rose by 45.82 baht and personal care by 74.70 baht per month, though the magnitude was smaller than household-level increases. These improvements suggest that the pension reform had spillover effects that enhanced children's daily lives.

As in 2009 reform, education spending showed no statistically significant increase. Although households with more children spent more on education in absolute terms, the effect remained weak. This suggests persistent structural or financial barriers to educational investment despite additional income.

Urban-rural disparities remained: urban households spent more on children across all categories. Households with school-aged children actually spent less on discretionary items—possibly due to increased costs associated with schooling. Income and education of the household head again had no significant effect, reinforcing the importance of household composition and location in determining household expenditure on children.

The Old Age Allowance (OAA) reforms in 2009 and 2011 on household expenditures related to children in Thailand. Using Difference-in-Differences estimation with data from the 2007, 2010, and 2012 Socioeconomic Surveys, the findings show mixed trends in household and children's spending patterns. Overall negative trends are observed in some group-level and time-period comparisons, likely reflecting broader macroeconomic stressors such as the 2008–2009 global financial crisis, rising household debt, political instability, the 2011 flooding, and escalating living costs.

Discussion

The OAA reforms significantly increased household spending among treated households compared to those did not on food and housing, with no notable change in education. Household expenditure on children also rose in food, housing, travel, entertainment, and personal items. Comparing the two sets of results shows that at the household level, increased income from the OAA was primarily allocated food and housing. In contrast, expenditures by children were more directed toward travel, entertainment, and personal expenditure. This indicates that the pension reforms helped improve children's well-being by supporting better nutrition, living environments, and personal development. These outcomes are consistent with Suwanrada & Leetrakun (2014), who found that elderly Thais often use pension income for children's needs. Similarly, Gorman (2004) noted that pensions in developing countries increase spending on food and clothing. The absence of significant results for education aligns with Herrmann et al. (2012), who also reported limited impact on educational spending in northern Thailand.

This study is limited by the lack of detailed child-specific expenditure data in the 2007, 2010, and 2012 Socioeconomic Status Surveys and reduced variation due to OAA universalization. It also overlooks income

and age group differences. Future research should use richer datasets and examine other transfer programs for broader insights.

Conclusion

The OAA reforms generated positive spillover effects, leading to increased household expenditures for children in areas such as food, housing, and personal care, suggesting improved child welfare in households that received OAA benefits compared to non-recipient households. However, the reforms did not result in a significant rise in education-related spending, highlighting a gap in long-term investment in human capital despite the short-term gains in children's well-being.

Policy recommendations

The 2009 and 2011 Old Age Allowance (OAA) reforms improved household spending on children, particularly in nutrition, housing, and personal care, indirectly supporting child well-being. To strengthen long-term human capital, the government should raise benefits for low-income households and expand coverage to vulnerable groups. Policies such as rental subsidies can ease urban housing burdens linked to education access. Financial literacy programs could help recipients use allowances more effectively. With declining fertility, the OAA should be integrated into broader family support policies, promoting intergenerational welfare and reducing child-rearing costs to enhance both elderly and child outcomes in multigenerational households.

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Table 1 Coverage change on household expenditure 2007-2010 data

	(1) expenditure	(2) education	(3) food	(4) housing	(5) decoration	(6) health
T	-2.042** (0.828)	0.172 (0.160)	-0.567* (0.328)	-0.119 (0.122)	-0.004 (0.047)	0.062 (0.131)
after	-5.863*** (1.113)	0.319* (0.185)	-2.428*** (0.408)	-0.278* (0.163)	-0.094** (0.038)	-0.311* (0.178)
D	5.959*** (1.499)	0.209 (0.592)	1.938*** (0.543)	0.574*** (0.204)	-0.006 (0.050)	0.068 (0.214)
hh_income	0.377** (0.171)	0.065*** (0.011)	0.059 (0.048)	0.027 (0.021)	0.008*** (0.003)	0.006 (0.009)
hh_asset	0.024*** (0.006)	-0.000 (0.001)	0.006*** (0.002)	0.001 (0.001)	0.001** (0.000)	0.002*** (0.001)
eld_ratio	-7.782*** (1.417)	-0.450 (0.551)	-3.214*** (0.487)	-0.332 (0.245)	-0.056 (0.040)	0.208 (0.173)
child_ratio	-2.726 (1.864)	0.218 (0.458)	-1.265* (0.689)	0.469 (0.289)	-0.144* (0.074)	-0.001 (0.142)
skip_gen	-1.389 (0.939)	-0.213 (0.173)	-0.360 (0.383)	-0.140 (0.175)	0.002 (0.036)	-0.034 (0.104)
head_elderly	0.583 (0.891)	0.022 (0.119)	0.597* (0.355)	-0.120 (0.143)	-0.006 (0.040)	-0.410** (0.192)
schooling	4.438*** (0.761)	1.101*** (0.178)	1.042*** (0.307)	0.254** (0.118)	0.048* (0.029)	0.025 (0.091)
head_edu	4.125*** (1.441)	0.236 (0.240)	1.164** (0.491)	0.434** (0.171)	0.021 (0.049)	0.161 (0.246)
handicraft	3.048 (4.132)	0.747* (0.437)	0.436 (1.043)	0.153 (0.224)	0.059 (0.133)	0.208 (0.165)
manufac	8.649* (4.873)	0.593 (0.657)	2.927* (1.669)	0.676 (0.555)	-0.157 (0.117)	0.167 (0.442)
trading	0.682 (1.150)	-0.000 (0.134)	0.492 (0.419)	0.177 (0.169)	-0.065** (0.032)	0.035 (0.146)
p_servant	3.834 (2.495)	1.440 (1.046)	-0.002 (0.660)	-0.228 (0.278)	0.411** (0.181)	-0.145 (0.288)
employee	4.845*** (1.479)	0.182 (0.263)	1.892*** (0.592)	0.526*** (0.189)	0.006 (0.043)	-0.095 (0.163)
labor	1.465 (2.473)	0.054 (0.153)	1.533 (1.436)	0.020 (0.187)	0.051 (0.076)	-0.234 (0.144)
mid	-2.961*** (1.078)	-0.203 (0.329)	-1.289*** (0.383)	-0.789*** (0.225)	0.028 (0.045)	0.352 (0.270)
north	-3.811*** (1.093)	-0.360 (0.404)	-1.489*** (0.405)	-1.013*** (0.231)	-0.022 (0.041)	0.120 (0.147)
ne	-4.853*** (1.007)	-0.349 (0.338)	-2.336*** (0.366)	-1.126*** (0.212)	0.011 (0.045)	0.179 (0.199)
south	-1.447 (1.271)	-0.262 (0.382)	-1.015* (0.522)	-0.849*** (0.241)	0.118** (0.055)	0.054 (0.147)
area	-0.492 (0.583)	-0.109 (0.118)	-0.388* (0.231)	-0.136 (0.108)	-0.011 (0.032)	-0.084 (0.174)
_cons	12.879*** (1.421)	0.136 (0.281)	6.154*** (0.513)	1.614*** (0.267)	0.091 (0.056)	0.184 (0.191)
N	808	808	808	808	808	808
r ²						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

Table 1 Coverage change on household expenditure 2007-2010 data (Cont.)

	(7)	(8)	(9)	(10)	(11)	(12)
	travel	entertainment	personal	social	external	else
T	-1.067*** (0.321)	0.101 (0.125)	-0.100 (0.098)	-0.010 (0.071)	-0.296** (0.134)	-0.200 (0.173)
after	-2.375*** (0.359)	-0.117*** (0.043)	-0.489*** (0.167)	-0.318** (0.131)	0.324 (0.208)	-0.087 (0.408)
D	1.704*** (0.443)	-0.041 (0.117)	0.175 (0.137)	0.521 (0.338)	0.297 (0.199)	0.506 (0.336)
hh_income	0.081 (0.064)	0.003 (0.003)	0.010 (0.012)	0.045*** (0.010)	0.019 (0.021)	0.052*** (0.018)
hh_asset	0.006*** (0.002)	0.001*** (0.000)	0.004** (0.002)	0.001*** (0.000)	0.000 (0.001)	0.003*** (0.001)
eld_ratio	-1.732*** (0.398)	-0.173* (0.090)	-0.332** (0.152)	-0.555* (0.331)	-0.383** (0.166)	-0.709*** (0.275)
child_ratio	-1.623** (0.633)	-0.260 (0.164)	-0.114 (0.148)	-0.377*** (0.143)	0.230 (0.356)	0.263 (0.596)
skip_gen	-0.350 (0.284)	-0.093 (0.096)	0.042 (0.094)	0.027 (0.094)	-0.084 (0.148)	-0.226 (0.294)
head_elderly	0.250 (0.348)	0.067 (0.060)	-0.051 (0.143)	0.042 (0.078)	0.181 (0.120)	-0.027 (0.169)
schooling	0.766*** (0.251)	0.114* (0.068)	0.056 (0.067)	0.087 (0.057)	0.481*** (0.130)	0.459* (0.240)
head_edu	0.773* (0.453)	-0.002 (0.109)	0.579** (0.237)	0.150* (0.090)	0.127 (0.180)	0.439 (0.326)
handicraft	1.289 (2.135)	0.079 (0.183)	0.085 (0.203)	0.104 (0.169)	-0.309* (0.162)	0.282 (0.692)
manufac	4.267* (2.282)	0.090 (0.211)	0.565 (0.629)	-0.270 (0.532)	0.310 (0.633)	-0.630 (0.577)
trading	0.460 (0.471)	0.023 (0.047)	-0.050 (0.169)	-0.218*** (0.058)	0.028 (0.167)	-0.175 (0.230)
p_servant	1.143 (0.864)	0.087 (0.107)	-0.002 (0.288)	0.060 (0.172)	1.197** (0.548)	-0.150 (0.490)
employee	1.183*** (0.420)	0.302 (0.274)	0.364 (0.307)	0.133 (0.106)	0.187 (0.149)	0.243 (0.342)
labor	0.203 (0.557)	0.096 (0.091)	0.128 (0.138)	-0.068 (0.098)	0.032 (0.093)	-0.214 (0.182)
mid	-1.004*** (0.327)	-0.012 (0.084)	-0.190 (0.129)	0.097 (0.073)	-0.005 (0.183)	0.032 (0.200)
north	-1.051*** (0.333)	-0.058 (0.070)	-0.089 (0.125)	0.003 (0.077)	-0.014 (0.182)	0.144 (0.230)
ne	-1.436*** (0.300)	-0.025 (0.137)	-0.146 (0.129)	0.075 (0.082)	-0.043 (0.191)	0.319 (0.291)
south	0.088 (0.521)	-0.042 (0.091)	-0.127 (0.144)	0.102 (0.106)	0.331 (0.265)	0.121 (0.280)
area	0.309 (0.200)	-0.064 (0.086)	-0.078 (0.086)	0.084* (0.050)	-0.043 (0.135)	-0.005 (0.173)
_cons	3.395*** (0.471)	0.177** (0.069)	0.678*** (0.142)	0.333* (0.187)	-0.088 (0.285)	0.214 (0.488)
N	808	808	808	808	808	808
r ²						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

Table 2 Coverage change on children expenditure 2007-2010 data

	(1)	(2)	(3)	(4)	(5)	(6)
	expen_c	edu_c	food_c	housing_c	decor_c	health_c
T	-0.392*	0.024	-0.171	-0.065	-0.002	-0.011
	(0.222)	(0.055)	(0.104)	(0.050)	(0.007)	(0.013)
after	0.377	0.258**	0.061	0.241**	-0.017	-0.015*
	(0.439)	(0.105)	(0.165)	(0.107)	(0.011)	(0.008)
D	1.602***	0.409	0.486***	0.269*	0.001	0.017
	(0.548)	(0.324)	(0.176)	(0.145)	(0.010)	(0.010)
hh_income	-0.002	-0.002	0.000	0.000	0.000	-0.000
	(0.008)	(0.003)	(0.003)	(0.001)	(0.000)	(0.000)
hh_asset	0.000	-0.000	-0.000	-0.000*	-0.000	0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
eld_ratio	-1.293***	-0.383	-0.362***	-0.219**	0.002	-0.010
	(0.445)	(0.297)	(0.131)	(0.106)	(0.004)	(0.013)
child_ratio	7.273***	0.744***	2.904***	1.111***	0.055***	0.050**
	(1.177)	(0.278)	(0.438)	(0.238)	(0.019)	(0.023)
skip_gen	0.227	0.045	-0.041	0.143	0.002	-0.005
	(0.499)	(0.120)	(0.187)	(0.158)	(0.017)	(0.007)
head_elderly	0.083	0.011	0.061	0.013	-0.001	0.008
	(0.196)	(0.031)	(0.097)	(0.055)	(0.006)	(0.022)
schooling	-0.699**	0.265***	-0.448***	-0.002	-0.030***	-0.013*
	(0.321)	(0.096)	(0.127)	(0.085)	(0.011)	(0.007)
head_edu	-0.466*	-0.084	-0.178	-0.003	0.001	0.008
	(0.280)	(0.077)	(0.122)	(0.097)	(0.007)	(0.011)
handicraft	-0.350	-0.046	-0.119	-0.048	-0.008	0.034
	(0.438)	(0.054)	(0.171)	(0.056)	(0.006)	(0.041)
manufac	1.057	-0.072	0.591	-0.067	0.000	-0.011
	(0.876)	(0.100)	(0.464)	(0.088)	(0.005)	(0.012)
trading	0.168	0.070	0.051	0.056	-0.008**	-0.005
	(0.254)	(0.047)	(0.100)	(0.082)	(0.003)	(0.008)
p_servant	1.036	0.671	0.323*	0.003	-0.012*	0.085
	(0.742)	(0.587)	(0.173)	(0.131)	(0.007)	(0.090)
employee	0.631*	0.079	0.374**	0.128	0.006	-0.008**
	(0.349)	(0.158)	(0.154)	(0.123)	(0.010)	(0.004)
labor	0.175	0.050	0.087	0.028	-0.016**	0.009
	(0.385)	(0.053)	(0.199)	(0.096)	(0.008)	(0.015)
mid	-0.474	-0.153	-0.182	-0.033	-0.002	0.017
	(0.346)	(0.174)	(0.126)	(0.083)	(0.009)	(0.016)
north	-0.432	-0.223	-0.137	0.054	0.003	0.002
	(0.405)	(0.216)	(0.145)	(0.112)	(0.009)	(0.008)
ne	-0.760*	-0.176	-0.357***	-0.105	-0.008	-0.001
	(0.408)	(0.180)	(0.124)	(0.083)	(0.006)	(0.005)
south	-0.102	-0.145	0.001	-0.031	0.012	-0.003
	(0.416)	(0.197)	(0.178)	(0.095)	(0.012)	(0.007)
area	-0.668***	0.020	-0.367***	-0.093*	-0.005	0.012
	(0.209)	(0.048)	(0.080)	(0.055)	(0.006)	(0.013)
_cons	0.646	-0.120	0.448**	-0.093	0.023*	-0.009
	(0.550)	(0.160)	(0.210)	(0.120)	(0.014)	(0.027)
N	808	808	808	808	808	808
r ²						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

Table 2 Coverage change on children expenditure 2007-2010 data (Cont.)

	(7)	(8)	(9)	(10)	(11)	(12)
	trav_c	enter_c	pers_c	social_c	exter_c	els_c
T	-0.131** (0.059)	-0.015 (0.009)	-0.034 (0.022)	-0.001 (0.007)	0.014 (0.020)	-0.002 (0.037)
after	-0.258*** (0.082)	-0.026** (0.011)	-0.034 (0.032)	-0.026*** (0.010)	0.034* (0.018)	0.168 (0.227)
D	0.288*** (0.090)	0.040** (0.016)	0.131*** (0.042)	0.003 (0.009)	-0.009 (0.036)	-0.032 (0.098)
hh_income	-0.002 (0.001)	-0.000 (0.000)	-0.001 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.003 (0.003)
hh_asset	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	0.000 (0.000)	-0.000 (0.000)	0.001 (0.001)
eld_ratio	-0.153** (0.069)	-0.031** (0.015)	-0.107*** (0.032)	-0.005 (0.005)	-0.017 (0.023)	-0.007 (0.041)
child_ratio	1.139*** (0.169)	0.101*** (0.021)	0.461*** (0.079)	0.052*** (0.014)	0.114** (0.051)	0.554 (0.439)
skip_gen	0.107 (0.104)	0.025 (0.020)	0.082 (0.054)	0.016 (0.017)	0.005 (0.043)	-0.144 (0.140)
head_elderly	-0.018 (0.052)	0.008 (0.010)	0.023 (0.019)	0.001 (0.005)	0.016* (0.009)	-0.032 (0.043)
schooling	-0.350*** (0.078)	-0.025** (0.011)	-0.091*** (0.027)	-0.035*** (0.010)	-0.016 (0.014)	0.052 (0.108)
head_edu	-0.090 (0.058)	-0.015 (0.012)	-0.025 (0.020)	0.001 (0.005)	-0.001 (0.024)	-0.094 (0.078)
handicraft	-0.099 (0.101)	0.023 (0.041)	-0.035 (0.038)	-0.015** (0.007)	-0.000 (0.013)	-0.035 (0.024)
manufac	0.295 (0.260)	0.096 (0.088)	0.055 (0.053)	0.041 (0.035)	0.002 (0.013)	0.057 (0.082)
trading	0.067 (0.073)	0.019 (0.018)	-0.002 (0.018)	-0.005 (0.005)	-0.002 (0.006)	-0.067 (0.063)
p_servant	0.084 (0.096)	0.023 (0.020)	0.050 (0.034)	-0.003 (0.006)	-0.010 (0.021)	-0.162 (0.139)
employee	0.038 (0.063)	-0.003 (0.010)	0.034 (0.026)	-0.005 (0.007)	0.072* (0.038)	-0.074 (0.050)
labor	0.016 (0.128)	0.018 (0.020)	0.009 (0.047)	-0.022*** (0.007)	-0.005 (0.011)	0.024 (0.067)
mid	-0.291*** (0.071)	-0.008 (0.012)	0.030 (0.032)	0.005 (0.006)	-0.009 (0.018)	0.143 (0.128)
north	-0.279*** (0.072)	-0.004 (0.013)	0.014 (0.028)	0.005 (0.007)	0.002 (0.026)	0.119 (0.132)
ne	-0.316*** (0.070)	-0.017 (0.011)	-0.016 (0.024)	0.006 (0.006)	-0.023 (0.018)	0.237 (0.252)
south	-0.102 (0.097)	-0.007 (0.013)	0.030 (0.030)	0.023** (0.010)	-0.018 (0.019)	0.126 (0.135)
area	-0.011 (0.035)	-0.012* (0.007)	-0.050*** (0.017)	-0.008 (0.006)	0.002 (0.009)	-0.167 (0.121)
_cons	0.496*** (0.111)	0.035** (0.014)	0.054 (0.041)	0.028** (0.011)	-0.021 (0.025)	-0.190 (0.288)
N	808	808	808	808	808	808
r ²						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

Table 3 Coverage and benefits change on household expenditure 2007-2012

	(1)	(2)	(3)	(4)	(5)	(6)
	expenditure	education	food	housing	decor	health
T	-1.214 (0.880)	-0.009 (0.113)	-0.450 (0.301)	-0.210* (0.112)	-0.055 (0.034)	0.177 (0.233)
after	-5.392*** (0.823)	0.266 (0.215)	-2.160*** (0.323)	-0.453*** (0.163)	-0.070 (0.065)	-0.279*** (0.093)
D	3.974*** (1.173)	0.145 (0.191)	1.556*** (0.421)	0.461** (0.225)	0.228* (0.136)	-0.067 (0.184)
hh_income	0.301** (0.125)	0.071*** (0.011)	0.027 (0.027)	0.011 (0.009)	0.010** (0.005)	0.003 (0.007)
hh_asset	0.014*** (0.003)	-0.000 (0.000)	0.002** (0.001)	0.001* (0.001)	0.000 (0.000)	0.001 (0.001)
eld_ratio	-6.804*** (1.076)	-0.151 (0.149)	-2.815*** (0.432)	-0.412* (0.218)	-0.141 (0.119)	0.099 (0.139)
child_ratio	-4.204** (1.900)	0.740 (0.520)	-1.670* (0.878)	-0.270 (0.212)	-0.153 (0.097)	0.030 (0.119)
skip_gen	-1.981** (0.809)	-0.326* (0.184)	-0.680** (0.317)	-0.077 (0.116)	0.037 (0.054)	-0.143 (0.110)
head_elderly	1.638** (0.831)	0.023 (0.113)	1.025*** (0.321)	0.174 (0.113)	-0.008 (0.037)	-0.284 (0.221)
schooling	3.660*** (0.797)	1.011*** (0.139)	0.799** (0.316)	0.108 (0.126)	0.082** (0.040)	0.076 (0.104)
head_edu	2.664** (1.338)	0.698** (0.341)	0.854* (0.477)	0.458*** (0.162)	0.052 (0.086)	-0.071 (0.124)
handicraft	1.698 (2.877)	0.473* (0.280)	0.176 (0.795)	0.059 (0.221)	0.011 (0.093)	0.096 (0.110)
manufac	8.928* (4.663)	0.447 (0.585)	4.437*** (1.840)	0.778* (0.427)	-0.280*** (0.103)	0.141 (0.381)
trading	1.533 (0.994)	-0.239* (0.126)	0.847*** (0.344)	0.291* (0.163)	-0.064 (0.051)	0.089 (0.138)
p_servant	5.789** (2.593)	-0.002 (0.452)	1.491** (0.621)	0.027 (0.256)	0.316 (0.242)	-0.171 (0.207)
employee	3.283*** (1.138)	-0.135 (0.185)	1.425*** (0.421)	0.326* (0.176)	-0.006 (0.060)	-0.088 (0.095)
labor	0.705 (2.040)	-0.164 (0.153)	1.379 (1.226)	-0.031 (0.160)	0.009 (0.070)	-0.210 (0.128)
mid	-2.776** (1.113)	-0.095 (0.164)	-1.498*** (0.428)	-0.621*** (0.186)	0.020 (0.068)	0.238 (0.270)
north	-5.184*** (0.998)	-0.216 (0.140)	-1.813*** (0.441)	-0.964*** (0.188)	-0.051 (0.070)	-0.029 (0.095)
ne	-5.805*** (0.920)	-0.165 (0.143)	-2.512*** (0.399)	-1.017*** (0.175)	0.004 (0.087)	-0.033 (0.105)
south	-0.843 (1.417)	0.056 (0.204)	-0.752 (0.539)	-0.918*** (0.221)	0.106 (0.083)	0.053 (0.134)
area	-0.738 (0.585)	-0.089 (0.094)	-0.335 (0.208)	0.008 (0.110)	-0.048 (0.052)	-0.082 (0.138)
_cons	13.956*** (1.335)	-0.029 (0.239)	6.288*** (0.523)	1.603*** (0.223)	0.156** (0.078)	0.312*** (0.102)
N	762	762	762	762	762	762
r2						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

Table 3 Coverage and benefits change on household expenditure 2007-2012(Cont.)

	(7)	(8)	(9)	(10)	(11)	(12)
	travel	entertainment	personal	social	external	else
T	0.050 (0.380)	-0.124* (0.071)	-0.091 (0.068)	0.007 (0.056)	-0.228** (0.110)	-0.287* (0.169)
after	-1.734*** (0.325)	-0.103** (0.045)	-0.420*** (0.063)	-0.027 (0.077)	0.080 (0.144)	-0.485*** (0.179)
D	0.677 (0.449)	0.204** (0.095)	0.154* (0.080)	-0.135 (0.107)	0.409** (0.192)	0.340 (0.219)
hh_income	0.073 (0.059)	0.003 (0.002)	0.007 (0.008)	0.039*** (0.009)	0.018 (0.020)	0.035** (0.017)
hh_asset	0.005*** (0.001)	0.000* (0.000)	0.000* (0.000)	0.001 (0.001)	0.000 (0.000)	0.003** (0.001)
eld_ratio	-1.869*** (0.375)	-0.252** (0.104)	-0.295*** (0.071)	-0.022 (0.114)	-0.449*** (0.162)	-0.505*** (0.176)
child_ratio	-1.695*** (0.626)	-0.231 (0.160)	-0.246** (0.111)	-0.234 (0.143)	-0.217 (0.345)	-0.178 (0.279)
skip_gen	-0.871*** (0.267)	-0.004 (0.046)	-0.102* (0.058)	-0.002 (0.066)	0.088 (0.163)	0.047 (0.264)
head_elderly	0.311 (0.349)	0.153 (0.095)	0.075 (0.059)	0.036 (0.056)	0.105 (0.121)	0.046 (0.176)
schooling	0.862*** (0.305)	0.149** (0.070)	0.067 (0.057)	0.064 (0.055)	0.342*** (0.126)	0.094 (0.181)
head_edu	0.628 (0.558)	0.026 (0.103)	0.112 (0.099)	0.094 (0.095)	0.033 (0.132)	-0.128 (0.181)
handicraft	0.876 (1.459)	0.083 (0.114)	0.017 (0.139)	0.099 (0.136)	-0.236* (0.131)	0.021 (0.412)
manufac	3.152 (2.322)	0.028 (0.202)	0.757 (0.658)	-0.266 (0.420)	-0.090 (0.309)	-0.185 (0.414)
trading	0.564 (0.438)	0.040 (0.041)	0.100 (0.066)	-0.116* (0.064)	0.004 (0.174)	0.032 (0.224)
p_servant	1.126 (1.197)	0.190 (0.125)	0.586* (0.347)	0.031 (0.207)	0.591 (0.542)	1.514* (0.780)
employee	1.375** (0.540)	0.329 (0.317)	0.086 (0.085)	-0.034 (0.059)	0.037 (0.125)	-0.068 (0.147)
labor	-0.123 (0.461)	0.105 (0.089)	0.021 (0.083)	0.122 (0.183)	-0.163** (0.080)	-0.325* (0.168)
mid	-0.905** (0.399)	-0.037 (0.088)	-0.151* (0.082)	0.318*** (0.110)	0.002 (0.165)	-0.025 (0.261)
north	-1.493*** (0.362)	-0.120 (0.082)	-0.198** (0.082)	0.022 (0.087)	-0.099 (0.165)	-0.201 (0.248)
ne	-1.607*** (0.360)	-0.069 (0.134)	-0.223*** (0.077)	0.030 (0.087)	-0.048 (0.177)	-0.160 (0.247)
south	0.273 (0.662)	-0.025 (0.103)	0.109 (0.152)	0.186** (0.086)	0.423* (0.252)	-0.347 (0.263)
area	-0.044 (0.230)	-0.071 (0.080)	-0.156*** (0.056)	0.072 (0.068)	-0.035 (0.121)	0.024 (0.129)
_cons	3.440*** (0.511)	0.246*** (0.060)	0.891*** (0.109)	0.090 (0.188)	0.187 (0.223)	0.771** (0.320)
N	762	762	762	762	762	762
r ²						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

Table 4 Coverage and benefits change on children expenditure 2007-2012

	(1)	(2)	(3)	(4)	(5)	(6)
	expen_c	edu_c	food_c	housing_c	decor_c	health_c
T	-0.414** (0.197)	0.040 (0.041)	-0.176* (0.090)	-0.074* (0.040)	-0.012 (0.008)	-0.002 (0.006)
after	-0.341 (0.466)	0.350* (0.208)	-0.146 (0.187)	-0.056 (0.080)	-0.012 (0.012)	-0.030*** (0.010)
D	1.149*** (0.339)	-0.009 (0.108)	0.468*** (0.139)	0.219*** (0.080)	0.006 (0.010)	0.005 (0.005)
hh_income	-0.005 (0.004)	0.001 (0.002)	-0.002 (0.002)	-0.001 (0.001)	0.000 (0.000)	-0.000 (0.000)
hh_asset	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
eld_ratio	-0.461* (0.262)	-0.034 (0.059)	-0.167 (0.116)	-0.104* (0.063)	0.007 (0.010)	0.014* (0.007)
child_ratio	6.298*** (1.220)	0.934** (0.464)	2.940*** (0.606)	0.392*** (0.124)	0.056** (0.025)	0.022*** (0.008)
skip_gen	0.245 (0.479)	-0.033 (0.153)	-0.011 (0.215)	0.119 (0.083)	0.033 (0.030)	-0.004 (0.004)
head_elderly	-0.130 (0.198)	-0.026 (0.031)	-0.023 (0.094)	-0.016 (0.054)	-0.003 (0.008)	-0.020** (0.009)
schooling	-1.381*** (0.337)	0.157 (0.111)	-0.710*** (0.142)	-0.092 (0.073)	-0.029** (0.012)	-0.021** (0.008)
head_edu	-0.081 (0.417)	0.161 (0.228)	-0.129 (0.123)	0.003 (0.052)	-0.015* (0.008)	0.002 (0.008)
handicraft	-0.208 (0.255)	-0.058 (0.040)	-0.077 (0.104)	-0.017 (0.028)	-0.004 (0.004)	0.024 (0.026)
manufac	1.728* (0.930)	-0.184 (0.139)	1.230** (0.617)	-0.030 (0.050)	0.006 (0.009)	-0.005 (0.006)
trading	0.261 (0.265)	-0.011 (0.052)	0.067 (0.108)	0.102 (0.082)	-0.004 (0.004)	-0.002 (0.007)
p_servant	-0.237 (0.369)	-0.206 (0.200)	0.075 (0.134)	-0.055 (0.043)	0.003 (0.006)	-0.015** (0.007)
employee	0.431 (0.299)	-0.075 (0.092)	0.307** (0.150)	0.032 (0.054)	0.027 (0.025)	0.000 (0.008)
labor	-0.245 (0.335)	-0.104 (0.073)	-0.055 (0.187)	-0.044 (0.080)	-0.012* (0.007)	0.002 (0.013)
mid	-0.599** (0.243)	-0.033 (0.044)	-0.344*** (0.123)	0.089* (0.053)	-0.008 (0.006)	-0.001 (0.006)
north	-0.496* (0.271)	-0.034 (0.039)	-0.261* (0.133)	0.116 (0.090)	0.006 (0.012)	0.003 (0.008)
ne	-0.976*** (0.236)	-0.039 (0.053)	-0.504*** (0.122)	-0.004 (0.037)	-0.011* (0.006)	-0.003 (0.004)
south	-0.337 (0.312)	-0.007 (0.070)	-0.195 (0.168)	0.029 (0.041)	0.009 (0.012)	-0.001 (0.006)
area	-0.074 (0.158)	0.086* (0.048)	-0.109 (0.068)	-0.045 (0.044)	0.002 (0.005)	-0.000 (0.004)
_cons	1.020* (0.533)	-0.327 (0.208)	0.545** (0.238)	0.056 (0.082)	0.016 (0.014)	0.031*** (0.011)
N	762	762	762	762	762	762
r2						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

Table 4 Coverage and benefits change on children expenditure 2007-2012(Cont.)

	(7)	(8)	(9)	(10)	(11)	(12)
	trav_c	enter_c	pers_c	social_c	exter_c	els_c
T	-0.108*	-0.018	-0.040**	0.003	-0.001	-0.028*
	(0.061)	(0.015)	(0.018)	(0.011)	(0.011)	(0.017)
after	-0.302***	0.005	-0.090***	0.004	0.009	-0.069
	(0.096)	(0.021)	(0.025)	(0.035)	(0.012)	(0.047)
D	0.200***	0.046**	0.075***	0.001	0.086	0.050**
	(0.069)	(0.023)	(0.021)	(0.019)	(0.072)	(0.025)
hh_income	-0.002*	-0.000	-0.001**	0.000	-0.000	-0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
hh_asset	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
eld_ratio	-0.021	-0.033*	-0.031**	-0.007	-0.059	-0.023*
	(0.064)	(0.017)	(0.015)	(0.009)	(0.050)	(0.013)
child_ratio	1.042***	0.130***	0.321***	0.173*	0.173	0.113**
	(0.210)	(0.039)	(0.060)	(0.104)	(0.142)	(0.045)
skip_gen	0.089	0.044	0.036	0.012	-0.035	0.001
	(0.111)	(0.033)	(0.033)	(0.032)	(0.028)	(0.019)
head_elderly	-0.061	0.011	0.007	0.010	-0.007	0.000
	(0.060)	(0.011)	(0.015)	(0.008)	(0.015)	(0.023)
schooling	-0.412***	-0.004	-0.119***	-0.054***	-0.015	-0.079***
	(0.087)	(0.015)	(0.023)	(0.013)	(0.019)	(0.029)
head_edu	-0.078	0.006	-0.022	0.033	-0.017	-0.018
	(0.073)	(0.024)	(0.019)	(0.030)	(0.012)	(0.015)
handicraft	-0.040	0.009	-0.022	-0.004	-0.010	-0.006
	(0.061)	(0.028)	(0.018)	(0.009)	(0.013)	(0.008)
manufac	0.371	0.071	0.064	0.053*	0.083	0.070
	(0.257)	(0.090)	(0.046)	(0.032)	(0.066)	(0.066)
trading	0.095	0.022	0.009	-0.005	-0.013	0.001
	(0.076)	(0.019)	(0.018)	(0.006)	(0.011)	(0.013)
p_servant	-0.004	-0.020	0.021	-0.029	-0.004	-0.007
	(0.075)	(0.020)	(0.026)	(0.024)	(0.010)	(0.017)
employee	0.128	0.005	0.019	-0.005	-0.003	0.001
	(0.089)	(0.013)	(0.020)	(0.012)	(0.008)	(0.021)
labor	-0.026	0.008	-0.010	0.063	-0.027	-0.038
	(0.109)	(0.018)	(0.040)	(0.078)	(0.022)	(0.025)
mid	-0.267***	-0.021	-0.010	0.001	0.003	-0.007
	(0.074)	(0.014)	(0.020)	(0.009)	(0.014)	(0.037)
north	-0.270***	-0.003	-0.024	0.007	-0.011	-0.023
	(0.067)	(0.015)	(0.019)	(0.008)	(0.011)	(0.021)
ne	-0.310***	-0.028**	-0.047**	-0.000	0.007	-0.036*
	(0.071)	(0.014)	(0.019)	(0.006)	(0.011)	(0.020)
south	-0.138	-0.027**	-0.002	0.036**	-0.012	-0.027
	(0.097)	(0.013)	(0.023)	(0.017)	(0.012)	(0.021)
area	0.027	0.002	-0.016*	-0.007	0.017	-0.029
	(0.033)	(0.007)	(0.009)	(0.007)	(0.015)	(0.020)
_cons	0.485***	0.006	0.117***	-0.009	-0.018	0.109**
	(0.130)	(0.023)	(0.035)	(0.040)	(0.017)	(0.055)
N	762	762	762	762	762	762
r ²						

Note: Author's calculations, expenditure values are reported in units of 1,000-baht, standard errors in parentheses, ***, **, and * indicate significant at 1%, 5%, and 10% level respectively.

The Effect of Digital Technology Adoption on the Labor Productivity of Informal Enterprises in Cambodia

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Abstract

This study examines the effect of digital technology adoption on the labor productivity of informal enterprises in Cambodia. The research analyzes secondary data from the 2024 Cambodian Informal Sector Enterprise Survey implemented by the World Bank Group, which followed an area-based sampling method in four Cambodian cities. Descriptive statistics reveal a low adoption rate of computer skills among workers in the surveyed enterprises (around 17%). The study finds that while computer usage increases electricity consumption and thus energy costs, implementing digital transactions through electronic devices negates the significant negative impact of energy costs on sales per worker. Moreover, informal enterprises that utilize digital technology for e-payments are more likely to generate higher sales per worker. It can be inferred that the shift towards digital payments provides available working capital, enabling businesses to sustain and even invest more in production to generate higher sales revenue.

Keywords: Cambodia, digital technology, informal enterprises, labor productivity



The Impact of Burmese Labor in the Informal Economy on the Economic Growth of Chiang Mai

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Abstract

This study was obtained to examine the impact of Burmese labor in the informal economy on the economic growth of Chiang Mai. The Multiple Indicators and Multiple Causes (MIMIC) model was employed to analyze data collected from 175 questionnaires, selected using snowball sampling from the local Burmese labor groups. Due to difficulties in accessing Burmese labor in the area caused by language barriers and a high level of distrust toward strangers, data collection started with one initial node and expanded through connected networks. The model's analysis revealed that the expansion of the informal economy was statistically significant and positively correlated with factors related to Burmese labor behavior, such as income, expenses, cash flow, work permits, the situation in Burma, and the number of laborers. Among these expenses had the strongest impact, with a standardized coefficient of 0.552. The results also indicated that the informal economy and the province's gross domestic product clearly reflect the influence of Burmese labor, affecting Chiang Mai's economic growth.

Keywords: Burmese labor, informal economy, migrant labors

Introduction

The interrelationship between politics, society, and the economy is widely recognized to cause various forms of dynamic social changes, such as the various economic crises which affect the living conditions of society and politics, or the occurrence of wars that may affect the politics and society of the participating countries. Therefore, studying the variable connections of political, economic and society could be a study of the trends and possibilities of what may occur within society. Since the 1970s, the study of the relationship between labor and economic growth has expanded worldwide, focusing on variables in each country's different social and political conditions. Regarding the increase of foreign labors in the economy, the study of the economic growth of Thailand from foreign labors (Sussangkarn, 1996) found that in 1995 Thailand had a proportion of 2.2 % of all foreign labors of the total labor force in the country and the arrival of foreign labors resulted in a 0.5 % increase in Thailand's gross domestic product. Similarly, Martin's study found that in 2005, the proportion of foreign labor increased to 5 % of the total labor force in the country, resulting in a 1.25 % increase in the gross domestic product (Martin, 2007). However, GDP growth may reflect only the formal economy and cannot fully capture the true scope of economic activity. Because international labor mobility combined with more complex economic structures has contributed to the emergence of the informal economy. The International Labour Organization defined the informal economy comprises all economic activities carried

out by workers and economic units that are not covered, or are insufficiently covered, by formal arrangements (International Labour Organization, 2012). Consequently, the study of the relationship between informal economy and economic growth has become increasingly important, particularly concerning the effects of migrant labor. For example, in the case of Madrid, Spain, the increase in migrants has resulted in an increase in GDP growth and 1% of GDP. The increase in GDP growth is a result of the increased size of the informal economic market (de Arce & Mahia, 2013). Therefore, this approach has become important for understanding the economic structure.

According to report from the National Economic and Social Development Council (NESDC), in 2023, Chiang Mai was considered as the 12th largest economy in Thailand and the largest economic center in the North with 1,075,021 domestic labors in the second quarter of 2022. In addition, the large economy of Chiang Mai has made it a target and destination city that attracts migrant labors. In 2022, according to statistics from Foreign Labors Administration Office, Department of Employment, and The Ministry of Labor found that in Chiang Mai, there were 138,308 migrant labors. 99.65% of them were Burmese migrant labors who came to work through registration and legal work permits from the Ministry of Labor.

Nevertheless, the inflow of labor into Chiang Mai continues in both legal and illegal forms. Consequently, undocumented labor remains a significant part of the province's labor structure. These undocumented labors may directly contribute to Chiang Mai's economy through their consumption and participation in various economic activities. This situation makes it difficult to analyze Chiang Mai's economic changes based solely on official data. Therefore, the study of the informal economy may serve as an essential approach to achieving more effective economic development, particularly by evaluating the actual role and contribution of Burmese laborers in Chiang Mai. Such understanding can lead to a clearer picture of the province's economic structure and serve as a foundation for accurate, stable, and sustainable policy planning.

Literature Review

Measuring the Impact of the Informal Economy

Since the informal economy has been recognized as one of the keys in the estimation of formal economic value, it is essential to examine the value that arises in order to understand the influence of an informal economic system. Although most of the study data pertains to unobservable variables, econometric techniques that can calculate the impacts of these variables must be applied. The Multiple-Indicators, Multiple-Causes (MIMIC) model is the most frequently applied econometric model for evaluating size and influence in the informal study of economic systems. The MIMIC model is a concept that examines the relationship between the size of the informal economy as a latent variable and a group of indicators, as well as the causes of the informal economy's expansion as an observable variable. For instance, in the study of the informal economic system in Ethiopia, the study selected The MIMIC model to determine the size of the informal economic system that occurred in Ethiopia by utilizing the tax burden variable. The causal variables are the sizable agricultural sector,

morality in paying taxes, and unemployment. The informal economic system's scale and the hazards it poses are latent variables. The sum of money that is not part of the banking system. It was determined that the data and the model were highly consistent, which enabled the study's findings to deduce that the informal scale of the economic system had an influence on the economic indicator variables under investigation (Wondimu, 2020).

The MIMIC model is typically employed to estimate variables that undergo gradual changes, such as institutional quality variables (Ohnsorge & Yu, 2021). Furthermore, The MIMIC model was employed to estimate the relationship between the variables of minimum wage, average wages, tax burden, trust in government, financing for development, and levels of corruption as factors affecting youth labor market entry rates and income inequality as variables indicated through latent variables such as the informal economy of youth in the case of more niche economic groups, such as the study of the relationship between the informal economy of youth in Lithuania (Morkunas, 2022). Alternatively, the study determined that the causal variable was the tax burden in the estimation of the impact of the informal economy of 30 provinces in China through The MIMIC model. Unemployment, tax structure, and employment in the agricultural sector. Financial autonomy the extent of the informal economy, which influences the indicator variables such as the growth rate of energy consumption, is determined by labor and FDI laws. The expansion of the informal economy and the increase in income inequality were positively influenced by the latter variables in each province, as well as the labor market entry rate and income inequality. The energy consumption rate and GDP growth are also substantial (Chen et al., 2019).

In addition, The MIMIC model has been employed to investigate informal economic systems in a variety of forms and variables. Consequently, The MIMIC model may be a critical model for comprehending the diverse economic activities in the informal economy that influence the economic development associated with further research in the context of the study of the scale and impact of informal economic systems. Furthermore, The MIMIC model has been employed to investigate informal economic systems in a variety of forms and variables. Consequently, The MIMIC model may be a critical model for comprehending the diverse economic activities in the informal economy that influence the economic development associated with further research in the context of the study of the scale and impact of informal economic systems.

The Role of Foreign Labor in the Informal Economy

Gardes and Starzec (2009) conducted a study that revealed that the informal economy is a contagious phenomenon, with the participation of one family member typically leading to the participation of other family members. The impact of migration on labor extends beyond the activities of labor within the country. The extent of the informal economy was positively correlated with the increase in immigrants in the labor force in the case study of Italy from 1996 to 2006 (Bracco & Onnis, 2020). The expansion of the informal economy in developed countries has been the subject of discussion regarding the impact of immigrants on the informal economy. The

informal economy in developed countries will be significantly influenced by the migration of labor from Third World countries, which will lead to the creation of inexpensive labor (Sassen, 1993).

Furthermore, the investigation of the correlation between the informal economy's size and the unemployment rate revealed that an increase in the unemployment rate would influence the informal economy's expansion. The economic crisis in the United States resulted in a reduction in employment, which in turn drove such labor into the informal economy (Dell'Anno & Solomon, 2008). Alternatively, the research found that high wages in OECD countries exacerbated the informal economy and unemployment rate (Enste, 2015) and a study in Poland found that the unemployment rate positively influenced the extent of the informal economy (Gardes & Starzec, 2009) one of the factors that contribute to the expansion and modification of the informal economy. Research on the economic development of individual nations can further explore this concept. In addition, in the context of Thailand, Junghus and Siripatthanakosol (ILO) and Ishida (FAO) reported that industrial restructuring and changes in employment structures have led to a significant labor shortage in the agricultural sector, which has increased the demand for illegal and undocumented migrant labor. This dynamic has further pushed agricultural employment into the informal sector (Siripatthanakosol & Junghus, 2019).

The Impact of Foreign Labor and the Informal Economy on Economic Growth

The informal economy's emergence in the 17th century has become an important topic of study in economics, particularly in the context of the economic development of individual countries. This research aims to highlight how important the informal economy is to these economic systems, helping to create solutions and policies for economic growth and education that fit each country's unique economy. The resulting outcomes will vary depending on the specific national economic structure. Using the Autoregressive Distributed Lag (ARDL) model, the relationship between GDP and the informal economy in Pakistan has been examined. The results suggest that the informal economy has an effect on GDP over various times. The informal economy has a positive impact on economic development in the long term, resulting in a higher GDP. Nevertheless, the informal economy has a detrimental impact on economic development in the short term, as evidenced by a lower GDP growth rate than in the long term (Mughal & Scheider, 2020). It was determined that the informal economic system served as a buffer during Turkey's financial crisis. This system is essential for the generation of employment, which in turn aids in the reduction of destitution and unemployment while simultaneously promoting economic development. Consequently, the informal economic system is an indispensable component of Turkey's economy (Chidoko et al., 2011).

The MIMIC model, which was employed to analyze the education system in Kosovo and the Western Balkan countries from 2000 to 2018, demonstrates that the informal economy has a beneficial impact on the unemployment rate. The unemployment rate increases by 0.3% as a consequence of a 1% increase in the informal economy. Simultaneously, the informal economy's expansion has a positive effect on GDP growth, with a 1% increase in the informal economy resulting in a 0.3% increase in GDP growth (Kahyalar et al., 2020).

The study of the education system in Kosovo and the Western Balkan countries from 2000 to 2018, using The MIMIC model, reveals that the informal economy has a positive effect on the unemployment rate. A 1% increase in the informal economy results in a 0.3% rise in the unemployment rate. Concurrently, the expansion of the informal economy positively impacts GDP growth, with a 1% increase in the informal economy leading to a 0.3% increase in GDP growth as well (Tafa et al., 2021). Including research conducted in Germany, which determined that 40 to 50 percent of informal economy activities significantly contribute to GDP and economic value (Schneider, 2008).

In a study conducted in eight developing countries in South Asia, namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka it was determined that a 0.109 percent increase in employment from a single informal economy unit would result in a change in the GDP growth rate (Islam, 2019). According to Kerdphol and Chiarainaipreeprem (1992), that the informal economy will contribute to reducing the problem of vacancy and increasing the distribution of income of people in Thailand. Studies in Romania found that labors who were pushed into the economy informally reduced income gaps and poverty among the country's population. Romanian researchers discovered that labors who were unofficially compelled to enter the economy were able to reduce poverty and income disparities among the populace (Kim, 2005). A report from a study conducted in Mexico that was based on the economic restructuring under the North American Free Trade Agreement found that informal economy played a role in the expansion of the gross national income (GNI) (Ghosh et al., 2009). In a comparison of economic growth and the informal economy, it was determined that the informal economy accounted for 18.4% of the total GDP in Europe in 2012, with two-thirds of the informal economy being sourced from the most powerful country in the European Union, Germany. Italy, Spain, France, and the United Kingdom (Stankevicius & Vasiliauskaitė, 2014). Research conducted in developed countries frequently demonstrates that the government is not interested in reducing the size of the economy, despite the fact that the informal economy's expansion is detrimental to government taxation. This is due to the fact that two-thirds of the spending generated by the informal economy is allocated to the formal economy (Rabia Ceren Kabatas, 2012). In the context of Thailand, Piriya Pholphirul and Jongkon Kamlai's study confirmed that immigrants have contributed around 0.75–1 percentage point of real GDP growth, particularly the agriculture sector (Kamlai & Pholphirul, 2014). In line with this, Wichulada's research mentions that both legal and illegal Burmese labor has migrated to Chiang Mai primarily for the purpose of working and earning income. If there are factors that lead the Burmese labor to return to their own country, it will have significantly impact on Chiang Mai's economy (Matanboon, 2024). Consequently, it is evident that the informal economy has a significant influence on the economy, as evidenced by the vacancy rates and GDP growth.

Methodology

This study utilizes data from two main sources: primary and secondary data. Primary data was collected through questionnaires administered to Burmese labor residing in Chiang Mai between July and

September 2023. The questionnaire was developed based on previous relevant studies and reviewed to ensure its relevance and accuracy. Questionnaires were distributed through Burmese labor networks by individuals with access to Burmese labor. Secondary data was gathered from the Foreign Labor Administration Office, Chiang Mai Provincial Labor Office, National Statistical Office, as well as relevant research, theses, and academic articles

This study employs a quantitative research approach. It begins with collecting data on income, expenditure, and related economic behaviors of Burmese labor living in Chiang Mai through questionnaires. This quantitative data is then analyzed using the MIMIC model to estimate the size of the informal economy within the economic system, and to compare it with the growth of the Gross Provincial Product (GPP).

Population and Sample

This study focuses on Burmese labor in Chiang Mai. Due to the legal status and undocumented migrants, the exact size and characteristics of this population cannot be clearly identified. Therefore, the researcher employed the snowball sampling technique and collected data from 175 Burmese laborers. The challenges in accessing the sample arose from language barriers and the high level of distrust toward strangers among Burmese labor, making traditional sampling methods impractical. The snowball sampling method was deemed appropriate for this hard-to-reach population that cannot be precisely identified. This approach began by initially contacting labor networks that were initially accessible to the researcher, then expanding data collection through these subjects' networks until reaching the required sample size of respondents. However, the snowball sampling technique, which starts with one initial node and expands through connected networks, may result in data being collected predominantly from closely related groups. This can introduce sampling bias and limit the diversity of the sample.

The multiple indicator-multiple cause model

The data analysis in this study uses Structural Equation Modeling (SEM), which is a model used to study relationships between observable variables and latent variables that cannot be directly observed. This model can analyze the informal economy as a latent variable related to many observable variables.

The MIMIC model has theoretical foundations in Zellner (1970) and was further developed by Jöreskog and Goldberger (1975). Currently, this model is widely used to estimate the size of informal economies with latent variables as key components. MIMIC is a model in the LISREL (Linear Structural Relationships Interdependent) group, which is divided into two main parts: the Measurement Equation related to indicator variables, and the Structural Equation related to the relationship between causes and latent variables.

In this study, we assume one unobservable latent variable, which is the size of the informal economy (S), and assume that this variable is influenced by external causal variables (C), consisting of C_1, C_2, \dots, C_n . With μ defined as the error term, we get the following structural equation:

$$S_1 = \beta_1 C_1 + \beta_2 C_2 + \dots + \beta_n C_n + \mu \quad (1)$$

Next, we define indicator variables (I) that result from the size of the informal economy or latent variable (S), comprising I_1, I_2, \dots, I_m , and define these variables as having variances $\epsilon_1, \epsilon_2, \dots, \epsilon_m$, giving us the following measurement equations:

$$I_{1t} = \lambda_1 S_t + \epsilon_1 \quad (2.1)$$

$$I_{2t} = \lambda_2 S_t + \epsilon_2 \quad (2.2)$$

$$I_{mt} = \lambda_m S_t + \epsilon_m \quad (2.3)$$

Where m represents the number of indicators (Afonso & Gonçalves, 2011), and in the measurement equations (2.1), (2.2), and (2.3), the relationship between the indicator variables under study and the latent variable is shown. In studying the informal economy, various causes affect the size of the informal economy, which is a latent variable that cannot be directly observed, and we can analyze the impact of this latent variable on various indicator variables in the economic system using the above equations.

Conceptual Framework and Model

The conceptual framework of this study focuses on analyzing the relationships between various factors affecting the size of the informal economy generated by Burmese labor in Chiang Mai, and the impacts of this informal economy on economic indicators. The study utilizes data in the following areas:

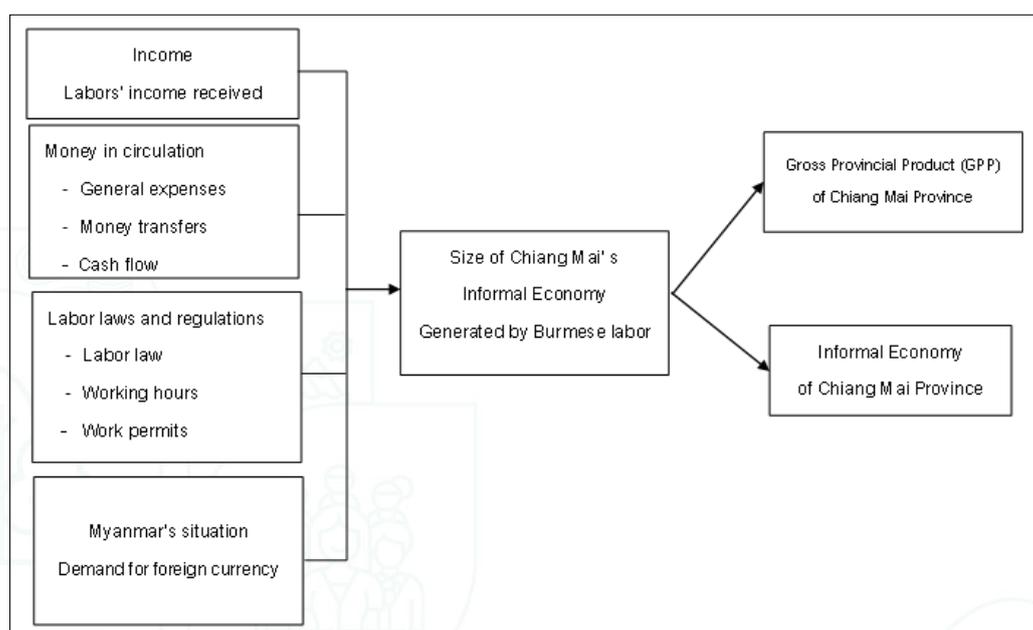


Figure 1 The conceptual framework for studying factors affecting the size of the informal economy of Burmese labor in Chiang Mai and its impact on the informal economy

1. Income - analyzed from the income data that Burmese labor receives from working in Chiang Mai
2. Money circulation in the system - considered from general expenses, daily money transfers received, and cash flows circulating in the economy
3. Labor laws and regulations - analyzing the impact of labor laws, working hours, and work permit requirements
4. Myanmar's situation - considering the demand for foreign currency and other relevant factors

These factors will be analyzed through the MIMIC model to estimate the size of the informal economy generated by Myanmar workers. Subsequently, the impact of this informal economy on the following indicators will be analyzed:

1. GPP of Chiang Mai - analyzing changes in GPP related to the economic activities of Burmese labor
2. The overall informal economy of Chiang Mai - studying the impact on the informal economic sector as a whole

Through this methodology, the study will be able to clearly and systematically demonstrate the impact of Burmese labor in the informal economy on the overall economy of Chiang Mai.

Hypothesis of the study

The economic behavior of Burmese labor contributes to the expansion of the informal economy, which affects the economic growth of Chiang Mai.

Results

This research study analyzes the impact of Burmese labor on the informal economy of Chiang Mai, which has a significant impact on the province's economy. It employs quantitative data analysis using the MIMIC model. The study's findings that Burmese laborers are instrumental in the informal economy and contribute to the creation of economic value. The MIMIC model was employed to evaluate the relationship between observable external variables and latent variables, which reflect the informal economy of Burmese labor in Chiang Mai. The data was derived from questionnaires completed by 175 Burmese laborers in Chiang Mai. The study results are split into two parts: how well the model fits and how visible outside factors affect hidden variables from the MIMIC model.

Results of the model suitability test

The results of the study, which have a chi-square value of 3.707, a degrees of freedom (*df*) value of 5, and a *p*-value of .592, are above the significance level of .05, indicating that the model can be used to correctly explain the data. Consequently, it can be inferred that this model is suitable for the investigation and is in accordance with the empirical data as presented in Table 1.

Table 1 Model consistency

Model Test User Model:	
Test statistic	3.707
Degrees of freedom	5
P-value (Chi-square)	.592

Note: * $p < .05$.

Results of the relationship analysis between variables in the MIMIC model

The informal economy of Chiang Mai, which was established by Burmese labor and was a latent variable, was positively influenced by six factors related to their behavior. These factors include income (INC), expenses (EXP), cash flow (PM), work permits (VISA), the situation in Burma (STI), and the number of labors (NUM). The results of the MIMIC model analysis (Table 2 and Figure 1) revealed this relationship. The standard coefficient (*Std.all*) of each factor was greater than the significance level of .05, with a range of .214–.552. Labor expenses were the most influential factor (*Std.all* = .552), suggesting that informal economic activities are significantly influenced by labors who engage in spending behavior in the region. The work permit and revenue flow factors have a similar influence (*Std.all* = .369 and .368, respectively), followed by the labor income factor (*Std.all* = .403). At the same time, the situation in Burma, which is a factor that may induce additional migration to Chiang Mai for employment, has a moderate impact (*Std.all* = .277), including the number of labors (*Std.all* = .214), demonstrating the correlation between the informal economy's expansion and the size of the labor population in Chiang Mai.

The analysis also revealed that the informal economy of Chiang Mai (*Std.all* = .385) and the gross domestic product of Chiang Mai (*Std.all* = .672) are both obviously indicative of the informal economy created by Burmese laborers as presented in Figure 2.

Table 2 The results of the MIMIC model analysis on the relationship between the informal economy in Chiang Mai and the behavior of Burmese laborers (MMIE)

	The informal economy in Chiang Mai that is driven by Burmese labor				
	Estimate	SE	<i>t</i> (z-value)	<i>p</i>	<i>Std.all</i>
INC	.136	.029	4.759	<.001***	.403
EXP	.186	.029	6.384	<.001***	.552
PM	.120	.028	4.380	<.001***	.368
VISA	.118	.027	4.361	<.001***	.369
STI	.086	.026	3.316	.001**	.277
NUM	.066	.026	2.585	.010*	.214

GPP	1.00				.672
CMIE	.657	.146	4.485	<.001***	.385

Note: INC = Income, EXP = Expenses, PM = Cash flow, VISA = Work permit, STI = Situation in Myanmar, NUM = Number of labors, GPP = Gross product of Chiang Mai, CMIE = Informal economy of Chiang Mai.

*p < .05. **p < .01. ***p < .001.

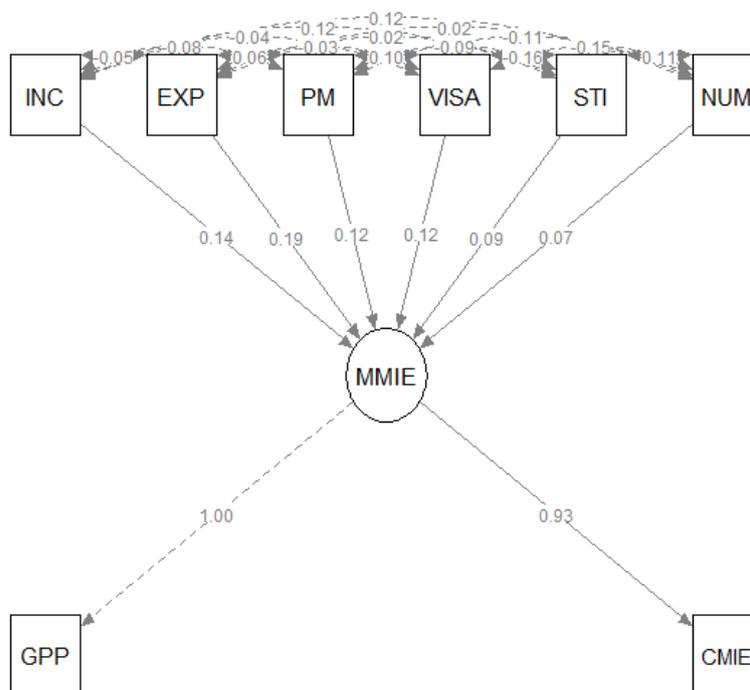


Figure 2 The results of the multiple indicators and multiple causes model analysis on the relationship between the behavior of Burmese labor and the informal economy in Chiang Mai caused by Burmese labor

Discussion

The results shown in the study are that the variables associated with the behavior of Burmese workers have a positive correlation with the expansion of the informal economy in Chiang Mai. Specifically, the main variables, which are expenses, income, and accessibility to work permits, are significant in the expansion of the informal economy. The quantitative analysis conducted with the MIMIC model clearly demonstrates that the informal economy of the province will continue to grow as a result of Burmese laborers having economic behavior. This is consistent with the primary hypothesis of the study, which suggests that the informal economy's scale will be positively impacted by the activities of Burmese labor. Similarly, the study by Islam (2019) found that the informal economy plays a beneficial role in economic growth in developing countries in the South Asian region, and Bracco and Onnis (2020) study in Italy indicated that the increase in migrant workers led to a significant expansion of the informal economy. In Zimbabwe, Chidoko et al. (2023) found that the informal economy can enhance productivity, employment, and investment, as well as solve poverty and other social issues. This type of economy can have a beneficial effect on the correction of societal issues. However, a study

conducted by Ohnsorge and Yu (2022) denies this assertion, asserting that the presence of large informal economies in those countries may be due to low labor productivity levels, which result in inefficient and unpredictable business operations. Additionally, the long-term viability of the economy is undermined by the fact that such labor will act as a substantial obstruction to economic recovery in the event of a financial crisis. Consequently, it can be assumed that the informal economy produced by Burmese labor not only affects minor or niche economies but also plays a significant role in the structure and development of the economy.

Conclusion

This study aims to analyze the role of Burmese labor in the informal economy in Chiang Mai, using both quantitative data collected from 175 Burmese laborers through the questionnaires and distributed by their labor networks. Secondary data, including GPP records and official reports on legally registered Burmese laborers, were also utilized from official government reports and relevant research. The study findings analyzed using the MIMIC model. The results unequivocally demonstrate that Burmese laborers are instrumental in the development of the informal economy. The MIMIC model's findings suggest that the latent variables reflecting the informal economy are positively and statistically significantly correlated with key variables, including expenses, income, cash flow, and access to work permits. Consequently, the dynamics of labor behavior will have a direct and indirect impact on the overall economy of Chiang Mai. These findings are supported by previous studies found that migrant labor has significantly contributed to economic growth and poverty reduction in Thailand and research also revealed that immigrants have a positive effect on Thailand's real GDP growth (Kamlai & Pholphirul, 2014; Pholphirul, 2012). Moreover, the study of Tai-Yai, sub-ethnic group of Burmese labor in Chiang Mai, found that their migration contributed to local economic activities by employment in labor-shortage sectors, economic expansion and fostering new economic activities such as labor transportation services (Phuwanatwichit et al., 2018). Therefore, this investigation may suggest that the informal economy, which was established by Burmese laborers, has emerged as a distinctive economic mechanism that has a direct impact on the economic development of Chiang Mai by means of income generation, productivity enhancement, and the expansion of economic activities across various parameters. Consequently, the economic development of Chiang Mai will be significantly influenced by the labor force in the manufacturing sector and the economic value that is received.

Recommendation

In the future, policymakers may consider incorporating this type of labor into the formal economic system. The government sector may consider two related proposals to ensure that labor has access to basic rights and a better quality of life while also bolstering the stability and security of the overall economic structure in the long term. The first proposal involves the development of criteria and regulations that are in accordance with the appropriate needs and standards. The second proposal addresses the issue of facilitating the access

of foreign labor to the system by reducing the complexity of the bureaucratic process, developing a modern technology system, and establishing a system to monitor and verify the legal status and rights of foreign labor. The second proposal is to broaden the scope of related benefits. In this case, the government sector may consider establishing international cooperation on related issues, such as promoting collaboration and establishing joint agreements on issues related to international labor exchanges, which would be advantageous to both parties. Labor from the country of origin can legally enter the labor system and receive full protection of labor rights. Simultaneously, the destination country will incorporate proficient labor into its labor system. In addition, such collaboration may also involve the effective development of the desired laborers' skills in tandem, thereby enabling the long-term benefits of Thailand's economic development to be realized by labor who enter the labor market and economic system.

Acknowledgments

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The Impact of Digital Workforce Transformation in Human Development Index: A Conceptual Model

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Abstract

This study aims to develop a conceptual model to enhance the Human Development Index (HDI) by optimizing digital economic growth, with a particular focus on the digital transformation of productive workforce management. The digital economy encompasses all economic activities driven by digital technologies, including the digitalization of Human Resource Management (HRM) functions within organizations. Globally, digital transformation has reshaped social, economic, and cultural landscapes, significantly influencing improvements in HDI. This article explores how digitalization—through workforce transformation and the Internet of Things (IoT)—affects the core dimensions of human development: health, education, and living standards. Additionally, a values-based approach grounded in spiritual principles provides a deeper understanding of sustainable and ethical development. By synthesizing recent research, this study proposes an integrative conceptual model to maximize the impact of digital transformation on HDI in the digital era.

Keywords: Digital Transformation, Human Development Index, Internet of Things, Human Resources Management

Introduction

The rapid advancement of digital technology has profoundly transformed nearly every aspect of human life. The integration of innovations such as the Internet of Things (IoT), artificial intelligence (AI), and virtual reality (including the metaverse) has created new opportunities to enhance overall quality of life. However, understanding their impact on the Human Development Index (HDI) requires a comprehensive analysis, as human interaction patterns and lifestyles are undergoing significant shifts in this era of digital civilization. The HDI is measured through three fundamental dimensions: health (physical and mental well-being), education (knowledge acquisition), and standard of living. The pervasive digitalization of daily life is increasingly recognized as a key driver of improvements in these indicators. According to 2024 data from the International Telecommunication Union (ITU), internet usage and digital adoption have risen substantially in many countries.

Previous studies (Nurhidayati & Zaenuri, 2023; Nurhidayati & Ratnasari, 2021; Adhiatma, Nurhidayati, & Fachrunnisa, 2023; Rikaltra & Soesilowati, 2023; Adhiatma, Fachrunnisa, et al., 2023; Jovanovic et al., 2018; Adhiatma, Nurhidayati, Fachrunnisa, et al., 2023) consistently demonstrate that digital transformation

significantly enhances work productivity. However, research remains limited on the broader economic impacts of digitalization, particularly its influence on human quality of life through the lenses of intellectual capital and self-worth. Additionally, inconsistencies persist in measuring the Human Development Index (HDI), especially when comparing traditional (pre-digital era) methodologies with those adapted for the digital age. Today, most companies have integrated digital tools into their production processes, contributing substantially to the expansion of the global internet economy. Nevertheless, according to the World Bank, human resource capabilities in the ASEAN region remain relatively underdeveloped compared to non-ASEAN countries. This disparity may stem from the predominant use of digital technologies in ASEAN for non-economic purposes, which offer limited added value to products and services.

Therefore, further research is essential to explore strategies for enhancing the quality of human development in Indonesia through the advancement of the digital economy. The World Trade Organization highlights several critical areas that need to be strengthened to support the global growth of e-commerce, including financing, taxation, consumer protection, communication infrastructure, logistics, education, and human resource quality. Addressing these challenges requires coordinated efforts among relevant institutions to develop comprehensive and well-aligned policies. One promising initiative is the integration of digital technologies into human resource management functions and practices within organizations.

Therefore, the research questions addressed in this study are as follows: (1) How does the digital economy, as reflected in the digitalization of human resource management functions and policies, impact the quality of human development? (2) How can the quality of the Human Development Index be enhanced through intellectual capital and human values?, and (3) How can the Human Development Index be measured in the digital era?

Literature Review

Previous studies have shown that community productivity significantly contributes to the Human Development Index (HDI) (Zangoueinezhad & Moshabaki, 2011; Maciaszczyk et al., 2019; Rikaltra & Soesilowati, 2023; Adhiatma, Fachrunnisa, et al., 2023; Jovanovic et al., 2018). Consequently, business entities that employ a large workforce play a crucial role in enhancing the three core components of HDI through the implementation of effective human resource management (HRM) policies. Several researchers have also suggested that the growth of the digital economy can improve societal productivity. However, this growth does not necessarily lead to a significant or positive impact on the quality of human development (Adhiatma, Nurhidayati, Fachrunnisa, et al., 2023; Fachrunnisa et al., 2023; Shevchenko et al., 2023; Deming, 2022; Kengatharan, 2019). In contrast, earlier research indicates that the use of digital technology has a significant effect on the development of human capital in a country (Zangoueinezhad & Moshabaki, 2011).

Other studies (Fachrunnisa et al., 2022; Fachrunnisa, 2022; Fachrunnisa et al., 2020; Adhiatma et al., 2022; Spangenberg, 2016; Adhiatma et al., 2021) identify several key factors that contribute to the formation of

intellectual capital. These include: educational attainment and the acquisition of practical skills, workplace health levels, decent living standards, the production of high-value-added goods and services, access to relevant information for sustaining well-being, levels of creativity and innovation, and the application of technological innovations. For instance, a study by Rozak et al. (2023) highlights that utilizing the metaverse as a virtual work environment requires significant changes in HRM practices and policies, including (a) the development of digital leadership and virtual work ethics, (b) the implementation of gamification in training and performance evaluation, and (c) the reinforcement of flexible work culture and social connectivity. Furthermore, Adhiatma, Nurhidayati, Fachrunnisa, et al. (2023) found that factors such as agile leadership and organizational ambidexterity significantly influence successful workforce transformation in SMEs across Indonesia and Malaysia. This transformation contributes to improvements in: (a) Education—through enhanced digital literacy and lifelong learning, (b) Health—via access to online healthcare services, and (c) Living Standards—through increased productivity and income enabled by business digitalization.

The Role of Digital Transformation in Measuring the Human Development Index (HDI)

Digital transformation and the health dimension

Digital technology has significantly improved access to healthcare services through telemedicine, health applications, and electronic medical records. These innovations allow communities, even those in remote areas, to receive quality healthcare without the need to travel long distances. This enhanced accessibility has contributed to increased life expectancy and reduced mortality rates, thereby directly improving the health component of the Human Development Index (HDI). A notable example is the use of online health consultation platforms in developing countries, which have successfully raised public awareness of disease prevention and promoted self-managed healthcare practices.

Digital transformation and living standard dimension

Digital transformation has become a key driver of economic growth, spurring the rise of technology-based industries, e-commerce, fintech, and the digital creative economy. These advancements generate new employment opportunities, boost household income, and accelerate economic mobility. As a result, per capita income—an essential component of the Human Development Index (HDI)—has significantly improved. Even within the informal sector, digital platforms empower small-scale entrepreneurs to access global markets and enhance their standard of living.

Challenges and risks

Despite its transformative potential, digital transformation also poses significant challenges. One of the most critical issues is the disparity in access to technology—commonly known as the digital divide—which can

intensify existing social and economic inequalities. Individuals without sufficient access or digital literacy risk being left behind, leading to uneven human development. Therefore, it is essential for both the government and the private sector to work together to ensure inclusive digital infrastructure, promote digital literacy, and reduce regional disparities.

This study seeks to address gaps in previous research by offering two primary contributions. First, it introduces a novel perspective on measuring the Human Development Index by highlighting human intellectual capital and individual self-worth as fundamental dimensions. Second, it aims to improve the quality of human resource development by digitalizing HRM functions and policies as part of broader digital economic initiatives. Figure 1 presents the state-of-the-art framework and the innovative contributions proposed in this study.

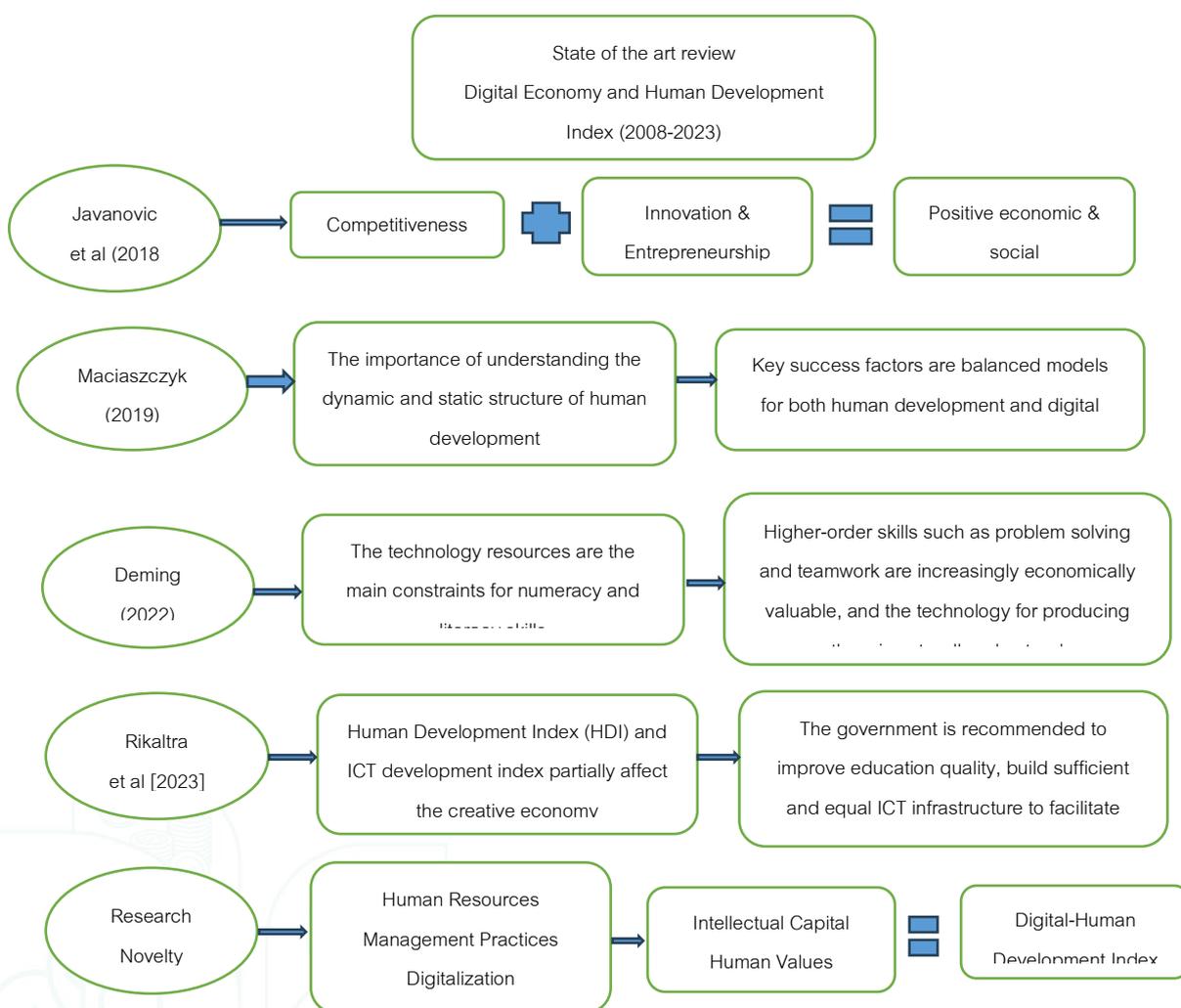


Figure 1 State of the art review

Source: developed by author (2025)

Proposed Conceptual Model

The measurement of the Human Development Index (HDI) using traditional methods differs significantly from its measurement in the digital era. These differences stem from the inclusion of several new concepts that capture the outcomes and impacts of digital economic activities. Table 1 highlights the key distinctions between these two approaches.

Table 1 Classic Human Development Index vs Digital Transformation

HDI Dimension	Classical HDI	HDI in the Digital Transformation Era
Health	Life expectancy at birth	Access to digital health services and digital health literacy
Education	Average and Expected Years of Schooling	Participation in e-learning, digital literacy, and access to MOOCs
Income	Gross National Income (GNI) per capita	Income from the digital economy and readiness for technology-based jobs
Infrastructure	Not explicitly included	Internet access, availability of digital devices, and overall connectivity
Ethics & Security	Not explicitly included	Awareness of digital ethics and literacy in data privacy and cybersecurity
Inequality/Gap	General socio-economic inequality measures	Measurement of the digital divide, such as disparities in technology access across regions and social groups

The Human Development Index (HDI) is traditionally measured based on three key components:

1. Health – represented by life expectancy at birth.
2. Education – measured by mean years of schooling and expected years of schooling.
3. Standard of Living – reflected by gross national income (GNI) per capita.

However, in the era of digital transformation, the measurement of the Human Development Index (HDI) should incorporate new dimensions that reflect the profound changes in human life brought about by technological advancements. These proposed dimensions include:

1. Digital Health
 - Access to digital healthcare services (e.g., telemedicine, health applications).
 - Enhancement of health literacy through technology-based platforms.
 - Utilization of health data for disease prevention and early detection.

2. Digital Education

- Participation in online education and Massive Open Online Courses (MOOCs).
- Level of digital literacy, particularly the ability to use technology for learning purposes.
- Access to AI- and VR-based e-learning platforms.

3. Digital Standard of Living

- Income generation from the digital economy (e.g., e-commerce, remote work, digital freelancing).
- Availability and affordability of digital infrastructure (internet access, hardware devices).
- Workforce adaptability to automation and artificial intelligence (AI) technologies.

4. Novel Indicator (Optional)

Several additional indicators are starting to be considered in the digital version of the HDI:

Level of technology literacy in society

Technology literacy refers to an individual's ability to understand, use, evaluate, and create technology effectively and responsibly. It includes basic technological knowledge, operational skills, and a critical awareness of technology's role in daily life.

At the societal level, technological literacy is a key indicator of a community's readiness to embrace digitalization and address the challenges of the Fourth Industrial Revolution. A technologically literate society is better positioned to adapt to global changes and to contribute meaningfully to digital-driven social, economic, and political development.

Table 2 Dimension of technology literacy

Dimension of Technology Literacy	Explanation
Basic Technology Literacy	The ability to operate digital devices—such as computers, smartphones, and tablets—and understand fundamental internet functions.
Digital Application Literacy	The ability to efficiently use various digital platforms, including e-commerce, e-banking, social media, and e-learning systems.
Digital Information and Media Literacy	The ability to critically, ethically, and responsibly search for, evaluate, and use digital information.
Digital Data and Security Literacy	The ability to protect personal data, ensure privacy, and effectively manage cybersecurity risks.

Innovation and Adaptation Literacy to New Technologies	The ability to learn, adapt to, and integrate emerging technologies—such as artificial intelligence (AI), the Internet of Things (IoT), and blockchain—into daily life.
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Digital workforce readiness

Digital workforce readiness refers to the ability of workers to adopt, utilize, and innovate with digital technologies in the workplace. It encompasses a range of competencies, including technical skills, digital literacy, adaptability, creativity, and the capacity for virtual collaboration. In the era of digital transformation, digital readiness is no longer a mere “added value” – it has become a fundamental prerequisite for individual competitiveness and career sustainability. Table 3 presents the dimensions of digital workforce readiness.

Table 3 Dimension of digital readiness

Dimension of Digital Readiness	Explanation
Basic Digital Literacy	The ability to operate digital devices (such as computers and smartphones), navigate the internet, and use standard applications including email, word processors, and spreadsheets.
Advanced Digital Skills	Proficiency in specialized digital tools and technologies, such as data analytics, cloud computing, artificial intelligence, cybersecurity, programming, and customer relationship management (CRM) software.
Adaptability to New Technologies	Ability to learn quickly when new technologies emerge (e.g., generative AI, blockchain, IoT).
Virtual Collaboration	The ability to work effectively in remote teams using digital platforms like Zoom, Slack, Microsoft Teams, and similar collaboration tools.
Digital Ethics Awareness	Understanding and awareness of data privacy, cybersecurity, responsible technology use, and the ethical implications of digital behavior.
Critical Thinking and Digital Problem Solving	The capacity to analyze complex digital challenges and devise effective solutions using innovative tools and technologies.

Digital workforce readiness is a fundamental pillar in supporting the growth of the digital economy, fostering social innovation, and promoting sustainable human development. Without this readiness, the workforce will face challenges in competing, adapting, and contributing effectively within the future digital ecosystem.

Digital divide across regions or social groups

The digital divide refers to disparities in access to, usage of, and proficiency in digital technologies among individuals, social groups, and geographic regions. These inequalities are shaped by factors such as infrastructure, economic resources, education, digital literacy, and the availability of technological devices. The digital divide typically appears at three levels: (a) Access – unequal availability of the internet, computers, or digital devices; (b) Usage – differences in individuals' ability to use digital technologies effectively; and (c) Outcomes – unequal distribution of the benefits gained from digital technology use. Table 4 presents the key factors contributing to the digital divide.

Table 4 Factors contributing to the digital divide

Factor	Example
Economic	Low-income communities face difficulties in purchasing digital devices and affording internet services.
Geographic	Rural and remote areas often lack sufficient network infrastructure (slow or unavailable internet).
Education	Lower levels of education exacerbate digital literacy skills.
Gender and Age	Women, the elderly, and other marginalized groups often experience limited access to and proficiency in digital skills.
Government Policy	Uneven distribution of digital development programs across different regions.

The digital divide significantly affects various sectors, including education, the economy, healthcare, and social participation. In education, children in areas without internet access are disadvantaged in distance learning. Economically, the distribution of opportunities for digital-based jobs and businesses remains unequal. In healthcare, access to online services such as telemedicine is limited for communities lacking connectivity. Furthermore, digitally marginalized groups are excluded from essential social interactions and vital information. This divide, which spans across regions and social groups, exacerbates existing inequalities in education, healthcare, economic opportunity, and social inclusion. Therefore, bridging the digital divide is crucial to achieving equitable, inclusive, and sustainable human development in the digital age.

Digital ethics index and data security

Digital ethics refers to moral principles guiding the usage of digital technologies, such as the Internet, social media, artificial intelligence, and other online platforms. Data security safeguards personal, organizational, and public data against threats like theft, manipulation, misuse, or breaches. The Digital Ethics and Data Security Index evaluates how individuals, organizations, and nations use digital technologies ethically while protecting privacy and securing personal and collective data.

Table 5 Key dimensions in the digital ethics and data security index

Dimension of Digital Ethics and Data Security	Explanation
Digital Ethics Awareness	The extent to which individuals understand the moral implications of digital activities (e.g., hoaxes, cyberbullying, online plagiarism).
Privacy Protection	The effectiveness of policies and practices in safeguarding personal data from misuse or breaches.
Cyber security	The level of preparedness of individuals, companies, and nations in anticipating and addressing digital threats (e.g., phishing, malware, hacking).
Digital Social Responsibility	The degree to which digital activities contribute positively to society (e.g., using data for well-being, not just for profit).
Compliance with Digital Regulations	The extent to which individuals and organizations follow data protection laws (e.g., GDPR in Europe, UU PDP in Indonesia).

The Digital Ethics Index has become increasingly vital in addressing the growing threats of the digital age. As the digital economy expands, so do the risks—ranging from data breaches and information manipulation to cyberattacks. In response, the call for digital justice becomes more urgent, underscoring the principle that technology should empower, not exploit, humanity. Sustaining digital trust is also critical, as a safe and ethical digital environment is essential for fostering innovation and global collaboration. The creation of a Digital Ethics and Data Security Index is therefore crucial—not only to measure technological progress but also to assess moral integrity, accountability, and the protection of human rights in cyberspace. Societies that score highly on such indices will be better equipped to build a just, secure, and sustainable digital future. [99]

Results and Discussion

Based on above analysis, a proposed conceptual model has been developed that illustrates the relationship between digital workforce transformation and the quality of the Human Development Index, as depicted in Figure 2.

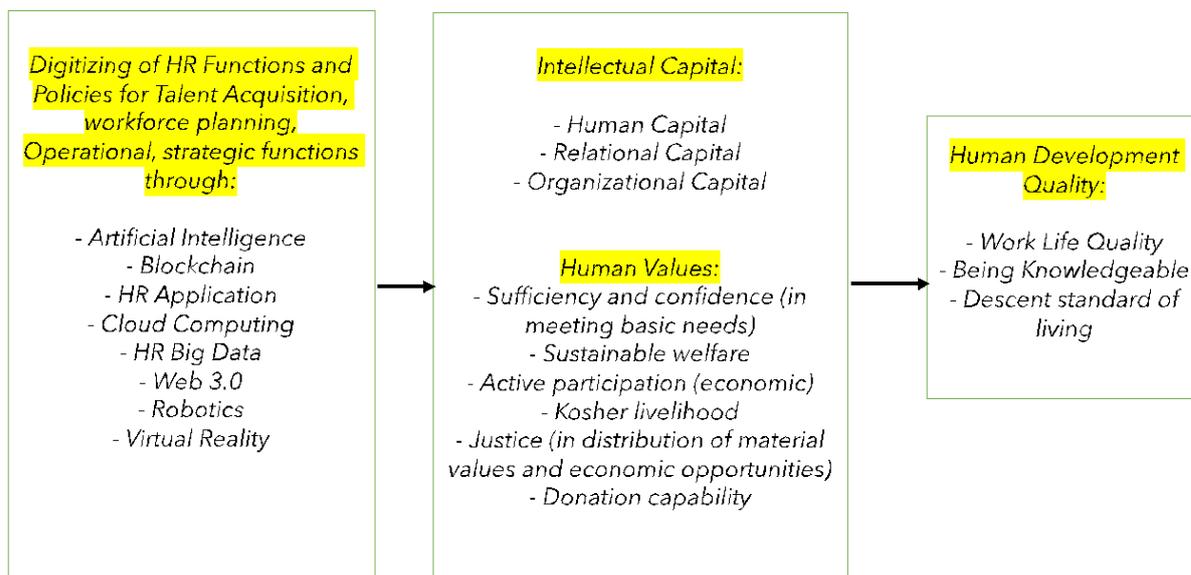


Figure 2 Conceptual model of digital workforce transformation and human development quality

Proposition 1. Digitalization of HRM functions and policies will enhance intellectual capital.

The digitalization of HRM refers to the integration of digital technologies throughout the entire human resource management cycle, including recruitment, training, performance development, and employee retention. Intellectual capital, on the other hand, represents the organization's intangible assets and comprises three key components: (a) human capital, which includes employee competencies, skills, and knowledge; (b) structural capital, encompassing systems, databases, and innovative processes; and (c) relational capital, which involves relationships with customers, partners, and stakeholders. The mechanisms through which HRM digitalization influences intellectual capital are illustrated in Table 6.

Table 6 Mechanisms of digitalized HRM's influence on intellectual capital

Digitalization of HRM Functions	Impact on Intellectual Capital
E-recruitment and AI-driven hiring	Attracts talent with advanced technological and adaptive skills.
E-learning and digital platform-based training	Enhances competencies and accelerates the dissemination of new knowledge.
Data-driven performance management systems	Provides rapid and measurable feedback to improve individual capabilities.
Cloud-based knowledge management systems	Ensures knowledge is effectively stored, shared, and utilized.
Gamification and digital rewards	Motivates innovation and promotes continuous learning within the organization.
Virtual collaboration tools	Expands internal and external relationships, thereby enhancing relational capital.

Digitalization enhances employee competencies by fostering adaptability, creativity, and continuous learning, thereby contributing to the growth of human capital. It also ensures that organizational knowledge is well-documented and easily accessible, which promotes innovation and strengthens structural capital. At the same time, digital platforms facilitate the expansion and intensification of business relationships and professional networks, indicating the development of relational capital. Consequently, an organization's intellectual capacity is enhanced, reinforcing its long-term competitive advantage. For example, Google utilizes AI-powered internal learning platforms to support employee development and accelerate product innovation. Likewise, Unilever employs chatbot-based recruitment and gamification strategies to improve the quality of its global human resources. These examples demonstrate that digital transformation in human resource management (HRM) goes beyond process efficiency; it represents a strategic initiative to accelerate the growth of intellectual capital—an essential asset in today's knowledge-based economy.

Proposition 2. The digitalization of HRM functions and policies will enhance individuals' self-worth (Human Value)

Digitalization of Human Resource Management (HRM) refers to adopting digital technology across all HRM-integrated processes, including recruitment, training, career development, performance evaluation, and employee retention. Human Value is individuals' inherent dignity and qualities, encompassing creativity, integrity, empathy, competence, respect for diversity, and meaningful contributions to social and organizational environments.

Table 7 mechanisms of digitalised HRM's influence on Human Value

Digitalization of HRM Functions	Impact on Human Value
E-learning personalized development	Provides opportunities for growth tailored to each individual's unique potential.
Real-time digital feedback and self-assessment tools	Enhances self-awareness, personal reflection, and character development.
Internal platforms for innovation and idea crowdsourcing	Offers space for creative expression and recognition of individual contributions.
Digital reward systems and performance recognition	Strengthen the sense of meaning and self-worth within the organization.
Increased work flexibility (remote/hybrid work)	Provides autonomy, improves work-life balance, and enhances the sense of self-esteem.
Digital work ethics enforced through HR policies	Foster a sense of responsibility, honesty, and value-based collaboration.

Digitalization empowers individuals to explore and express their unique potential. Employees feel more valued, connected, and recognized for their contributions. Work processes become increasingly human-centered—focused not only on economic outcomes but also on personal growth and development. Consequently, the digitalization of HR enhances performance while also elevating dignity, self-awareness, and the overall quality of individuals in both professional and social spheres.

For instance, Salesforce promotes self-development through its Trailhead platform, which strengthens skills, boosts confidence, and supports a broader social mission. Similarly, SAP implements digital well-being initiatives that address employees' emotional and social development, extending beyond traditional work performance metrics.

Therefore, when managed with a humanistic perspective, the digitalization of HR functions and policies can serve as a powerful catalyst for enhancing human self-worth—reinforcing individuals' sense of meaning, dignity, and social role in the digital age.

Proposition 3. An increase in intellectual capital will enhance the quality of human development

Intellectual capital is an intangible asset comprising knowledge, skills, innovation, relationships, and organizational systems that collectively reflect the capacity to create value. It consists of three key components: (a) Human Capital, which includes individual competencies, creativity, and expertise; (b) Structural Capital, referring to organizational systems, processes, and a culture that fosters innovation; and (c) Relational Capital, which encompasses external networks such as partnerships, customer relations, and community engagement. Meanwhile, Human Development Quality refers to the achievement of dimensions such as health, education,

and income, as well as non-material aspects including social participation, psychological well-being, and equality.

Table 8 mechanisms of intellectual capital's influence on Human Development

Dimension of Intellectual Capital	Contribution to Human Development
Human Capital	Enhances educational attainment, work competence, productivity, and individual innovation.
Structural Capital	Creates an ecosystem of innovation and technology-based public services to broaden access to healthcare, education, and economic opportunities.
Relational Capital	Expands cross-sector collaborations to accelerate human development programs (e.g., community education programs, community-based health initiatives).

The enhancement of intellectual capital empowers individuals by improving their education, health, and economic capabilities. At the same time, organizations and nations become more innovative in delivering essential social services, leading to societies that are more resilient, collaborative, and adaptable to global changes. As a result, the overall quality of human development—referring to both capabilities (what people can achieve) and opportunities (access to resources)—significantly improves. For instance, Nordic countries like Sweden and Finland have shown that substantial investments in education, research, and innovation (forms of intellectual capital) correlate directly with their high rankings in the global Human Development Index. Similarly, initiatives in India, such as the Digital India program, have enhanced the employability of millions, thereby improving their quality of life and expanding economic opportunities. In conclusion, strengthening intellectual capital is a fundamental pillar for promoting inclusive and sustainable human development. By enhancing knowledge capacity, fostering innovation, and encouraging collaboration, societies are better positioned to pursue well-being, social justice, and sustainable progress.

Proposition 4. An increase in human self-worth (Human Value) will enhance the quality of human development

Human self-worth (Human Values) refers to the awareness, dignity, integrity, empathy, responsibility, creativity, and commitment of individuals towards their personal development and the betterment of their surroundings. In addition, the quality of human development encompasses not only economic achievement, health, and education but also the attainment of human values such as justice, psychological well-being, freedom of creativity, social participation, and sustainability.

Table 9 mechanisms of Self-Worth's (Human Value) on Human Development

Aspect of Self-Worth (Human Value)	Impact on Human Development
Self-awareness and reflection	Motivates individuals to engage in continuous learning, self-improvement, and take an active role in community development.
Empathy and social concern	Strengthens social solidarity, inclusion, and cooperation in development programs.
Integrity and responsibility	Fosters a transparent and ethical society that supports good governance.
Creativity and Innovation	Drives the development of novel solutions to social, economic, and environmental challenges.
Commitment to the common good	Reinforces a development orientation that is suitable and rooted in social justice.

When individuals possess high self-worth, they not only pursue personal well-being but also contribute to collective welfare. They become agents of change who strengthen the pillars of human development: health, education, economy, and social justice. Development is not solely measured by economic growth but also by the growth of the quality of life and human relationships.

Thus, human self-worth serves as a source of moral and social energy that deepens and broadens the quality of human development. Practically, the example of social movements based on community awareness, such as volunteerism in education and healthcare, illustrates how the awareness of self-worth accelerates the achievement of sustainable development goals (SDGs). Moreover, character-building programs in various Scandinavian countries have proven to enhance happiness indexes and the quality of social development, not just economic growth. Therefore, it can be concluded that the enhancement of human self-worth enriches the dimension of human development by strengthening character, ethics, and social orientation. This makes development more meaningful, equitable, and sustainable — focusing not only on "what humans possess" but also on "who they are" and "how they live together."

Conclusion and Recommendations

This study concludes that digital transformation has a strong positive impact on improving the Human Development Index (HDI). Through enhancing healthcare services, expanding access to education, and creating new economic opportunities, digitalization accelerates the achievement of human development goals. However, for these benefits to be experienced equitably, systematic efforts to address the digital divide and strengthen community capacity to navigate the digital era are crucial. With an inclusive and sustainable approach, digital transformation can become a key driver in building a more qualified and competitive Indonesian populace. Digital transformation offers significant opportunities to accelerate HDI improvement but

must be supported by adaptive leadership, innovations in Human Resource Management policies, and the integration of spiritual and ethical values. With this approach, human development will be both competitive and dignified. Additionally, there is a need for new measurements of HDI in the digital context. Future research is expected to develop empirical models and test hypotheses derived from several propositions and population contexts/regions to obtain more valid conclusions.

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The Role of CO₂ Emissions and Energy Use in Thailand's Economic Growth: Long-Run and Short-Run Evidence from Time-Series Analysis

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Abstract

Energy consumption positively contributes to economic growth, taking into account the effects of CO₂ emissions. This study investigates the dynamic relationships among CO₂ emissions, energy consumption (renewable and non-renewable), and economic growth in Thailand from 1995 to 2022. Using the autoregressive distributed lag (ARDL) bounds testing method and the vector error correction model (VECM), the analysis reveals both short-run and long-run interactions among the variables. The results of the ARDL short-run analysis showed negative relationships between CO₂ emissions and non-renewable energy consumption on economic growth. The VECM and Granger causality tests indicated bidirectional long-run causality between CO₂ emissions and economic growth and between economic growth and renewable energy consumption. The results show that CO₂ emissions have a statistically significant positive effect on economic growth in both the short and long term, with a 1% increase in emissions associated with a 0.439% increase in GDP per capita in the long run. Additionally, CO₂ emissions are found to have a unidirectional short-run causality, suggesting a complex interaction between environmental degradation and economic development. Non-renewable energy consumption shows a mixed effect, negatively impacting short-run growth but contributing positively to the long term. Renewable energy consumption, while showing no short-term impact, contributes positively to economic growth in the long run, specifically, a 1% rise in renewable energy use is linked to a 0.101% increase in GDP per capita. These findings highlight Thailand's continued reliance on carbon-intensive growth and underscore the need for policies that decouple economic development from emissions. CO₂ emissions are currently growth-enhancing in Thailand, but this comes at the cost of environmental sustainability. Strategic investment in renewable energy and low-carbon technologies will be essential for transitioning toward sustainable growth.

Keywords: ARDL, CO₂ emissions, economic growth, sustainability, Thailand, VECM

The Impacts of Oil Prices on the Consumption of Oil, Renewable Energy, and Nuclear Energy in the 12 European Union countries

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Abstract

This study aims to investigate the impact of oil prices on the consumption of oil, renewable energy, and nuclear energy in the 12 European Union countries using annual panel data covering the period from 1990 to 2019. The analysis utilizes the panel smooth transition regression (PSTR) model and uses oil prices as the threshold variable. The empirical results provide evidence of a nonlinear impact of oil prices on the consumption of all three energy types. Specifically, the estimated oil price threshold values for the consumption of oil, renewable energy, and nuclear energy are 2.531, 4.289, and 3.543, respectively. Furthermore, the results indicate that oil prices negatively affect oil consumption while positively influence renewable energy consumption in both low- and high-oil-price regimes. However, oil prices positively affect nuclear energy consumption when oil prices are less than the oil price threshold value of 3.543.

Keywords: oil prices, energy consumption, PSTR, European Union countries



Introduction

Crude oil is the fossil fuel most consumed in the world, accounting for 40.4 percent of total energy consumption (International Energy Agency, 2021). Crude oil is considered an essential factor of economic growth because it is the primary energy source used in various economic activities, particularly transportation, manufacturing, and electricity generation. Thus, crude oil price fluctuations have a dramatic influence on the economy because they can lead to increased inflation rates, economic recessions, and political instabilities (Zhang et al., 2008; Salisu et al., 2017; Qiang et al., 2019). Similarly, changes in crude oil prices also influence energy consumption (Yuan et al., 2010; Haque, 2021).

The war between Russia and Ukraine has significantly affected global energy prices, especially crude oil and natural gas (Xing et al., 2023). According to the International Energy Agency (2024), Russia is not only the world's third-largest oil producer, ranking behind Saudi Arabia and the United States, but also the second-largest exporter of crude oil in the world. Moreover, the majority of Russia's crude oil exports supply European countries. Therefore, in response to Russia's actions against Ukraine, the European Union and the North Atlantic Treaty Organisation (NATO) have imposed economic sanctions against Russia by imposing trade restrictions on Russia's commodities like crude oil and natural gas. As a result, Russia's crude oil imports to the European Union countries have decreased by 90 percent within a single year. The European Union countries reduced imports of Russia's crude oil from 10.54 million metric tonnes (Mt) in February 2022 to 2.3 million metric tonnes (Mt) in February 2023 (Statista, 2024). Therefore, the European Union launched the REPowerEU plan to accelerate the clean energy transition and end dependence on Russia's fossil fuels by 2030. (European Commission, 2022).

In addition, concern about climate change, global warming, and the environmental consequences of fossil fuels has become a major global issue. As a result, many countries have increased renewable energy consumption such as wind, solar, hydro, and geothermal energy, which are environmentally friendly energy sources (Bloch et al., 2015; Ponce and Alvarado, 2019). Renewable energy consumption also contributes to mitigating environmental degradation (Alvarado et al. 2018). Besides renewable energy, nuclear energy consumption is recognized as a factor to reducing carbon emissions (Iwata et al., 2010; Saidi and Omri, 2020). Furthermore, renewable energy and nuclear energy can substitute for oil during periods of high oil prices in some countries (Lee and Chiu, 2011; Guo et al., 2021; Li and Leung, 2021). Hence, renewable energy and nuclear energy consumption may help to cope with environmental issues as well as the energy crisis.

Previous studies have commonly focused on the impact of oil prices on renewable energy consumption (Apergis and Payne, 2014; Nguyen and Kakinaka, 2019; Chen et al., 2021; Mukhtarov et al., 2022). In addition, there are also studies examining the consumption of other types of energy, such as gasoline, crude oil, renewable energy, and nuclear energy (Sadorsky, 2009; Narayan and Wong, 2009; Lee and Chiu, 2011; Li and Leung, 2021). However, none of the studies have considered the impacts of oil prices on consumption of oil, renewable energy, and nuclear energy simultaneously. Although the impact of oil prices on the consumption of various types of energy has been analyzed before, most studies only examined the linear effect. It can be said

that the previous studies may have overlooked the nonlinear effect of oil prices on energy consumption. These research gaps motivated us to investigate the nonlinear impact of oil prices on consumption of oil, renewable energy, and nuclear energy. We apply the panel smooth transition regression (PSTR) model as developed by González et al. (2005) as an efficient method for analyzing the nonlinearity issue. A crucial advantage of the PSTR model is it allows the effect of oil prices on the consumption of oil, renewable energy, and nuclear energy to vary not only across countries but also over time. Moreover, it also can identify the threshold value of oil prices for each type of energy consumption.

This study investigates how changes in oil prices impact on the consumption of oil, renewable energy, and nuclear energy in the 12 European Union countries, namely Belgium, Bulgaria, Czechia, Finland, France, Germany, Hungary, Netherlands, Slovakia, Slovenia, Spain, and Sweden over the period from 1990 to 2019 by using PSTR model. This study contributes to understanding the influence of oil prices on three types of energy consumption: oil, renewable energy, and nuclear energy in European Union countries facing energy shocks. Therefore, the findings of this study will be beneficial for policymakers in the 12 European Union countries.

Literature Review

The impacts of energy prices on energy consumption have been widely studied, with varying results depending on the variables, countries, and methodology considered. Many empirical studies showed that oil prices significantly influence energy consumption. Studies about the impact of oil prices on energy consumption are reviewed as follows.

The majority of literature has been focused on the effect of oil prices on renewable energy consumption over recent decades. For instance, Apergis and Payne (2014) studied the factors of renewable energy use in 7 Central American countries from 1980 to 2010 by using a nonlinear panel smooth transition vector error correction model, their reported price of coal and oil had a positive and statistically significant effect on renewable energy consumption. Padhan et al. (2020) examined the impact of real oil price on total renewable energy use for 30 OECD countries with panel data over the period 1970 to 2015 by applying the panel quantile regression approach. The results show a positive and significant relationship between real oil and total renewable energy consumption. The study by Bamati and Roofi (2020) investigated the determinants of renewable energy production in the 25 countries spanning the period from 1990 to 2015 by applying the Panel Generalized Least Square (Panel GLS) method. They found oil prices were positive and significant on production of renewable energy in both developed and developing countries. Besides, Chen et al. (2021) utilized the panel threshold model to study effects of real oil price on consumption of renewable energy in 97 countries covering the period between 1995 and 2015 and found that real oil prices lead to increased renewable energy consumption in less democratic countries but it is insignificant in more democratic countries. Guo et al. (2021) employed both Autoregressive Distributed Lag (ARDL) and Nonlinear ARDL (NARDL) models to explore the dynamic relationship between oil prices and renewable energy consumption across G7 countries in the period 1980–2018. They found that an increase in crude oil prices leads to an increase in renewable energy

consumption, while a decrease in oil prices leads to reduced renewable energy consumption. Their findings are consistent with those of Sahu et al. (2022), who analyze the impact of oil price shocks on renewable energy consumption in the United States from 1970 to 2018 by utilizing the NARDL model. Atems et al. (2023) examined the nonrenewable energy prices impact on US renewable energy consumption by using the Structural Vector Auto-Regressive (SVAR) model for the period 1973:1–2018:12. The estimation showed that prices of nonrenewable energy have positive and statistically significant effects on consumption of total biomass, geothermal, wood, and solar. Furthermore, the study of Zou and Chau (2020) used the cointegration analysis and vector autoregressive (VAR) model and found evidence that higher international crude oil prices encourage consumption of crude oil and hydropower in the long run. Similarly, Escoffier et al. (2022) utilized the Panel Smooth Transition Regression (PSTR) method, and the results indicate that higher oil prices promote renewable energy investment in OECD and BRICS countries. However, several studies have found a negative relationship between oil prices and renewable energy consumption. For example, Omri and Nguyen (2014) investigated the determinants of renewable energy consumption in 64 countries during the period 1990 to 2011 by using the dynamic panel system-GMM method. Similarly, Haque (2021) also applied the same method to examine oil price shocks on energy consumption in GCC countries for the period 1985 to 2014 and found that oil prices exert a negative effect not only on renewable energy consumption but also on total energy consumption. In addition, Murshed and Tanha (2021) used panel DOLS and FMOLS methods to assess the global oil price shocks on the renewable energy transition in South Asia, finding that a rise in oil prices hinders the renewable energy transition in Bangladesh, India, Pakistan, and Sri Lanka. The study by Mukhtarov et al. (2022) employed the General to Specific (Gets) approach to examine the effect of high oil prices on consumption of renewable energy for Iran in the period of 1980 to 2019.

Additionally, many studies using the Granger causality test and the results released that a unidirectional causal relationship from oil prices to energy consumption were discovered by Gallo et al. (2010) in the case of the OECD countries, Troster et al. (2018) the case of the United States, and Raggad et al. (2021) in the case of the United States, and Wang et al. (2019) in case of 186 countries. Furthermore, the study of Brini et al. (2017) using the Granger causality test to explore in the case of Tunisia and found a unidirectional relationship from oil prices to renewable energy consumption in the short run. Li and Leung (2021) used the panel cointegration test to investigate cases in Europe for the period of 1985-2018, indicating that a unidirectional relationship running from prices of coal and natural gas to renewable energy consumption both in the short run and long run.

From the above literature, most of the studies focus on the oil prices impact on renewable energy consumption. However, studies investigating the effects of oil prices on different types of energy consumption are limited. To the best of our knowledge, no study has simultaneously examined the impact of oil prices on the consumption of oil, renewable energy, and nuclear energy. Moreover, few studies examine nonlinear relationships between oil price and energy consumption. Therefore, this study will fill the gap in literature by

determining the impact of oil prices on consumption of oil, renewable energy, and nuclear energy in the 12 European countries by using the Panel Smooth Transition Regression (PSTR) model, which has potential to detect the nonlinear effect and identifies the threshold value.

Data

The study utilizes annual panel data covering a 30-year period from 1990 to 2019 for 12 European Union nations, namely Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Slovakia, Slovenia, Spain, and Sweden. The independent variable is oil prices calculated by deflating nominal crude oil prices using the consumer price index (CPI). According to existing literature, oil prices are widely recognized as a significant influence on energy consumption (Nguyen and Kakinaka, 2019; Guo et al., 2021; Haque, 2021). Thus, oil prices are employed as the transition variable in this study. The dependent variables include the consumption of oil, nuclear energy, and renewable energy. Moreover, the study employs three control variables comprising the human development index (HDI), GDP per capita as a proxy for economic growth, and trade openness as measured by the sum of exports and imports and divided by the GDP. Data obtained from the Energy Information Administration, BP Statistical Review of World Energy, CEIC database, Human Development Report, and World Development Indicators. All variables are transformed into the logarithmic form before estimation.

Methodology

To explore the impact of oil prices on consumption of oil, renewable energy, and nuclear energy, we study applies the PSTR model developed by González et al. (2005). This study utilizes the PSTR model with single transition function and two regimes and uses oil prices as the transition variable. The models are as follows (Equation 1):

$$y_{it} = \alpha_i + \beta'_0 x_{it} + \beta'_1 x_{it} G(OP_{it}; \gamma, c) + \varepsilon_{it} \quad (1)$$

Thus, we built three models of the analyses specific to three dependent variables: oil consumption (Equation 2), renewable energy consumption (Equation 3), and nuclear energy consumption (Equation 4) with a single transition function and two regimes.

$$OILC_{it} = \alpha_i + \alpha_i OILP_{it} + \sum_{j=1}^r a'_{ij} OILP_{it} \cdot G_j(OILP_{it-1}^j; \gamma_j, c_j) + A_i(HDI_{it}, TO_{it}, GDP_{it}) + \sum_{j=1}^r A'_{ij}(HDI_{it}, TO_{it}, GDP_{it}) G_j(OILP_{it-1}^j; \gamma_j, c_j) + \varepsilon_{it} \quad (2)$$

$$\begin{aligned}
REC_{it} = & \alpha_i + b_i OILP_{it} + \sum_{j=1}^r b'_{ij} OILP_{it} \cdot G_j(OILP_{it-1}^j; \gamma_j, c_j) + B_i(HDI_{it}, TO_{it}, GDP_{it}) \\
& + \sum_{j=1}^r B'_{ij}(HDI_{it}, TO_{it}, GDP_{it}) G_j(OILP_{it-1}^j; \gamma_j, c_j) + \varepsilon_{it}
\end{aligned}
\tag{3}$$

$$\begin{aligned}
NUC_{it} = & \alpha_i + c_i OILP_{it} + \sum_{j=1}^r c'_{ij} OILP_{it} \cdot G_j(OILP_{it-1}^j; \gamma_j, c_j) + C_i(HDI_{it}, TO_{it}, GDP_{it}) \\
& + \sum_{j=1}^r C'_{ij}(HDI_{it}, TO_{it}, GDP_{it}) G_j(OILP_{it-1}^j; \gamma_j, c_j) + \varepsilon_{it}
\end{aligned}
\tag{4}$$

where $i = 1, 2, \dots, N$ and $t = 1, 2, \dots, T$ represents the cross-sectional and time dimensions of the panel, respectively. The dependent variable y_{it} represents the dependent variables, which is a matrix scalar. The dependent variables include oil consumption (OC_{it}), renewable energy consumption (REC_{it}), and nuclear energy consumption (NUC_{it}). The x_{it} represents the control variables that influence consumption of energy. The control variables include human development index (HDI_{it}), trade openness (TO_{it}), and GDP per capita (GDP_{it}). The function $G(OP_{it}; \gamma, c)$ is transition function of the threshold variable (OP_{it}) which is continuous and bounded between 0 and 1. Thus, the extreme values are associated with regression coefficients β_0 and $(\beta_0 + \beta_1)$. The term α_i represents the fixed individual effect, and ε_{it} is the error term.

Following Gonzalez et al. (2017), the study considers the following transition function of logistic function, where the transition variables can be given as oil prices ($OILP_{it}$) as Equation 5:

$$G(OILP_{it}; \gamma, c) = \left(1 + \exp \left(-\gamma \sum_{j=1}^m (OILP_{it} - c_j) \right) \right)^{-1}, \gamma > 0, c_1 \leq c_2 \leq \dots \leq c_m
\tag{5}$$

where c is an m -dimensional vector of location parameters and γ is slope parameters determines the smoothness of the transition, and m is the number of regimes. This study considers the cases of $m = 1$, as they are sufficient for capturing the nonlinearities caused by regime switching. For $m = 1$ refers to a logistic PSTR model and the model has two extreme regimes that separate between low and high values of the threshold variable ($OILP_{it}$) with a single monotonic transition of the coefficients from the low regime (β_0) to higher regime ($\beta_0 + \beta_1$) when the threshold variable ($OILP_{it}$) increases. When $\gamma \rightarrow \infty$, the transition function $G(OILP_{it}; \gamma, c)$ is

expected to be converted into an indicator function $G(OILP_{it}, c)$. In addition, when transition function $G(OILP_{it}; \gamma, c) = 1$, if threshold variable $(OILP_{it}) \geq c$ and transition function $G(OILP_{it}; \gamma, c) = 0$ if threshold variable $(OILP_{it}) < c$. When $\gamma \rightarrow 0$, transition function $G(OILP_{it}; \gamma, c)$ is constant and the PSTR model becomes a linear panel model.

The elasticity coefficient of oil prices to oil, renewable energy, and nuclear energy consumption for country i at time t is as follows in Equations 6-8:

$$e_{it}^{OILP(1)} = \frac{\partial OILC_{it}}{\partial OILP_{it}} = a_i + \sum_{j=1}^r a'_{ij} \cdot G_j(OILP_{it-1}^j; \gamma_j, c_j) \quad (6)$$

$$e_{it}^{OILP(2)} = \frac{\partial REC_{it}}{\partial OILP_{it}} = b + \sum_{j=1}^r b'_{ij} \cdot G_j(OILP_{it-1}^j; \gamma_j, c_j) \quad (7)$$

$$e_{it}^{OILP(3)} = \frac{\partial NUC_{it}}{\partial OILP_{it}} = c + \sum_{j=1}^r c'_{ij} \cdot G_j(OILP_{it-1}^j; \gamma_j, c_j) \quad (8)$$

where a_i, b_i , and c_i are the elasticity coefficients of the linear model and a'_i, b'_i and c'_i are elasticity coefficients of the nonlinear model.

Furthermore, we test the linearity in a PSTR model under the null hypothesis of linearity is $H_0: \gamma = 0$. However, the PSTR model contains unidentified nuisance parameters. To address this issue, replace the transition function with its first-order Taylor expansion at $\gamma = 0$ and test of equivalent hypothesis in the auxiliary regression, as follows in Equations 9-11:

$$OILC_{it} = \alpha_{1i} + \beta'_{10} x_{it} OILP_{it} + \dots + \beta'_{1m} x_{it} OILP_{it}^m + \theta_{1j} X_{j,it} + \varepsilon_{it} \quad (9)$$

$$REC_{it} = \alpha_{2i} + \beta'_{20} x_{it} OILP_{it} + \dots + \beta'_{2m} x_{it} OILP_{it}^m + \theta_{2j} X_{j,it} + \varepsilon_{it} \quad (10)$$

$$NUC_{it} = \alpha_{3i} + \beta'_{30} x_{it} OILP_{it} + \dots + \beta'_{3m} x_{it} OILP_{it}^m + \theta_{3j} X_{j,it} + \varepsilon_{it} \quad (11)$$

where $\beta'_0, \dots, \beta'_m$ the parameter is multiple of γ and $\varepsilon'_{it} = \varepsilon_{it} + R_m \beta'_1 x_{it}$, and show the residue of the Taylor function. Therefore, the testing of $H_0: \gamma = 0$ in Equation 2-4 is like test the $\beta'_0 = \dots = \beta'_m = 0$ in Equation 9-11. Following Colletaz and Hurlin (2006), this study applies the Wald Lagrange Multiplier test (LM_w)

and Fisher Lagrange Multiplier test (LM_f) to examine the null hypothesis of the linearity as follows in Equations 12-13:

$$LM_w = \frac{TN(SSR_0 - SSR_1)}{SSR_0} \quad (12)$$

$$LM_F = \frac{\left[\frac{SSR_0 - SSR_1}{mk} \right]}{\left[\frac{SSR_1}{TN - N - mk} \right]} \quad (13)$$

where SSR_0 is the panel sum of squared residuals under null hypothesis (H_0), which refers to linear panel model with individual effects, SSR_1 is the panel sum of squared residuals under alternative hypothesis (H_1), which refers to a transformed PSTR model with two regimes or nonlinear model, and k is the number of explanatory variables, T is the number of time observation, N is the total number of countries. Whereas the LM_w statistics have a chi-square distribution with mk degrees of freedom, the LM_F has an approximate $F(mk, TN - N - m(k + 1))$ distribution. If the null hypothesis of linearity test (H_0) is rejected, implying that the existence of a nonlinear effect.



Estimation results

Data analysis and panel unit root test

Table 2 shows common descriptive statistics for all variables. There is significant variation in the minimum and maximum of oil price, with a minimum value of 4.709 and a maximum value of -4.869. On mean values of consumption of oil, renewable energy, and nuclear energy are approximately 5.633, 0.052, and -3.814 respectively.

Table 2 Descriptive statistics.

Variables	$\ln \ln OP_{it}$	$\ln \ln OC_{it}$	$\ln \ln REC_{it}$	$\ln \ln NUC_{it}$	$\ln \ln HDI_{it}$	$\ln \ln TO_{it}$	$\ln \ln GDP_{it}$
Mean	3.291	5.633	0.052	-3.814	-0.164	-5.317	9.161
Median	3.535	0.029	0.259	-3.721	-0.150	-5.553	9.950
Max	4.709	6.927	2.602	-2.396	-0.050	-2.494	2.300
Min	-4.869	4.667	-3.694	-6.453	-0.359	-6.717	11.020
Std. Dev.	1.260	0.565	1.586	0.885	0.075	0.961	2.233
Skewness	-2.257	0.313	-0.297	-1.061	-0.728	0.734	4.455
Kurtosis	9.526	-0.675	-1.025	1.240	-0.278	-0.316	-2.307
Number of	360	360	360	360	360	360	360

Note: $\ln \ln OP_{it}$ = Oil prices, $\ln \ln OC_{it}$ = Oil consumption, $\ln \ln REC_{it}$ = Renewable energy consumption, $\ln \ln NUC_{it}$ = Nuclear energy consumption, $\ln \ln HDI_{it}$ = Human development index, $\ln \ln TO_{it}$ = Trade openness, and $\ln \ln GDP_{it}$ = GDP per capita.

Table 3 presented the results of panel unit root tests. We used Levin, Lin and Chu and Im-Pesaran-Shin test to assess the stationarity of the logarithmic data. The results show that all variables in this study were nonstationary at level $I(0)$. However, all variables were stationarity at the first difference $I(1)$ with a significance level of 0.01, as the null hypothesis of a panel unit root test was rejected.

Table 3 The results of panel unit root tests.

Test	Levels		First differences	
	LLC	IPS	LLC	IPS
$\ln \ln OP_{it}$	-0.279	1.345	-12.438***	-10.097***
$\ln \ln OC_{it}$	-0.568	0.164	1.230***	-7.328***
$\ln \ln REC_{it}$	-0.591	0.751	-6.063***	-7.698***
$\ln \ln NUC_{it}$	-1.385	-0.031	-8.936***	-12.567***
$\ln \ln HDI_{it}$	-6.387	-1.611	-4.819***	-5.926***
$\ln \ln TO_{it}$	-1.213	-2.002	-9.239***	-8.839***
$\ln \ln GDP_{it}$	0.941	1.036	-8.093***	-7.901***

Notes: ***, **, and * indicate the significance at the levels of 0.01, 0.05, and 0.1 respectively.

Table 4 presents the results of the linearity tests. The results show that both the Wald Lagrange Multiplier (LM_w) and Fisher Lagrange Multiplier (LM_f) were significant at 0.01 level. Therefore, the study rejects the null hypothesis of linearity for three types of energy consumption. These findings imply that the effect of oil prices on consumption of oil, renewable energy, and nuclear energy is nonlinear and thus can be analyzed by the Panel Smooth Transition Regression (PSTR) model.

Table 4 The results of linearity test

Dependent variables	$\ln \ln OC_{it}$	$\ln \ln REC_{it}$	$\ln \ln NUC_{it}$
Wald Lagrange Multiplier (LM_w)	35.01(0.000) ***	64.92 (0.000) ***	54.43 (0.000) ***
Fisher Lagrange Multiplier (LM_f)	11.09 (0.000) ***	20.56 (0.000) ***	17.23 (0.000) ***

Notes: ***, **, * indicate the significance levels at 0.01, 0.05, and 0.1 respectively.

The null hypothesis of linearity test H_0 : the model is linear; the alternative hypothesis H_1 : model is nonlinear.

The numbers in parentheses show P -values.

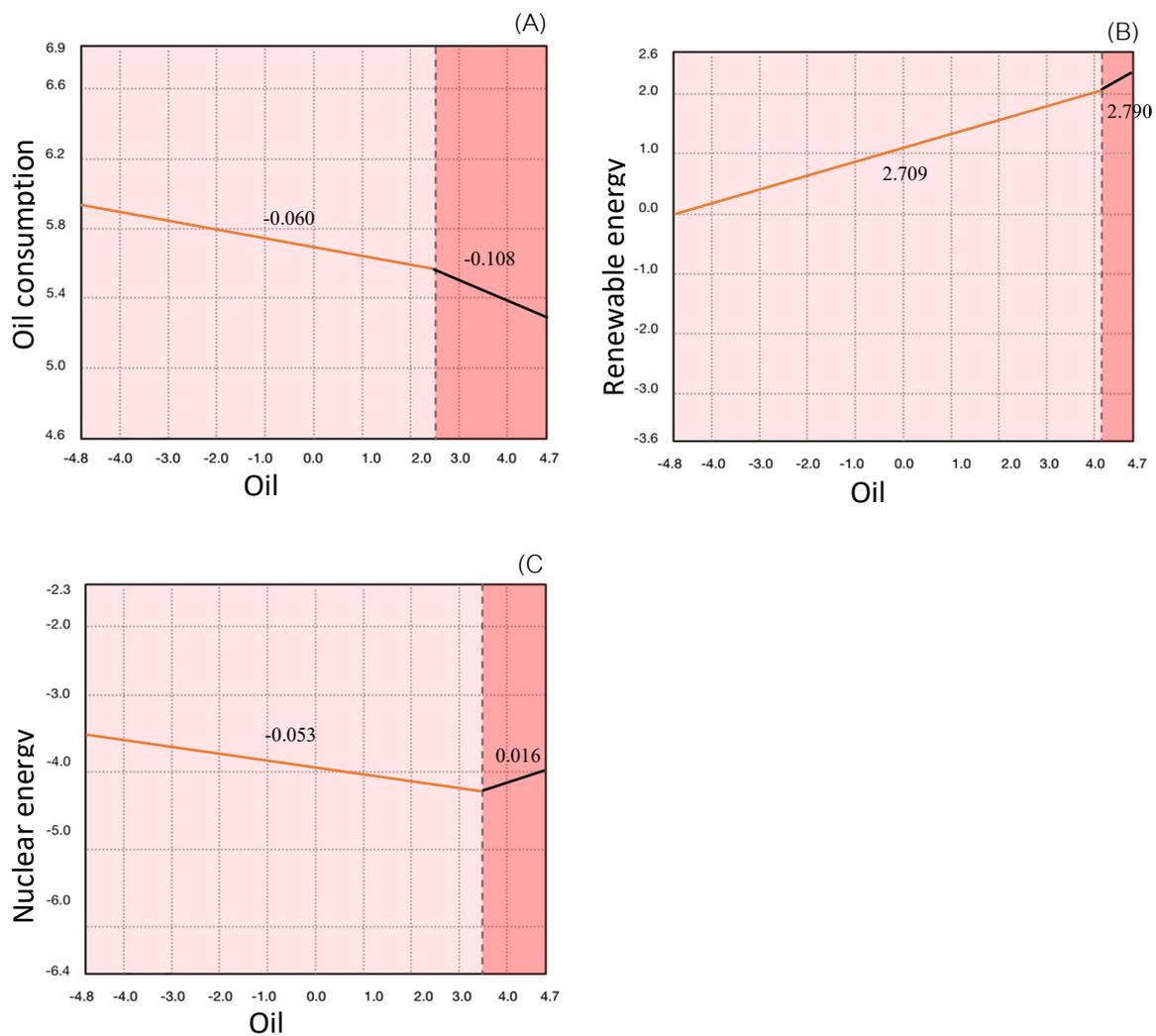


Figure 1 The effect of oil prices on consumption of oil (A), renewable energy (B), and nuclear energy

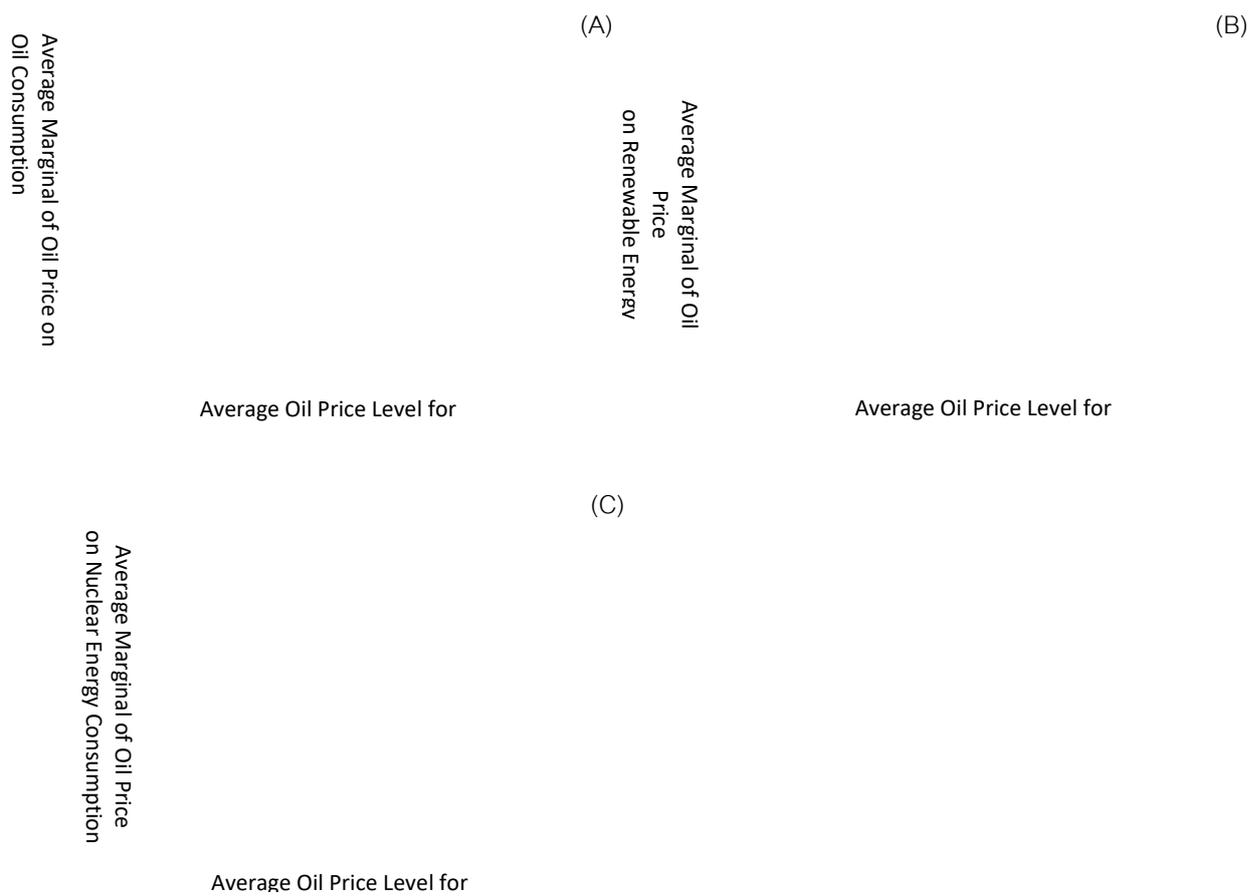


Figure 2 The Average Marginal effect of oil prices on oil consumption (A), renewable energy (B), and nuclear energy (C).



Table 6 PSTR model estimation

Variables	Oil Consumption		Renewable Energy Consumption		Nuclear Energy Consumption	
	Low regime	High regime	Low regime	High regime	Low regime	High regime
$\ln \ln OP_{it}$	-0.060 *** (-5.071)	-0.108 *** (-5.345)	2.709 *** (11.443)	2.790*** (10.657)	0.016 (1.261)	-0.053(-1.567)
$\ln \ln HDI_{it}$	-0.466(-1.277)	-0.649 (-1.914)	-66.935 *** (-10.946)	83.833*** (11.880)	0.185(0.410)	-0.547 (-1.010)
$\ln \ln TO_{it}$	-0.095 (-1.672)	-0.109* (-2.011)	-3.299*** (-7.668)	4.612 *** (10.657)	-0.016(- 0.203)	0.030(0.406)
$\ln \ln GDP_{it}$	0.030 (0.470)	0.060 (1.006)	1.133*** (4.476)	-0.907*** (-5.628)	0.174 (1.829)	0.199 (2.178)*
c	2.531		4.289		3.543	
γ	4.580		0.118		44.037	
No. of Obs.	72	288	288	72	180	180

Notes: ***, **, and * indicate the significance at the levels of 0.01, 0.05, and 0.1 respectively.

The number in parentheses is the T-statistic.

Dependent variables: consumption of oil, renewable energy, and nuclear energy consumption respectively.

Empirical results

To investigate the impact of oil prices on the consumption of oil, renewable energy, and nuclear energy in the 12 European Union countries from 1990 to 2019, the oil prices as a threshold variable. The study estimates the results of the PSTR model by using the nonlinear least squares (NLS) technique. The PSTR estimation results are shown in Table 7.

The oil prices impact on oil consumption is presented in Figure 1(A). The estimated threshold value for oil consumption is 2.53. For a low oil price regime, where the oil price is below the threshold value, a one percent increase in oil prices leads to a decrease in oil consumption by -0.060 percent. For the high oil price regime, where oil prices exceed the threshold value, a one percent increase in oil prices leads to a decrease in oil consumption by -0.108. These findings demonstrate a negative and statistically significant impact of oil prices on oil consumption in both price regimes. Thus, the effect of oil prices on oil consumption is nonlinear. These results are similar to those of Bloch et al. (2015) and Oltulular (2024), who found that rising oil prices cause a reduction in oil consumption. The above results imply that the 12 European Union countries were likely to reduce their reliance on fossil fuels like crude oil. Thus, a surge in oil prices may motivate them to accelerate their transition to alternative energy sources, such as renewable energy and nuclear energy.

In terms of individual countries, oil prices have a negative effect on oil consumption for all 12 European Union countries as displayed in Figure 2(A). Especially in Bulgaria, a country with the lowest average oil price levels, it exhibits the lowest average marginal effect coefficient of approximately -0.100. In contrast, countries with higher average oil price levels, such as Sweden, Finland, France, and Germany, have an average marginal effect coefficient of approximately -0.075. Thus, these results suggest that the largest negative impact of oil price is in Bulgaria, while the smallest negative impact is in Sweden, Finland, France, and Germany.

The effect of oil prices on renewable energy consumption is shown in Figure 1(B). Due to the estimated threshold value is 4.289 for renewable energy consumption. When oil prices are less than this threshold, a one percent increase in oil prices will enhance renewable energy consumption by 2.709 percent. When oil prices exceed the threshold, a one percent increase in oil prices will also enhance renewable energy consumption by 2.790 percent. The results show that oil prices have a positive and statistically significant effect on renewable energy in both price regimes with a slightly stronger effect in the high oil price regime. This suggests that rising oil prices encourage a greater shift toward renewable energy as a substitute for oil. However, our findings confirm a nonlinear effect of oil prices on the consumption of renewable energy. This finding is in line with the literature that found a positive influence of higher oil prices on renewable energy use. For example, Brini et al. (2017) in the case of Tunisia, Bamati and Raof (2020) in the case of 25 countries, Chen et al. (2021) in the case of 97 countries, Guo et al. (2021) in the case of G7 countries, Padhan et al. (2020) in the case of OECD countries, Rasheed et al. (2022) in the case of European countries, and Sahu et al. (2022) in the case of the United States. The reason may be the 12 European Union countries strongly promote renewable energy, which is clean and carbon-free energy, to achieve the energy targets outlined in the Europe 2020 strategy, which

emphasizes reducing the amount of greenhouse gas emissions, improving energy efficiency, and boosting renewable energy share in the European Union (European Commission, 2010).

Additionally, our estimate for individual countries reveals a positive impact of oil price growth on renewable energy consumption across all 12 European Union countries. This is shown in Figure 2 (B). Bulgaria has the highest average marginal effect coefficient, reflecting the largest positive oil price impact on renewable energy consumption. Furthermore, Finland, Germany, Sweden, France, and Belgium have an average marginal effect coefficient less than 4.18, reflecting the smallest positive impact. This indicates that oil prices have a more beneficial influence on renewable energy consumption in countries with lower average oil price levels rather than countries with higher average oil price levels.

The effect of oil prices on nuclear energy consumption is presented in Figure 1(B). The estimated threshold value is determined to be 3.543. For the low oil price regime, a one percent increase in oil prices leads to an increase in nuclear energy consumption by 0.016 percent. On the other hand, when oil prices exceed the threshold value and shift into the high oil price regime, a one percent increase in oil prices leads to a decrease in nuclear energy consumption by -0.053 percent. The results show a positive effect of oil prices on nuclear energy consumption in a low oil price regime, confirming a substitution relationship between oil and nuclear energy, which is consistent with the findings of Lee and Chiu (2011). Nevertheless, oil prices have a negative effect on nuclear energy in a high oil price regime, which is consistent with the findings of He et al. (2016), who reveal evidence of a negative relationship between relative energy prices and energy consumption. This implies that the effect of oil prices on nuclear energy consumption is nonlinear. This could be due to nuclear power plants having high production costs and expensive technology, including the costs of infrastructure, maintenance, and regulatory compliance. As a result, nuclear energy may not be an attractive alternative option during periods of high oil prices.

At the country level, the estimates suggest that an increase in oil prices declines nuclear energy consumption in all the countries studied as demonstrated in Figure 2 (C). Notably, Bulgaria has the lowest average marginal effect of oil prices by approximately -0.0103, indicating the highest sensitivity to oil price changes. Meanwhile, Sweden has the highest average marginal effect by approximately -0.0097, suggesting the lowest oil prices sensitivity. This implies that countries with lower average oil price levels tend to experience a more pronounced negative effect of oil price growth on nuclear energy consumption compared to countries with higher average oil prices.

Regarding the control variables, we found that economic growth has a positive but insignificant effect on consumption of oil and nuclear energy in both oil price regimes. Simultaneously, economic growth has a positive and statistically significant effect on renewable energy consumption only in a low oil price regime. The results support the findings of Liddle and Sadorsky (2020), who observed the positive effect of economic growth on energy consumption. It means higher economic growth leads to increase in economic activities, which tend to raise energy demand, particularly for oil and nuclear energy.

Our findings also reveal that trade openness has a negative and statistically significant impact on oil consumption in low and high oil price regimes, which is similar to the empirical results of Koengkan and Fuinhas (2022), who found that trade openness reduces fossil fuel consumption. Furthermore, trade openness has a positive impact on the consumption of renewable and nuclear energy when oil prices exceed the threshold values of 4.289 and 3.543, respectively. The results support the findings of Alam and Murad (2020) and Chen et al. (2021), finding that trade openness encourages clean energy. A possible reason could be that trade openness enhances investment in modern and advanced technological innovations, providing access to more efficient and cost-effective energy technologies like renewable energy and nuclear energy.

Additionally, the Human Development Index (HDI) has a negative and statistically insignificant impact on oil consumption in both low and high oil price regimes. However, it exerts a positive and significant effect on renewable energy consumption in high oil price regimes when oil prices exceed 4.289. On the other hand, the effect of the Human Development Index (HDI) shifts from encouraging to inhibiting nuclear energy consumption when oil prices are more than 3.543. These findings align with those of Pegkas (2024), who found that the Human Development Index (HDI) reduces nonrenewable energy consumption while promoting renewable energy consumption. The results reflect that countries with a high Human Development Index (HDI), indicating better education, quality of life, and life expectancy, tend to focus on renewable energy consumption while reducing their reliance on nonrenewable energy sources, such as oil and nuclear energy.

To confirm the robustness of our results presented earlier, we compare the Panel Smooth Transition Regression (PSTR) model estimated using fixed effects (as the baseline) and pooled OLS. The results of the robustness are reported in Table 7. We find that the majority of estimated coefficients of the pooled OLS are similar to those of the fixed effects estimation, confirming the robustness of our estimation.

Conclusion

This study employed the Panel Smooth Transition Regression (PSTR) model to investigate the impact of oil prices on consumption of oil, renewable energy, and nuclear energy in the 12 European Union countries over the period 1990–2019 by using oil prices as transition variable.

The empirical findings revealed that the estimated oil price threshold values for the consumption of oil, renewable energy, and nuclear energy are 2.531, 4.289, and 3.543, respectively. In addition, we find evidence of a nonlinear effect of oil prices on the consumption of all three types of energy. The results show that oil prices have a negative and statistically significant impact on oil consumption that effect is more pronounced when oil price levels are above the threshold value of 2.531. On the other hand, oil prices exhibit a positive and statistically significant impact on renewable energy consumption across both low and high oil price regimes. This finding suggests that increases in oil prices even beyond the threshold value of 4.289 are particularly beneficial for the transition toward renewable energy. Specifically, when the oil price exceeds the threshold value of 3.543, its effect on nuclear. Our results reveal that oil prices significantly influence energy consumption, with different impacts on consumption on oil, renewable energy, and nuclear energy changes from promoting

to inhibiting. Overall, our results reveal that oil prices have different effects patterns on three types of energy consumption.

At the country level, the findings showed that countries with lower average oil price levels such as Bulgaria, had stronger negative impacts of oil prices on oil and nuclear energy consumption compared to countries with higher average oil price levels such as Sweden, Finland, France, and Germany. Conversely, oil prices have a positive influence on renewable energy consumption across all countries especially those with lower average oil price levels.

The findings of this study provide valuable policy recommendations for the 12 European Union countries. The empirical findings reveal that oil prices positively influence renewable energy consumption in both low- and high-oil-price regimes. Therefore, policymakers in these countries should actively promote renewable energy to cope with the energy crisis triggered by the Russia–Ukraine conflict. This can be achieved by offering financial incentives such as low interest loans, tax credits, and subsidies to stimulate investment in renewable energy infrastructure and the development of advanced renewable energy technologies. Overall, these measures can help accelerate the transition to renewable energy, reduce reliance on Russian oil imports, and enhance long term energy security in line with the REPowerEU targets in the European Union.

For limitation and future research, this study did not consider the impact of oil prices on the consumption of oil, renewable energy, and nuclear energy during the periods pre- and post-implementation of the Russian oil import ban. Therefore, future study should investigate the differential impact of oil prices across these two periods. Moreover, this study only focused on the oil prices effect on three types of energy consumption. Future research should expand the scope to include a broader range of energy sources such as natural gas, coal, and various renewable energy forms. This part requires further investigation to enhance understanding of the effect of oil prices on different types of energy consumption.

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Table 7 Results of the robustness test.

PSTR model with fixed effects						
Variables	Oil Consumption		Renewable Energy Consumption		Nuclear Energy Consumption	
Oil price regimes	Low regime	High regime	Low regime	High regime	Low regime	High regime
$\ln \ln OP_{it}$	-0.060 *** (-5.071)	-0.108 *** (-5.345)	2.709 *** (11.443)	2.790*** (10.657)	0.016 (1.261)	-0.053(-1.567)
c	2.531		4.289		3.543	
γ	4.580		0.118		44.037	
PSTR model with pooled OLS						
$\ln \ln OP_{it}$	-0.106***(-3.822)	-0.145***(-2.720)	2.931***(4.961)	4.413***(4.552)	-0.001(-0.022)	-0.076(-0.896)
c	3.529		4.289		2.611	
γ	53.249		0.2282		17.924	

Notes: ***, **, and * indicate the significance at the levels of 0.01, 0.05, and 0.1 respectively.

The number in parentheses is the T-statistic.

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Remittances, Sanitation and Child Malnutrition in Middle-income Countries: A Case Study from Rural Northeast Thailand and Central Vietnam

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Abstract

Sanitation and child undernutrition are critical for sustainable development, and remittances have become an important source of income in several emerging economies. However, the interlinkages between remittances, sanitation, and child undernutrition have not been investigated. In this study, we examine the impact of remittances on the propensity of rural households to have a flush toilet and the impact of having a flush toilet on child undernutrition in two emerging economies, Thailand and Vietnam. We use a four-wave panel dataset of rural households collected in 2007, 2010, 2013, and 2016 in six provinces in rural Northeast Thailand and Central Vietnam and employ an instrumental variable (IV) approach to address endogeneity concerns. Our results show that (i) remittances have a positive effect on the probability of having a flush toilet; (ii) children from rural households without a flush toilet suffer more from wasting, underweight, and stunting; and (iii) the impact of having a flush toilet on child undernutrition varies among different child groups. Female children and children from poor households benefit more, while children from less educated mothers benefit less. Our findings confirm that remittances are a source of funding to improve rural sanitation and highlight the importance of improved sanitation for child health in middle-income countries. Therefore, supporting rural households in obtaining a flush toilet is recommended and can be facilitated through economic growth for remittances. In addition, improving rural education and village public water systems also contributes to reducing child undernutrition among rural households.

Keywords: Middle-income, Remittances, Sanitation, Thailand, Vietnam



Shocks and the Dynamics of Multi- and Single-dimensional Poverty and Subjective Well-being: Evidence from Thailand Vietnam Socio Economic Panel (TVSEP) Data

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Abstract

Poverty in developing countries should be seen as “multi-dimensional” deprivation (MDP) covering non-monetary aspects and “dynamic” as people not only move in and out of poverty but are also vulnerable to unexpected shocks such as climate shocks and pandemics. While recent studies focused on the importance of psychology or subjective well-being in poverty traps, few studies have analysed this in MDP or its relation to the role of shocks. Although Vietnam and Thailand have dramatically reduced both income poverty and MDP, poverty has not been eliminated and is still an important policy issue. However, less attention has been paid to SWB as a cause and a consequence of poverty changes for vulnerable groups (e.g., older adults and adolescents). Drawing upon three waves of the TVSEP data (2013-2017), we ask (i) What are the determinants of monetary poverty, MPI and SWB and their changes over time? (ii) What are the differences in determinants of these three different sets of measurements and their various combinations? (iii) Does the aggregate shock, including the past shock (i.e., the exposure to Agent Orange, Vietnam), affect these different poverty measures? (iv) Are there any bi-directional effects between poverty and SWB? and (v) Do public transfers or remittances alleviate these shocks? Methodologically, we apply the Item Response Theory to derive the underlying capability that would determine dimensional poverty status and a dynamic panel probit model for the MDP binary index and estimate the multivariate probit model. We plan to expand the data to 2008, 2010, and 2022 and match them with the rainfall and temperature data.

Keywords: Poverty, Shock, Thailand, Vietnam, Well-being

Farming Efficiency and Rural Labor Transitions: Evidence from panel data for Thailand.

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Abstract

Rural transformation is important for economic growth and characterized by the reallocation of labor from farm to non-farm sectors. However, there is limited evidence on how farming efficiency affects the allocation of labor from farm to non-farm sectors at the household level. In this study, we explore the effects of farming efficiency on rural transformation and investigate the impact of farming efficiency on the shift from full-time to part-time farming. We use panel data from the Thailand-Vietnam Socio-Economic Panel (TVSEP), a long-term project for empirical analyses. Our sample includes 10,549 observations collected in Thailand from seven survey waves between 2007 and 2019. We first estimate the farming efficiency of rural households by employing a stochastic frontier model with true random-effects and Mundlak's adjustments. Then, we employ a heteroscedasticity-based approach with instrumental variables to examine the effects of farming efficiency on six indicators of rural transformation, reflecting labor allocation, livestock development, and farm mechanization. Our results reveal that farming efficiency positively and significantly affects the share of farm income, per capita farm income, and per hectare agricultural machinery expense, while it has a negative and significant effect on the share of non-farm income, per capita non-farm income, and the share of livestock income in farm income. These results imply that more efficient farmers tend to stick to farming and apply mechanization in crop production, while less efficient ones shift to non-farm sectors. Policies designed to support and encourage farm enlargement and labor allocation to accelerate rural transformation are recommended.

Keywords: full-time to part-time farming, heteroscedasticity-based approach, instrumental variable, rural transformation

Food Consumption Transformation and its effect from COVID-19. Case study Northeast Rural Thailand.

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Abstract

This paper investigates the evolving food consumption patterns among rural households. Utilizing secondary data from the TVSEP for quantitative analysis, enhanced by primary qualitative insights from in-depth interviews, the study reveals significant transformations in food consumption attributed to economic growth and improved infrastructure. These changes offer both advantages and challenges. On the positive side, rural residents benefit from a more diverse, convenient, and hygienic diet. Conversely, there are concerns regarding careless consumption, which has led to diet-related diseases such as hypertension and diabetes, creating substantial health risks, particularly in rural areas with limited healthcare access compared to urban settings.

During the COVID-19 pandemic, rural areas had sufficient food supply due to rich natural resources. However, there are concerns that this natural resource may decrease in the future. Short-term issues with food accessibility were noted, whereas the long-term effects of the pandemic appear to encourage rural residents to adopt more cautious approaches to food hygiene, potentially fostering improved health outcomes. Econometric analyses indicated a general reduction in household expenditures during the pandemic, although food expenditure remained a priority, leading to an increased share of their budget dedicated to essential food items relative to non-essential goods.

Keywords: Covid-19, Food Consumption, Rural Transformation



The Impact of AI on Career Readiness: The Role of Learning Goal Orientation and Digital Skills in the Industry 5.0

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Abstract

This study aims to develop a conceptual model that explains students' career readiness in the era of Industry 5.0, which emphasizes the synergy between humans and intelligent technologies. The model investigates the direct influence of learning goal orientation and digital skills on learning performance, which in turn affects career readiness. Learning performance is positioned as a mediating variable, while Artificial Intelligence (AI) technology is examined as a moderator that enhances the relationship between learning outcomes and career readiness. In the context of Industry 5.0, educational transformation requires not only digital competence but also human adaptability, ethical awareness, and the capacity for human-machine collaboration. Therefore, fostering digital skills grounded in strong learning goals becomes essential in shaping human resources who are competent and prepared for the complexities of future employment. This article synthesizes recent literature and presents a theoretical framework to guide higher education development strategies that are both relevant and human-centered.

Keywords: Learning Goal Orientation, Digital Skills, Learning Performance, Career Readiness, AI Technology, Industry 5.0

Introduction

The advent of Industry 5.0 marks a paradigm shift from the automation-centric focus of Industry 4.0 to a more human-centric approach that emphasizes collaboration between humans and intelligent technologies. This evolution necessitates a reevaluation of the competencies required for future professionals, particularly in the realm of higher education. As the labor market increasingly demands a blend of technical and soft skills, educational institutions are challenged to equip students with the necessary tools to thrive in this dynamic environment.

Learning Goal Orientation (LGO) and digital skills have emerged as critical factors influencing students' learning performance and, subsequently, their career readiness. Moreover, the integration of Artificial Intelligence (AI) technologies in educational settings offers new avenues to enhance learning outcomes and better prepare students for the complexities of the modern workforce.

This study aims to develop a conceptual model that elucidates the relationships among LGO, digital skills, learning performance, and career readiness, with a particular focus on the moderating role of AI technology within the context of Industry 5.0.

Literature Review

Learning Goal Orientation and Learning Performance

The advent of Industry 5.0 marks a paradigm shift from the automation-centric focus of Industry 4.0 to a more human-centric approach that emphasizes collaboration between humans and intelligent technologies. This evolution necessitates a reevaluation of the competencies required for future professionals, particularly in the realm of higher education. As the labor market increasingly demands a blend of technical and soft skills, educational institutions are challenged to equip students with the necessary tools to thrive in this dynamic environment.

Digital Skills and Career Readiness

Digital skills encompass a range of competencies, including information literacy, communication, content creation, safety, and problem-solving in digital environments. These skills are increasingly recognized as vital for career readiness, as they enable individuals to navigate and leverage digital tools effectively in the workplace. The integration of digital skills into educational curricula is thus critical to prepare students for the demands of the modern labor market (1).

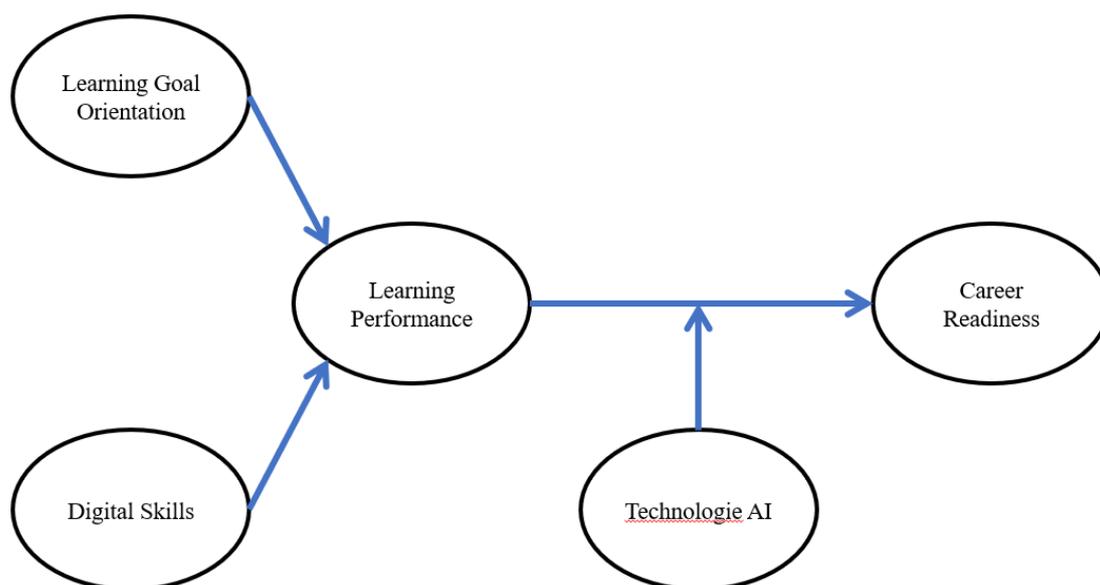
Artificial Intelligence as a Moderating Variable

Artificial Intelligence technologies have the potential to personalize learning experiences, provide real-time feedback, and identify areas for improvement, thereby enhancing learning performance. As a moderating variable, AI can influence the strength and direction of the relationship between learning performance and career readiness. The incorporation of AI in educational settings aligns with the principles of Industry 5.0, which advocates for synergistic human-machine collaboration (2).

Conceptual Framework

The proposed conceptual model posits that Learning Goal Orientation and digital skills positively influence learning performance, which in turn enhances career readiness. Furthermore, AI technology is hypothesized to moderate the relationship between learning performance and career readiness, potentially amplifying the impact of learning performance on career readiness outcomes.

Figure 1: Conceptual Model



Methodology

This study will employ a quantitative research design using survey methodology. The target population comprises undergraduate students across various disciplines in Indonesian universities. Data will be collected through standardized questionnaires measuring LGO, digital skills, learning performance, and career readiness. The moderating effect of AI technology will be assessed by evaluating students' exposure to and utilization of AI tools in their learning processes. Statistical analyses, including Structural Equation Modeling (SEM), will be conducted to test the hypothesized relationships within the conceptual model.

Expected Contributions

This study aims to contribute to the existing literature by:

- Elucidating the interplay between Learning Goal Orientation, digital skills, learning performance, and career readiness in the context of Industry 5.0.
- Highlighting the moderating role of AI technology in enhancing the impact of learning performance on career readiness.
- Providing empirical insights to inform educational strategies and curriculum development aimed at preparing students for the evolving demands of the labor market.

Conclusion

In the era of Industry 5.0, the integration of human-centric approaches and advanced technologies necessitates a reevaluation of educational practices to ensure students are adequately prepared for future careers. By exploring the relationships among Learning Goal Orientation, digital skills, learning performance, and career readiness, and considering the moderating role of AI technology, this study seeks to inform

educational stakeholders on effective strategies to enhance student outcomes and align educational objectives with industry needs.

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Strategic Orientation for Competitive Advantage and Economic Sustainability in Thai Agricultural Cooperatives

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Abstract

This study investigates the impact of various strategic orientations—membership, customer relations, competition, network connections, technology, innovation, regulatory compliance, and good governance—on the economic sustainability of agricultural cooperatives in Thailand, with *competitive advantage* as a mediating variable. Utilizing a sample of 274 participants selected through simple random sampling and employing a structural equation model (SEM), the research identifies both direct and indirect effects of these orientations on economic sustainability. The findings reveal that *competitive advantage* plays a critical role in enhancing economic sustainability, while specific strategic orientations—particularly customer focus, innovation, and good governance—directly influence economic outcomes. The effect of competitive advantage was the highest (0.349), whereas customer orientation had the lowest direct effect (0.135). The analysis also highlights the negative impacts of networking and regulatory frameworks on profitability, with odds ratios of -0.914, suggesting that these areas require more cautious strategic planning. Membership, on the other hand, yielded the highest probability of profit achievement, with an odds ratio of 0.724. The study offers policy implications aimed at strengthening competitive advantage by strategically emphasizing competitors, customers, innovation, and good governance. It also recommends that governments provide more regulatory flexibility to support the profitability of agricultural cooperatives. Overall, the research underscores the importance of strategic orientation in achieving sustainable economic outcomes for agricultural cooperatives.

Keywords: Economic sustainability, Profitability, Strategic Orientations, Competitive advantage, Structural equation model (SEM)

Understanding Farmer Decision-Making on Native Planting in Canterbury: Economic and Attitudinal Drivers

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Abstract

Native vegetation on farmland offers substantial ecological benefits, including pollination and pest suppression, yet farmer uptake remains limited. This study investigates the socio-economic and perceptual drivers behind Canterbury farmers' choice to plant native species. This study combined field insect surveys with a behavioral questionnaire completed by 134 landholders using a mixed-methods approach. Factor analysis revealed five key dimensions influencing farmer decisions: 1) knowledge, 2) motivation, 3) economic constraints, 4) environmental beliefs, and 5) operational barriers. K-means clustering segmented respondents into three groups: Action-Oriented Advocates, Motivated but Cautious, and Barrier-Dominated Farmers, highlighting the heterogeneity in attitudes and constraints.

Logistic regression identified financial cost as the only statistically significant predictor of choosing natives for planting ($p = 0.045$). At the same time, Random Forest analysis confirmed that expected maintenance costs and farm size were the strongest influences on that choice. These results indicate that even motivated and environmentally aware farmers are unlikely to adopt native planting without economic support.

The study recommended tailored outreach strategies and the integration of native planting into broader sustainability programs, with targeted financial incentives from regional councils and national agencies. This study supports biodiversity policy development under the Sustainable Food and Fibre (SFF) Futures program and identifies future research needs, including cost-benefit analysis and willingness-to-accept assessments.

Keywords: Native Plants, Biodiversity, Pollination, New Zealand Farmers, Agricultural Economics

Introduction

Native plants play a vital role in sustaining biodiversity and ecosystem resilience, particularly on agricultural land where habitat loss has dramatically reduced the abundance and diversity of pollinators and natural enemies of crop pests. Across the globe, integrating semi-natural habitats (SNH) within farmlands has been shown to enhance ecological outcomes and improve crop productivity. In New Zealand, the use of native plant species on farms presents an opportunity to restore biodiversity while supporting economically beneficial insects such as pollinators. Despite the biological benefits and growing awareness, the uptake of native planting remains limited.

Enhancing the diversity of beneficial insects on farms can strengthen the resilience of pollination and natural pest control (Carvalho et al., 2011; Feit et al., 2019). Greater pollinator diversity has been linked to increased crop yields (Garibaldi et al., 2016) and improved yield stability across years (Senapathi et al., 2021). Similarly, a diverse community of natural enemies can enhance pest suppression. To sustain populations of these beneficial insects, the establishment or conservation of supportive habitats, such as native SNH, remnant vegetation, and floral strips, is widely recommended by scientists and supported through governmental policies in various countries (Bommarco et al., 2013; Kovacs-Hostyanszki et al., 2017; Howlett et al., 2023; Müller et al., 2024). In some instances, these measures have successfully improved pollination (Blaauw & Isaacs, 2014) and pest management (Bianchi et al., 2006; Qian et al., 2021; Crowther et al., 2023), including a reduction in insecticide use (Gurr et al., 2016).

In Aotearoa-New Zealand, research has and continues to explore the creation of SNH to support beneficial on-farm insects by establishing either exotic species (Stephens et al., 1998; Berndt et al., 2006) or native species (Davidson et al., 2010; Tompkins et al., 2010; Curtis et al., 2019; Howlett et al., 2021). As native SNH is increasingly established across Aotearoa-New Zealand farmland for a variety of environmental and social benefits, such as reducing nutrient run-off, preventing soil erosion, enhancing native biodiversity, improving aesthetics, and supporting intergenerational equity (Maseyk et al., 2017; Maseyk et al., 2018), there is an opportunity to design these habitats to deliver additional benefits, including supporting beneficial insects for pollination and pest control (Fiedler et al., 2008; Wratten et al., 2012; Howlett et al., 2023). However, the economic benefits of native SNH for Aotearoa-New Zealand farmers, specifically in terms of enhancing pollination and pest control services, remain poorly understood. It is known that some native insects play functional roles as natural enemies of farmland pests, while others are themselves notable agricultural pests (Ferguson et al., 2019). Additionally, the adult stages of various introduced natural enemies often utilize the floral resources provided by native plant species (Tompkins, 2010; Howlett et al., 2021).

The Canterbury Plains, one of Aotearoa-New Zealand's most agriculturally intensified regions, offers a valuable opportunity to assess how establishing SNH on farms can support beneficial insects and provide tangible benefits to farmers, land managers, and the wider community. The region's land use is dominated by livestock farming (dairy, sheep, and beef) and crop production, with remnant vegetation covering less than 1%

of the landscape (Leathwick et al., 2002; Meurk, 2004). Farmers in Canterbury depend heavily on pesticide use for insect pest control (Hageman et al., 2019; Mansfield et al., 2019) and on managed honeybees for crop pollination (Goodwin, 2012). Nevertheless, there is foundational knowledge about the diversity of beneficial insect species providing pollination and pest control services in this region (Rader et al., 2009; Howlett et al., 2021; Fijen et al., 2022). Additionally, insights exist regarding how these insects interact with on-farm native SNH, including which plant species support specific beneficial insects (Davidson & Howlett, 2023), how SNH supports various life stages of beneficial insects (Howlett et al., 2021), its influence on insect abundance and distribution (Fijen et al., 2022), and how insects disperse from SNH into the surrounding agricultural landscape (Schmidlin et al., 2021).

The SFF Futures research program, "Biodiversity for Beneficial Insects: Designing Native Plantings for Beneficial Insects," aims to build on previous research efforts. The current program includes the establishment of sites for restoration and native SNH across cropping, dairy, and other livestock farms. It is studying insects associated with older mixed native SNH, established between 2013 and 2018, as well as new mixed native SNH. These will be compared to sites without any native vegetation, such as bare wire fence sites, to evaluate differences in insect diversity and abundance.

This research program also seeks to evaluate the contributions of beneficial insect pollinators, predators, and parasitoids to ecosystem functions such as pollination and pest suppression. Additionally, it explores the perceptions of farmers and the broader community regarding native plant SNH through data collected using questionnaires. Engagement with local iwi has also been conducted to understand the cultural significance of native plants to hapu. The program's goal is to demonstrate that establishing native plants on farms can help farmers capitalize on ecosystem functions provided by beneficial insects. Ultimately, the project aims to encourage more farmers to incorporate native SNH on their farms to boost insect diversity and the associated benefits these insects bring to agricultural landscapes.

This study emerges from the SFF Futures program, which seeks to design and promote on-farm SNH that supports beneficial insects. It investigates how Canterbury farmers perceive native plantings, focusing on the motivations, constraints, and beliefs that shape their decision-making. The central research question is: What are the key factors influencing the choice to plant native species among farmers in Canterbury?

Literature Review

The ecological benefits of incorporating native vegetation into agricultural landscapes have been well documented in both global and New Zealand-specific studies. Kleijn et al. (2015) highlight that SNH, including hedgerows and flower-rich margins, provide nesting, foraging, and overwintering sites for pollinators and natural enemies. Garibaldi et al. (2016) demonstrate that increased pollinator diversity is positively correlated with higher and more stable crop yields. Bommarco et al. (2013) and Bianchi et al. (2006) show that pest suppression is enhanced by a more diverse natural enemy community, while Gurr et al. (2016) discuss the

potential for reduced pesticide reliance when native or perennial plantings are present. In the New Zealand context, Howlett et al. (2021) and Davidson & Howlett (2023) provide empirical evidence of the role of native plant species in supporting local insect biodiversity. These studies emphasize that native SNH can offer dual ecological and agronomic benefits.

Adoption of biodiversity-supportive practices by farmers, however, depends not only on ecological efficacy but also on socio-economic drivers. Prokopy et al. (2008) developed a framework integrating farmer attitudes, knowledge, and constraints to explain adoption behaviors. In New Zealand, studies by Maseyk et al. (2017, 2018) suggest that farmers may support native planting for cultural, aesthetic, or stewardship reasons, but economic viability and practical barriers often inhibit implementation. These findings are consistent with Pannell et al. (2006), who argue that for a land-use change to be adopted at scale, it must be seen as both profitable and feasible by landholders.

To better understand the determinants of such land-use decisions, previous studies have increasingly used statistical models such as logistic regression and machine learning techniques like Random Forest. Logistic regression is widely used in environmental and behavioral sciences to model binary outcomes such as yes/no decisions based on continuous and categorical predictors (Hosmer et al., 2013). It allows for straightforward interpretation of coefficient direction and significance and has been applied in numerous agricultural studies examining conservation practice adoption (e.g., Baumgart-Getz et al. 2012). However, logistic models are limited when dealing with complex, non-linear interactions or when multicollinearity is present.

To address these limitations, ensemble methods like Random Forest have gained popularity in recent years. Random Forest is a nonparametric algorithm that constructs multiple decision trees and aggregates their results, which helps improve predictive accuracy and model stability (Breiman, 2001). It is beneficial for identifying variable importance, handling large datasets with many predictors, and accommodating non-linear relationships. In agricultural behavioral studies, a Random Forest has been used to predict the adoption of sustainable practices (e.g., Wuepper et al. 2020) and to model heterogeneous farmer responses under various policy scenarios. Thus, this study is able to capture both the interpretable relationships between individual factors and the more complex patterns in farmer decision-making by applying both logistic regression and Random Forest. This dual approach enhances the robustness and relevance of our findings regarding policy.

Data and Methods

This study employed a mixed-methods research design, combining field-based ecological monitoring with a detailed behavioral survey and statistical modeling to understand the factors influencing the decision to plant native species in Canterbury, New Zealand.

Field Study of Beneficial and Pest Insects

As part of the broader SFF Futures research program, ecological data were collected using traps and visual observations across various farms with established native SNH, newly planted SNH, and bare control sites. This component focused on assessing biodiversity and ecosystem service delivery by beneficial insects such as pollinators and natural enemies of crop pests.

Survey of Canterbury Farmers

A structured questionnaire has been approved by Plant and Food Research's Ethics Committee and distributed to farmers in the Canterbury region between March 2022 and July 2024, resulting in 134 valid responses. The survey was designed to capture a comprehensive profile of each respondent, including the farm system, attitudes, knowledge, motivations, and barriers related to native planting. The questionnaire consisted of both closed and Likert-scale questions and was divided into five key sections:

1) Background Information

Survey questions included farm size (in hectares), production system (e.g., arable, dairy, sheep/beef, fruit, vegetables), and ownership structure. The questionnaire also asked whether native vegetation was already present on the property and whether the current landholder established these plantings.

2) Knowledge and Experience with Native Plants

Respondents were asked whether they had heard or read information about the role of native plants in supporting beneficial insects and how familiar they were with establishing and maintaining such plantings on their farms. They were also asked to describe their observational experience with insect activity near native vegetation.

3) Motivations for Planting Natives

This section assessed the importance of various drivers, such as improving biodiversity, enhancing crop/pasture yields, supporting insect pollinators, aesthetic appeal, and contributing to ecological restoration. Respondents rated these motivations on a 5-point scale.

4) Financial and Operational Barriers

A range of potential constraints was listed, including plant and maintenance costs, loss of productive land, time and labor requirements, access to quality native plants, and fear of pest harboring. These were rated from "Not a barrier" to "Major barrier."

5) Beliefs about the Benefits of Native SNH

This section used a 5-point Likert scale to measure agreement with statements related to ecological services (e.g., pest control, pollination, resilience) and farm sustainability.

The questionnaire was available in digital and paper formats, and respondents could remain anonymous. The survey design was informed by prior qualitative interviews and pilot testing to ensure clarity and relevance to New Zealand farmers.

Factor Analysis

Principal Component Analysis (PCA) with varimax rotation was used to reduce the questionnaire data to five underlying factors: knowledge/experience, motivation, economic constraints, environmental beliefs, and operational barriers. These scores enabled dimensionality reduction for further analysis.

Cluster Analysis

K-means clustering was applied to the standardized factor scores to group landholders into three behavioral typologies: Action-Oriented Advocates, Motivated but Cautious, and Barrier-Dominated Farmers. These profiles guided the interpretation of heterogeneity in attitudes and constraints.

Logistic Regression

A binary logistic regression model was used to identify which perceived barriers (e.g., cost, maintenance, land loss) significantly predicted whether a farmer planned to plant native species. The dependent variable was a binary indicator of whether the farmer plans to plant native species on their property (1 = Yes, 0 = No). The independent variables included key responses to perceived barriers from the questionnaire.

The logistic regression model takes the form in Equation (1):

$$\log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_6 X_6 \quad (1)$$

where p	is the probability of planting natives,
β_0	is the intercept,
β_i	are coefficients associated with predictor variables $X_i, i = 1$ to 6
X_1	is the size of the farm (ha),
X_2	is the proportion of income derived from farming (percent),
X_3	is the expected cost needed to plant and maintain natives (NZD),
X_4	is planting natives is "Too expensive" (1 = Yes, 0 = No),
X_5	is planting natives is "High maintenance" (1 = Yes, 0 = No),
X_6	is planting natives a "Loss of productive land" (1 = Yes, 0 = No)

Random Forest Classification

A random forest classifier was built using economic and attitudinal predictors to validate the regression results and explore non-linear interactions.

Results

Factor Analysis

This study applied the PCA with Varimax rotation to reduce the complexity of the questionnaire data and identify underlying constructions. This technique identifies patterns of correlation among the survey questions and groups them into latent variables or "factors." This step is essential for uncovering the primary psychological and practical dimensions that influence farmer behavior.

After preprocessing (including imputation and removing variables with >30% missing data), the final dataset included responses from 135 farmers and 90 questionnaire variables. Based on the Scree plot and Cattell's criterion, the study's result retained five components, which explained a substantial portion of the total variance. The extracted factors and their interpreted meanings are described in Table 1.

Table 1 Principal Components and Their Interpretations

Component (PC)	Meaning
PC1	Knowledge/Experience
PC2	Motivation for Native Planting
PC3	Economic/Financial Constraints
PC4	Environmental Protection Beliefs
PC5	Operational Barriers and Risks

Each component represents a unique dimension of farmer attitudes and perceptions:

PC1 is 'Knowledge/Experience', which includes variables indicating familiarity with native plants and their use for ecological functions.

PC2 is 'Motivation' that reflects intrinsic interest and values related to native biodiversity.

PC3 is 'Economic Constraints', which captures financial limitations and concerns about cost-effectiveness.

PC4 is 'Environmental Beliefs', which highlights awareness of ecosystem services and the moral imperative to act.

PC5 is 'Operational Barriers', which includes practical, time-related, or risk-based challenges that may deter action

Factor scores were computed for each respondent, representing how strongly respondents expressed attitudes corresponding to each factor. The analysis of factor scores among respondents showed significant variability. For example, the Motivation and Knowledge factors exhibited bimodal or skewed distributions. This variation indicates that while some farmers are highly engaged, others remain unconvinced about the benefits of native species.

These factor scores were later used in K-means clustering to group farmers based on overall attitudinal profiles. They also served as exploratory variables to understand how different beliefs and constraints correlate and interact. Interestingly, the result of a multiple regression using the four other factors to predict motivation showed that the R^2 was near zero. This situation means that motivation is largely independent and not linearly explained by Knowledge, Beliefs, or Constraints, highlighting the complexity of farmer decision-making.

The strength of this factor analytic approach lies in reducing many overlapping survey items into a smaller number of interpretable constructs that inform both predictive modeling (logistic regression and random forest) and farmer segmentation (cluster analysis).

Cluster Analysis

To better understand the diversity of farmer perspectives and behavioral drivers, this study used K-means clustering on the standardized factor scores derived from factor analysis. The goal was to segment the sample into meaningful groups with similar patterns of knowledge, motivation, beliefs, and perceived barriers. The elbow method and silhouette analysis supported the use of three clusters. Each cluster represents a distinct typology of farmer, see Table 2:

Cluster 0: Motivated but Cautious: These farmers had moderate to high motivation to plant natives but reported significant financial or operational barriers.

Cluster 1: Action-Oriented Advocates: Characterized by high knowledge and motivation, low concern over costs or operational burdens, and strong environmental beliefs.

Cluster 2: Barrier-Dominated Farmers: These respondents reported low motivation and knowledge, and high operational and financial concerns.

Table 2: Mean Factor Scores by Cluster

Cluster	Knowledge/Experience	Motivation	Economic Constraints	Environmental Beliefs	Operational Barriers
0	-1.89	-1.68	-0.12	-0.13	2.02
1	2.88	0.11	0.11	-0.55	1.04
2	-1.01	3.02	0.05	1.13	2.23

These scores represent standardized values, where zero is the average across all respondents. Positive values indicate higher-than-average factor scores, while negative values indicate below-average. For example, Cluster 0 has strongly negative values for knowledge and motivation (-1.89 and -1.68, respectively), but an extremely high score for operational barriers (2.02). These farmers feel significantly burdened by time, labor, or practical constraints, despite having average financial concerns and beliefs.

Cluster 1, in contrast, scores very high on knowledge (+2.88) and shows slightly positive or near-average scores for motivation, economics, and operational concerns. Despite having relatively neutral scores in some areas, this group is best characterized by their strong confidence and awareness, which likely enables them to pursue native planting without significant concern.

Cluster 2 stands out with the highest motivation score (+3.02) and elevated environmental beliefs (+1.13), but this group lacks practical knowledge (-1.01) and reports the highest operational barriers (+2.23). This suggests that although they are highly interested and environmentally motivated, their lack of experience and strong logistical concerns hold them back.

These profiles suggest different types of outreach or policies may be needed for each group. For instance:

Cluster 1 may be reached with knowledge-sharing and leadership opportunities.

Cluster 0 could benefit from financial assistance or practical support.

Cluster 2 might require long-term engagement and demonstration of tangible benefits.

This segmentation adds valuable depth to the analysis by highlighting that not all farmers who are hesitant to plant natives share the same barriers, and that structural limitations still hold back some motivated individuals.

Logistic Regression

This study fitted a binary logistic regression model to quantitatively assess which perceived barriers most significantly influence farmers' decisions to plant native species.

After testing multiple models, the final model included the most relevant predictors, and the results are summarized in Table 3.

Table 3: Logistic Regression Results for Predictors of Native Planting Intention

Variables	Coefficient	Std. Error	p-value
Intercept	0.85	0.63	0.18
X_4 (planting natives is "Too expensive")	-1.69	0.83	0.045**

The variable X_4 , which indicates that respondents view planting native species as "too expensive," was the only one statistically significant at the 5% level. This finding suggests that respondents who perceived high costs as a barrier were significantly less likely to plan for native plantings. This finding also supports economic theory and aligns with previous studies that emphasize cost as a principal obstacle to adopting conservation practices.

The model had a modest fit, with pseudo R^2 (McFadden's) around 0.12, indicating a limited but meaningful explanatory power, appropriate for behavioral and survey-based studies where multiple interacting factors influence decision-making.

Random Forest

A random forest classification model was applied to validate the findings from the logistic regression and explore potential non-linear relationships and variable interactions. A Random Forest is a machine learning ensemble method that constructs multiple decision trees using random subsets of data and predictor variables and then aggregates their predictions for classification. The Random Forest model used three key predictors: 1) X_3 is the expected cost needed to plant and maintain natives (NZD), 2) X_1 is the size of the farm (ha), and 3) Cluster is farmer typology derived from k-means clustering of factor scores.

The model was trained using a 70:30 train-test split, and parameter tuning was performed using grid search cross-validation. Although overall classification accuracy was moderate (~60%), the Random Forest provided valuable insights into the relative importance of predictors, as shown in Table 4.

Table 4: Random Forest Variable Importance

Variables	Mean Decrease in Gini	Interpretation
X_3	0.50	Most important predictor: high expected cost reduces planting intent
X_1	0.44	Larger farms are more likely to plant natives
Cluster	0.06	Minor influence: farmer type adds little beyond economic predictors

The results confirm that economic variables are the dominant factors influencing the decision to plant natives. The model highlights that X_3 , representing perceived economic burden, had the highest predictive power, followed closely by X_1 . The Cluster variable, though reflecting motivational and attitudinal traits, played a relatively minor role in improving model performance.

While Random Forest does not provide the same level of statistical inference as logistic regression, it is valuable for identifying complex relationships and determining which variables consistently influence outcomes. These findings support the conclusion that addressing financial constraints may be the most effective way to increase the adoption of native planting by Canterbury farmers.

Discussion

Factor and Cluster Findings

Factor analysis validated the presence of well-defined psychological and practical constructions. Knowledge/Experience and Motivation were positively associated with planting intention. However, these alone did not explain behavior in isolation.

Clusters revealed meaningful segmentation. For example, Cluster 1 farmers had both high motivation and capacity, suggesting they are prime candidates for low-cost outreach programs. In contrast, Cluster 0 farmers, though motivated, faced financial barriers, indicating a need for subsidies or cost-sharing models. Meanwhile, Cluster 2 farmers had high motivation but lacked knowledge and faced high operational constraints, revealing an opportunity for targeted training and peer mentoring. These cluster insights suggest that no one-size-fits-all policy will succeed. Instead, interventions should reflect the multidimensional barriers experienced by different farmer groups, ranging from informational to financial to operational. Designing support mechanisms tailored to these segments will likely improve adoption rates of native planting.

Logistic Regression Results

Among the perceived barriers tested, X_4 (planting natives is “Too expensive”) was the only statistically significant predictor ($p = 0.045$), suggesting that cost remains the most substantial constraint. Other variables, including maintenance burden and land use, did not reach significance in this model. This finding is sharply aligned with earlier qualitative work and emphasizes the importance of financial incentives (Scheper et al., 2013). Even highly motivated or ecologically aware farmers are likely to delay or avoid planting if cost barriers are not addressed. This result underscores the limits of education or persuasion campaigns when economic feasibility is not ensured.

Random Forest Validation

Random Forest analysis reinforced the primacy of economic concerns. X_3 , the cost respondents expect to spend on establishing plantings, had the highest importance score (0.50), followed by X_1 , the size of respondents' property (0.44), while Cluster contributed marginally (0.06). These findings align with the notion that farm economics dictate much of the planting behaviour, outweighing attitudinal factors.

The convergence between Random Forest and logistic regression strengthens the robustness of the conclusion: while attitudes, motivations, and knowledge are present in the system, **they are not sufficient to predict action**. Economic capacity—particularly perceived or anticipated maintenance cost is a gating factor for behavioural change.

These findings provide a strong empirical foundation for policy design. Programs aimed at promoting native plantings should prioritize reducing perceived and actual costs, either through subsidies, maintenance support, or access to affordable planting kits. Simultaneously, it is crucial to address the informational and operational gaps revealed through clustering. By segmenting the audience and tailoring interventions to match their unique profiles, policy and outreach strategies can become significantly more impactful.

Conclusion

This study provides clear evidence that economic factors are the most significant determinants influencing farmers' decisions to plant native species in Canterbury. Although farmers may express strong environmental values, interest in biodiversity, and practical experience with native plants, these characteristics alone do not drive their decisions. Instead, the choice to plant natives is primarily influenced by the perceived costs of maintenance and the trade-offs associated with land use.

The analysis reinforces the fact that financial barriers, not a lack of motivation or ecological knowledge, pose the most substantial constraint. This finding, corroborated by both logistic regression and Random Forest models, underscores the urgent need for economic solutions to encourage behavioral change. Moreover, the segmentation of farmers into distinct clusters, including Action-Oriented Advocates, Motivated but Cautious, and Barrier-Dominated, reveals that different groups face different challenges and, therefore, require tailored support.

Recommendations

1) Implement Direct Financial Support: Introduce subsidies, cost-share schemes, or low-interest loans specifically targeted at covering native planting and maintenance costs. Agencies such as the Ministry for Primary Industries (MPI) and the Ministry for the Environment (MfE) could create funding streams under existing climate resilience, freshwater, and biodiversity initiatives. Regional councils may also administer local funds to incentivise on-the-ground implementation.

2) Simplify and Reduce Operational Burdens: Develop low-maintenance planting kits, offer access to eco-sourced native plant stock through nurseries supported by the Department of Conservation (DOC) and community trusts, and create practical seasonal guidance tailored to specific farming systems. Crown Research Institutes and extension services can play a role in delivering this guidance in partnership with farmer collectives.

3) Tailor Outreach Based on Cluster Profiles:

Action-Oriented Advocates can serve as demonstration leaders and peer educators, potentially supported by MPI's Extension Services or through catchment group initiatives.

Motivated but Cautious farmers should be prioritized for financial assistance and hands-on support, such as one-on-one advisory visits facilitated by He Waka Eke Noa or Beef and Lamb NZ.

Barrier-dominant farmers may benefit from long-term engagement led by regional councils and NGOs focused on biodiversity, using social proof and visual demonstration of outcomes.

4) Embed Native Planting Within Broader Agricultural Support Programs: Integrate native planting goals into existing programs such as the Sustainable Land Management and Climate Change (SLMACC) fund, freshwater farm planning regulations, and carbon offsetting schemes. This approach creates coherence across environmental, economic, and social goals.

5) Monitor and Evaluate Impact Over Time: Establish long-term monitoring frameworks supported by Crown Research Institutes like AgResearch and Manaaki Whenua. Feedback loops can be maintained through farmer self-reporting, satellite imagery, or in-field biodiversity surveys to iteratively refine program design.

This work informs ongoing outreach under the SFF program and can support the design of more effective biodiversity policies at the regional level. Future research may explore willingness-to-accept (WTA) and incorporate cost-benefit analysis frameworks to guide resource allocation.

Ultimately, if native planting is to become a mainstream practice across Canterbury and other agricultural regions, policy design must align ecological ambition with economic reality. This study offers actionable insights to make that alignment possible.

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Factors Influencing Farmers' Needs for Organic Rice Production Extension in Savannakhet Province, Laos.

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Abstract

The limited success of agricultural development at the grassroots level may stem from a mismatch between the content, methods, and models of agricultural extension and the actual needs of farmers. Traditional top-down approaches, where extension models are designed centrally and imposed locally, often overlook the specific needs of farming communities, leading to limited engagement and implementation by farmers. This study aimed to assess the level of farmers' need for organic rice production extension services and identify key factors influencing these needs in Savannakhet Province, Laos. A structured questionnaire was used to gather data from a sample of 200 farmers across four districts in the province. Data were analyzed using descriptive statistics and multiple regression analysis to determine the extent and determinants of farmers' needs. The findings indicated that the overall need for organic rice production extension among farmers was at a moderate level (mean = 2.18). Among the components evaluated, the highest average need was observed in government support, followed by knowledge and principles of organic production and organic extension methods. Further analysis identified four significant factors that influenced the farmers' needs for organic rice extension services: landholding size, cost of rice production, access to quality rice seed, and overall rice production levels. These findings highlight the importance of tailoring extension services to local needs and suggest that more participatory, bottom-up approaches may enhance farmer engagement and adoption of organic practices. The study emphasizes the necessity of revising agricultural extension models to reflect the specific economic and technical conditions of farmers, thereby supporting more sustainable and effective organic rice production at the community level.

Keywords: organic rice production, farmers' needs assessment, agricultural extension services

Introduction

Rice is the staple food of the world's population. In many countries, rice consumption is considered part of the country's culture. Rice is an important crop for the lives of the Lao people, related to the livelihood of the Lao people and the country's economy, and is also an important export product that brings in a lot of income to the country every year. The Lao population 86% is engaged in farming and activities related to rice production, such as transportation, processing, and trading. (Ministry of Agriculture and Forestry. 2019).

Modern agriculture, which is the widespread use of synthetic chemicals in production in many countries, is beginning to cause harm to the environment, farmers, and consumers by causing toxic pollution in the soil, water, and air, as well as toxic residues in the products that may be harmful to human life. In Laos, synthetic chemicals are used in high-yield rice production, especially irrigated rice production. It is reported that farmers use chemical fertilizers, weed control agents, rice pest control and eradication agents, and chemicals to kill insects and pests in high-yield rice. In addition, they are used incorrectly in the right type, time, and method, which has an impact on the environment, the ecosystem, and the quality of life of the Lao people (Nilda PC 2005).

A new farming concept called Organic Agriculture has emerged. It avoids the use of all types of synthetic chemicals in crop cultivation and animal husbandry but emphasizes the use of organic substances in the production system to ensure safety for producers and consumers, a production system that restores and conserves the environment according to sustainable agricultural principles.

For the Lao PDR, organic rice production has high potential because rice farming is the main occupation of farmers. Due to the suitable geographical conditions, favorable climatic conditions for rice cultivation, and a variety of rice varieties that are suitable for each area, farmers have accumulated knowledge and experience in continuous rice farming for a long time. Therefore, organic rice production in Laos has the opportunity to develop its potential to become one of the world's major organic rice producers. Currently, public and private development organizations have provided support to farmers in other areas of organic rice production, such as Vientiane Capital, but there is no system in place to inspect and certify production according to international standards.

Savannakhet is the largest rice-producing area in Laos with total area of rice cultivation is 243,452 hectares. Approximately 26% of total rice production area in the country, total production of 911,325 tonnes, includes 20% of the total rice production in the country (Silinthone, 2020). The government has promoted and advised farmers to switch to organic rice production by organizing knowledge transfer training and distributing technical documents, demonstrations, and study tours. However, the promotion of agriculture in Savannakhet province has not been as successful as it should be, resulting in a shortage of organic agricultural products that do not meet consumer needs. Organic rice is a type of organic agricultural product that will have a high need in the future, especially in foreign markets where consumers have a fairly good understanding of organic

agricultural products and know that the production process of organic agricultural products must be certified to be truly organic agricultural products.

Agricultural promotion at the local level has not been successful in achieving the set objectives. This may be due to the content, methods, and forms of agricultural promotion that do not meet the needs of farmers, causing farmers to lack interest in learning, training, and implementing them. Because in the past, most of the promotion models were determined from the central to the local level (Top-Down Approach) Which is not born from the needs of the people and the community. Therefore, this study aims to assess the needs of farmers for organic rice cultivation promotion and to assess the factors that affect farmers' needs for organic rice cultivation promotion. The results of this study will be another way to help understand the needs of farmers for promotion and what aspects they need government agencies to promote. The information obtained from the study can be used to determine guidelines for developing agricultural extension work in line with the problems and needs of farmers to increase the effectiveness of agricultural extension work in the area to achieve the set goals and objectives.

Literature Review

Extensive research has been conducted on the factors influencing farmers' needs for organic rice production extension across various regions and crop types. Reviewing these studies provided a foundation for identifying relevant variables appropriate to the selected study site.

Busadee (2021) examined the factors related to the adoption of organic rice production in Ngew Don Sub-district, Mueang Sakon Nakhon District, Sakon Nakhon Province. The findings indicated a high level of adoption among farmers. Significant factors influencing adoption at the 0.05 level included gender, age, household size, and the cost of rice production.

Orawan et al. (2021) explored small-scale farmers' acceptance of the organic rice production system in Maha Sarakham Province. The study revealed that health attitudes, promotion attitudes, education level, household size, agricultural organization membership, and participation in field trips positively influenced adoption. Conversely, farmers with non-agricultural income sources were less likely to adopt organic methods. Policy recommendations included increasing awareness of the health risks associated with chemical use, targeting farmers whose primary income source is rice cultivation, and promoting participation in field activities.

Supunnee et al. (2011) investigated the factors affecting decision-making on organic rice production in Surin Province. The study found that farmers possessed a high level of knowledge about organic farming. Age was negatively associated with decision-making at the 0.05 significance level, while the price of organic rice had a positive impact at the 0.01 level.

Priyakorn and Thienchai (2022) studied factors influencing the acceptance of organic rice production extension in Ranot District, Songkhla Province. The average acceptance score was 3.45. Influential factors included farming style, farming experience, raw material management, soil degradation due to chemical systems, training from external agencies, the presence of secondary occupations, limited sources of produce, economic status, low market prices, and health considerations.

Aroonsak et al. (2020) analyzed factors influencing farmers' decisions to adopt organic, good agricultural practices (GAP), or chemical rice cultivation in Ban Nong-Sok-Dao Subdistrict, Nunsung District, Udon Thani Province. The results revealed that health concerns were the most influential factor in choosing both organic and GAP rice cultivation. However, marketing challenges were reported as the most significant problem in both practices. For chemical rice cultivation, key factors included access to capital, production processes, labor, and marketing. Major obstacles were identified as insufficient knowledge of organic practices and inadequate government support.

Methodology

Scope of study

The scope of this study will be divided into three areas: location, content, and time.

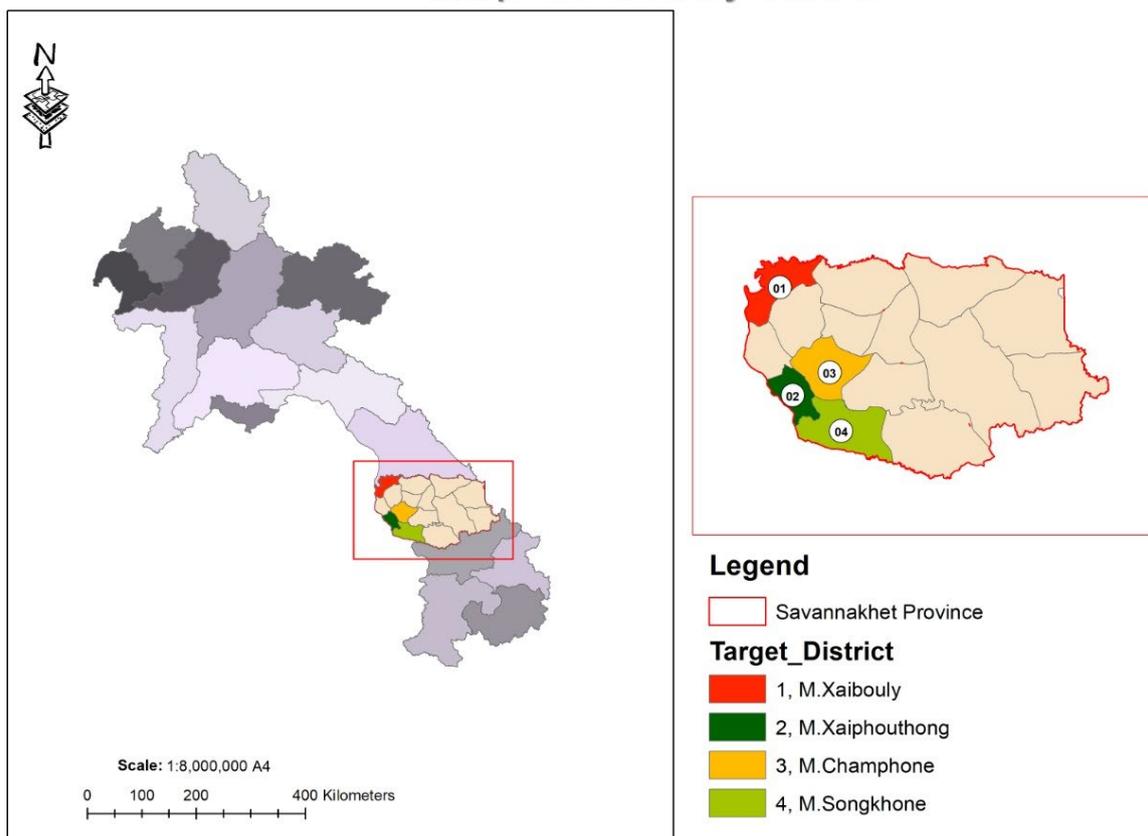
- Location: This study selected Ban Thuat (Champhone District), Ban Namphou (Xayphouthong District), Ban Phonsavang (Songkhone District) and Ban Kang (Xayboury District) in Savannakhet Province as target villages for the study because they have the potential to develop organic rice production in the future.

- Scope of content: This study will delve into the need for extended organic rice production, divided into 3 areas: knowledge and principles of organic rice production, promotion methods, and support needs.

Area selection

The study was conducted in four districts of Savannakhet Province: Champhone District, Xayphouthong District, Songkhone District, and Xayboury District. In collaboration with district authorities, one target village was selected from each district to represent all villages within that district. These four districts were chosen because they have the highest rice production in the province and feature diverse geographical conditions.

Map of Study Area



Population and sample group

The population used in this research study consisted of rice farmers from four villages in four districts of Savannakhet Province: Champhone District, Xayphouthong District, Songkhone District, and Xayboury District. A proportional random sampling method was used, based on the formula by Krejcie and Morgan (1970), as shown in the table below.

Table 1 shows the population and sample groups used in the study.

Village/ District	Population	Proportion of the sample group	Number of sample groups
Thuat (Champhone District)	247	15%	37
Namphou (Xayphouthong District)	384	15%	58
Phonsavang (Songkhone District)	354	15%	53
Kang (Xayburi District)	346	15%	52
Total	1,331	15%	200

After determining the number of sample groups in each village, the samples to be interviewed will be selected using a probability sampling method, specifically simple random sampling, by using the house number method. All population units have an equal chance of being randomly assigned to an appropriate sample group for each characteristic within the population.

Research tools

The research tool used was an interview schedule. Two hundred sets of questions were prepared based on the required information related to various issues, in line with the research objectives. These included both open-ended questions and open-ended questions that required respondents to choose answers based on factual information. The questions were divided into three sections, as follows:

Part 1: Questions about basic personal, economic, and social information of farmers, such as gender, age, education level, marital status, income, number of family members, amount of land owned, farming experience, group membership, rice yield, access to agricultural information, information channels, and characteristics of community life.

Part 2: The needs for extension in organic rice production consist of three aspects: knowledge and principles of organic rice production, methods of promotion, and support requirements. The level of need is measured using a Likert scale and is divided into four levels as follows:

High Need	rate	3
Moderate Need	rate	2
Less Need	rate	1
No need	rate	0

Data analysis

In this study, the data obtained from the interviews will be used to check the integrity of the data, create a code for the data, and then analyze the data using a computer program. The data will be divided into the following analysis objectives :

Objective 1: To analyze the need to extension organic rice production, analyze the data using statistics such as frequency, Percentage, and the standard exchange rate (S.D) And interpret the text according to the level of need, with the level of need for promoting organic rice production by farmers as follows:

Average	0.00 – 0.75	Means: No Need .
Average	0.76 – 1.50	Means Less Need
Average	1.51 – 2.25	Means Moderate Need
Average	2.26 – 3.00	Means High need.

Objective 2: To analyze the factors influencing the need for organic rice production extension using multiple regression analysis, and to identify the factors that affect farmers' needs.

Results

The Level of need for organic rice production extension among farmers in Savannakhet province

An analysis of the level of need for organic rice production extension promotion among farmers in Savannakhet Province was conducted by calculating the mean and standard deviation, both overall and by specific need areas. These values were then compared with the criteria based on Best's concept. The analysis categorizes the needs into three aspects, as detailed in Table 2.

Table 2 shows the level of need for organic rice production extension among farmers in Savannakhet province.

Need Aspects	\bar{X}	S. D	Description
1. Knowledge and principles of organic rice production	2.09	0.54	Moderate Needs
2. Organic extension method	1.83	0.57	Moderate Needs
3. Government's supported	2.23	0.52	Moderate Needs
Average	2.18	0.42	Moderate Needs

From Table 2, it is found that the overall need for organic rice from farmers in Savannakhet province is at a moderate level ($\bar{X} = 2.18$). When looking at each aspect, it was found that farmers have moderate needs in all three aspects, with the aspect with the highest average value being support from the government, followed by knowledge and principles of organic rice production, and the lowest being methods for promoting organic rice production with an average value of 2.23; 2.09. and 1.83 In order.

Factors influencing the need for organic rice production extension among farmers in Savannakhet province

From an analysis of factors influencing the need for promoting organic rice production among farmers in Savannakhet province, it was found that a total of 14 Factors influence the need for organic rice production extension 16 %, while the remaining 84 % are influenced by other factors that we did not determine in this study. When considering the variables that influence the need for organic rice production extension, it was found that there were only 4 factors: land area, cost of rice cultivation, rice variety, and rice yield with a statistical significance level ($p \leq .05$). The remaining 10 factors, such as gender, age, education level, number of workers, income from rice cultivation, water source, experience, access to information, participation in training, and membership in a production group, did not influence farmers' willingness to receive organic rice cultivation promotion (see Table 3).

Table 3 Shows factors that influence the need for organic rice production extension among farmers in Savannakhet province.

Change the original	Farmers' need for extension of organic rice production		
	Coefficient	t-Statistic	P-Value
1. Gender	.058	.834	.405
2. Age	-.004	-.896	.371
3. Education level	.025	.330	.742
4. Amount of land	.074	2.451	.015 *
5. Household labor	1.589E-08	1.252	.212
Amount of rice production			
6. Income from rice production	3.740E-09	.199	.842
7. Rice production costs	-.044	-2.311	.022 *
8. Rice Variety	-.068	-2.149	.033 *
9. Amount of rice production	6.793E-05	2.835	.048 *
10. Water sources used in rice production	.037	.556	.579
11. Farming experience	.004	1.227	.221
12. Exposure to media	-.130	-1.109	.269
13. Agricultural training/educational trip	-.006	-1.445	.150
14. Group membership	.026	.385	.701
Constant	2.164	8.937	.000
R² = 0.16; F = 2.624; Sig = 0.002			

Discussion

The results of the analysis on the need for organic rice production extension among farmers indicate only a moderate level of demand, which does not align with the established hypothesis. This outcome is primarily due to the limited support from relevant agencies—especially the District Agriculture and Forestry Extension Office, the Provincial Agriculture and Forestry Department, and the Agriculture Promotion Committee. These agencies have not provided sufficient training to local farmers on the processes involved in organic rice and crop production. There is still a lack of guidance and explanation to help farmers understand the benefits and importance of organic farming.

This finding is consistent with the study by Phutthisan et al. (2018), which found that the demand for the promotion of fruit trees among farmers in the Luang Nong Khieu Development Center area, Chiang Mai Province (Thailand), was at a moderate level. Similarly, Phuangsiri (2009) studied the needs of vegetable farmers in Dan Mak Kham Tei District, Kanchanaburi Province (Thailand), and concluded that agricultural extension workers should provide education on organic farming, along with financial support and opportunities for production.

Atthalapee (2013) examined farmers' needs regarding the operation of service centers for transferring agricultural technology in the Non-Sing River area, Pa Mok District, Ang Thong Province. He suggested that effective operation requires collaboration with agricultural volunteers and relevant agencies to provide continuous, modern, and appropriate knowledge and technology transfer to farmers. Additionally, access to water sources that farmers can divert for use in their fields is crucial.

Thalumparng (2012) investigated the needs of rice farmers regarding production promotion in Tha Mai District, Chanthaburi Province. The study recommended that the Ministry of Agriculture organize mobile units to educate farmers on proper rice harvesting techniques.

From the analysis of factors influencing the need for organic rice production extension among farmers in Savannakhet Province, four key factors were identified: land area, rice cultivation costs, rice varieties, and rice yield. These findings align with the established hypothesis.

The research suggests that since rice production requires a significant amount of land, farmers are cautious in changing production methods due to land ownership limitations. This is consistent with the findings of Kongkeo (2010), who reported that land area was associated with farmers' compliance with organic rice cultivation standards in Sangthong District, Vientiane Capital. Similarly, Natthavut (2009) found that land tenure influenced farmers' decisions to adopt organic rice production in Pathum Thani Province (Thailand).

The cost of rice cultivation also impacts the need for organic rice extension services. Since agricultural production inherently involves costs, farmers with limited budgets must carefully consider any changes to their production model. This is consistent with Natthavut's (2009) findings on the influence of cultivation costs on organic rice production decisions.

Rice varieties affect the demand for organic rice production extension because the availability of high-quality varieties can enhance yield. This aligns with the study by Pattana et al. (2012), which found that access to high-quality organic rice varieties influenced farmers' acceptance of organic rice production in northern Thailand.

Lastly, rice yield itself plays a significant role in driving the need for organic rice production extension. Higher yields serve as a strong incentive for farmers to transition to organic farming, especially since organic

rice commands a higher market price than conventional rice. This supports the findings of Pornpratansombat et al. (2011), who concluded that rice yield affects farmers' acceptance of organic rice cultivation in northern Thailand.

Conclusion

This quantitative study examined the needs for organic rice production extension among farmers in four districts: Champhone, Songkhone, Xayphoothon, and Xayboury in Savannakhet Province. The research aimed to assess both the level of need and the factors influencing farmers' interest in adopting organic rice farming practices. The findings indicate that farmers generally exhibit a moderate level of need for organic rice production extension across all evaluated dimensions. Key factors significantly influencing this need include the amount of land, rice production costs, types of rice varieties used, and the amount of rice production. These results suggest that effective extension strategies must consider these variables to enhance adoption rates and tailor support mechanisms that align with farmers' practical and economic conditions.

Recommendation

Based on the study results, the researchers make the following recommendations:

1. The findings indicate that farmers currently exhibit only a moderate level of need for organic rice production extension. To increase this need, relevant agencies: particularly the agricultural extension Committee, the provincial department of agriculture and forestry (PAFO), and the district agriculture and forestry office (DAFO) should enhance their support efforts. Field-level operations should include training programs to educate farmers on organic rice production methods and techniques for cultivating other crops within organic systems. These programs should also clearly communicate the benefits and growing importance of organic farming to improve farmer understanding and engagement.

2. The study shows that factors such as the amount of farmland, available capital, rice varieties used, and rice yield positively influence the need for organic rice production extension promotion. This implies that farmers with more land, greater capital, and higher production levels are more likely to need organic rice promotion than those with fewer resources. Therefore, while promotional efforts should aim for inclusivity, it may be practical to initially implement pilot projects with better-resourced farmers. Once success is demonstrated, the initiative can be gradually expanded to include other farmers in the region.

3. The study also reveals that the type of rice varieties used by farmers has a significant impact on their need for organic cultivation promotion. Farmers who already use improved rice varieties show greater interest in adopting organic practices. As a result, promotional programs should encourage the adoption of rice varieties that are well-suited to local conditions and offer high yields. In addition, agencies should introduce

and promote improved varieties to help farmers transition toward more productive and sustainable organic rice farming systems.

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