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Managing changes in payment systems and its effects on western economics

Doctoral (PhD) dissertation

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Managing changes in payment systems
and its effects on western economics

Dissertation to obtain a PhD degree

Written by:

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TABLE OF CONTENTS

10.13147/SOE.2025.11

LIST OF TABLES

LIST OF FIGURES

List of Abbreviations

ACH	Automated Clearing House
AI	Artificial Intelligence
A2A	Account-to-Account
AMEX	American Express
AML	Anti-Money Laundering
BACS	Bankers' Automated Clearing Services
BBVA	Banco Bilbao Vizcaya Argentaria
BIC	Bayesian Information Criterion
BIS	Bank for International Settlements
BTC	Bitcoin
CBDC	Central Bank Digital Currency
CHAPS	Clearing House Automated Payment System
CSC	Card Security Code
CVV	Card Verification Value
dApps	Decentralized Applications
DeFi	Decentralized Finance
ECC	Elliptic Curve Cryptography
EDA	Exploratory Data Analysis
EFTPOS	Electronic Funds Transfer at Point of Sale
EU	European Union
FATF	Financial Action Task Force
FinTech	Financial Technology
GDP	Gross Domestic Product
HDFE	High-Dimensional Fixed Effects
IMF	International Monetary Fund
IoT	Internet of Things
KYC	Know Your Customer
NFC	Near Field Communication
NPP	New Payments Platform
OLS	Ordinary Least Squares
P2P	Peer-to-Peer
PCI	Payment Card Industry
PCI DSS	Payment Card Industry Data Security Standard
PIN	Personal Identification Number
POS	Point of Sale

10.13147/SOE.2025.11

List of Abbreviations (Continued)

QR	Quick Response
RFID	Radio Frequency Identification
SEPA	Single Euro Payments Area
SWIFT	Society for Worldwide Interbank Financial Telecommunication
TAM	Technology Acceptance Model
2FA	Two-Factor Authentication
USA	United States of America
USD	United States Dollar
WDI	World Development Indicators

10.13147/SOE.2025.11

ABSTRACT

This thesis aims to analyse whether the variety of different payment systems impacts financial transactions and, consequently, changes consumer behaviour and global economics. Through a comprehensive literature review, quantitative analysis, and consumer survey, this research explores the relationship between payment system diversity, consumer choice, and financial behaviour. Findings reveal a positive correlation between the number of available cashless payment options and consumer adoption of digital transactions. This shift is shown to be significant across both developed and less-developed nations, where an increase in cashless transactions per 1,000 adults aligns with higher per capita GDP. Ease of use and convenience emerged as the most influential factors driving consumer preference for digital payments, underscoring the need for user-friendly app development. These results suggest that expanding and optimizing cashless payment systems could foster economic growth by simplifying consumer transactions and increasing financial inclusion. This thesis, therefore, recommends that developers and policymakers prioritize accessible, secure, and intuitive payment solutions to support the global trend toward a cashless economy.

i. INTRODUCTION

In every sphere of life, change is inevitable, especially in the shifting landscape of global economics and politics. This is particularly true for payment systems and the variety of possibilities currently available for conducting financial operations worldwide. Starting with the introduction of credit and bank cards, people can now pay with their phones, smartwatches, cryptocurrencies, and other digital means of payment. Some financial experts even believe that a digital revolution is taking place in banking and the entire financial industry, potentially leading to a cashless society and significantly impacting the global economy and the way transactions are conducted. Gąsiorkiewicz and Monkiewicz (2024) are among those who share this view.

According to Papadopoulos (2007), progress in technology is leading to new and improved electronic payment systems and revolutionary solutions for monetary transactions. Papadopoulos (2007) highlights that card payments provide significant value to customers by simplifying transactions, reducing reliance on cash, and consequently decreasing demand for cash-based payments. The author believes this shift may be a tipping point toward a cashless society. Costa Storti and De Grauwe (2001) also suggest that new internet technologies may reduce cash usage, potentially leading to a fully cashless system. They identify a key characteristic that a cashless system must meet to be considered truly cashless: the complete absence of coins and banknotes issued by the central bank, meaning no physical currency is in circulation. Fabris (2019) argues that all money could become virtual, with new money issued either by central banks or private institutions. The essential requirement for a cashless society is the removal of coins, notes, and checks from circulation so that virtual and digital currencies become the sole means of payment like it is happening in Sweden as described by the author.

According to the German Bundesbank, cash is defined as a payment method that allows holders to purchase goods and services while also serving as a store of value. The total amount of money issued by the European Central Bank stood at 15.83 trillion euros as of October 2024 (European Central Bank, 2024). Consumers consider cash a safe and highly convenient payment method for everyday transactions. It is universally accepted and does not present initial hurdles like debit or credit cards, which are sometimes rejected for small transactions or micropayments. Although the trend toward cashless payments is growing steadily, the German Bundesbank (2015) does not believe this will render cash obsolete.

Digital banking can nowadays also be integrated into social media such as Snapchat, Facebook, or X (formerly Twitter) for more customer reach. As found by McWaters et al. (2015), virtual banks like Fidor Bank, which is based in Germany, or mBank are actively focusing on implementing social media to offer more attractive financial products for their clients. In addition to that, mobile banking has evolved too, and virtual banks can offer customers services via apps such as photo bill payment, Peer-to-Peer (P2P) money transactions, online customer service, voice recognition, and much more (McWaters et al., 2015). Payment services such as M-PESA in Kenya have changed the way people pay in Africa as well (Musembi, 2024). These technological innovations are greatly reducing the need for physical money, such as bills and coins.

The trend towards cashless or digital payments is also noticeable in practice. According to Borzekowski, Kiser, and Ahmed (2008), in recent years, credit and debit card usage, as well as online banking, has grown a lot. The widespread use of smartphones and digital platforms has facilitated easier access to cashless payment systems such as mobile wallets, contactless cards, and online banking, which marks important steps towards a cashless society (Ibrahim et al., 2024).

Another big focus is consumer behaviour. According to King (2013), people get used to innovations, which means that new technologies are understood faster and used more frequently. Consumers also expect that new innovations will be introduced regularly. A good example of this is smartphones. Every year, hundreds of new models are introduced with even more features and technology than the previous ones. Ramayanti et al. (2024) underline this by stating that innovations in the payment sector accelerate consumer behaviour changes and open up new possibilities for consumers in their daily financial lives.

Banks, however, are not used to innovating quickly, states King (2013). Nowadays, people simply do not care if banks first have to comply with all regulations before even starting to create and innovate new financial services and products. With changing consumer behaviour and banks either not adjusting or not adjusting fast enough to this trend by changing their channels to more digital ones to meet customer demands and expectations, this leads to a loss of market share. As a result, non-banks like Apple, PayPal, P2P lenders, and even companies like Starbucks are taking advantage of this weakness by providing better solutions (King, 2013). This, in turn, leads to a decline in cash payments.

Additionally, mobile payment is of great importance nowadays and cannot be ignored. Fintechs can make money transfers a lot cheaper, allowing foreign workers to send money to their relatives without having to worry about high fees (Chishti & Barberis, 2016). Moreover, cash is not required for this transaction.

As an example, mentioned by Tapscott (2016), a foreign worker in the USA receives his monthly paycheck and spends a 4% fee to withdraw his money from a money mart. He then needs to go to a convenience store to wire it to his relatives in his less-developed home country. In doing so, he also has to pay additional costs for the transaction, exchange rate fees, and other hidden charges. This process is not very practical and is considerably costly, especially since no one in his family can open a bank account, making it the only way to transfer money to his relatives.

According to Demirgüç-Kunt et al. (2012) 2.5 billion adults worldwide do not have a bank account, which is a significant number. The reasons for not having a bank account include not needing one or being restricted from opening one due to factors such as distance, lack of credibility, unfamiliarity with paperwork, or simply not having enough money to afford or maintain a bank account. As outlined by Tapscott (2016), nearly 2.2 billion people survive on less than two dollars per day, yet they still need to transfer money. However, for traditional banks, servicing these populations is too costly, and they see no economic incentive to provide financial services to less-developed countries. Additionally, opening a bank account with little to no income is nearly impossible. Minimum fees associated with credit and debit cards are another reason why such micropayments remain unfeasible (Tapscott, 2016).

To sum up, it is evident that an ongoing digital revolution and transformation is occurring in the banking, financial, and monetary sectors, leading to significant changes in the global economy. The importance of cash and cash payments may be declining, though this needs to be further analysed and scientifically proven. It is also essential to understand whether a change in payment systems results in a shift in the global financial system and influences the trading behaviour of consumers and buyers. Furthermore, it is necessary to assess whether this transformation could be substantial enough to transition into a fully cashless system relying solely on electronic currency and digital banking.

In the current era of technological change, e-commerce has played a major role in the spread of the internet across the world. With these advancements, payment systems in the trading and business sectors have also evolved, shifting from hard cash to various digital payment methods

(Sumanjeet, 2009). Among these, credit and debit card transactions provide a convenient and secure way of conducting business in nearly every part of the world.

Previously, payment transfer systems had numerous flaws, particularly regarding large fund transfers between accounts and across locations. Traditional payment methods frequently encountered issues such as bounced checks, signature forgeries, and complications related to open cross-checks. However, electronic payment systems have introduced clear and secure solutions, allowing transactions to be conducted safely from anywhere in the world (Bouri et al., 2017).

Payment systems across the globe can be categorized into different types, which will be discussed in this chapter. Understanding these categories is crucial before delving into the assessment of payment processes, the technologies involved, and comparisons between different countries in the sequent chapters of this thesis.

ii. Previous research and research gaps

Globalization like we see it nowadays results largely from transformative technological advances. As such innovations in technology have reshaped the landscape of payment systems, advancing towards an increasingly digital economy and reducing the need for cash. These modern advancements have transitioned traditional payment methods into efficient, cashless systems that facilitate safer, faster transactions and streamlined access to funds. As a result, e-payment systems have achieved greater prominence compared to traditional cash-based approaches, offering a more practical and effective method for conducting financial transactions in the global market. Interestingly, in Nigeria, the online payment system has picked up prominence to the extent that customers have to do monetary exchanges without going to the banks. As a result, cash-based payment systems are gradually fading away, with credit-driven economies increasingly dominating modern financial systems. Of late, the online payment framework has also transformed into a quality that moved the fiscal elements on the profit side (Siyanbola, 2013).

Various investigations were done on the frameworks of web payment and improvement of the economy in the current time. Research shows that digital and cashless payment systems significantly drive economic growth, particularly in emerging markets, by fostering increased consumption and economic participation. For example, studies by the IMF and World Bank highlight that greater access to digital payments enhances financial inclusion, allowing more individuals to participate in formal economic activities and boosting GDP (Sahay et al., 2015;

Demirgüç-Kunt et al., 2018). Moreover, research from the European Central Bank and Moody's Analytics found that higher card penetration improves transaction efficiency, with emerging economies seeing especially pronounced impacts as they transition from cash to digital systems (Hasan et al., 2013; Zandi et al., 2013). These findings indicate that cashless systems not only streamline transactions but also foster robust economic growth by expanding access and increasing financial efficiency.

In like manner, World Payments Reports (2012) researched the state and progression of non-paper cash frameworks around the world and found out that non-money payments make it speedier for people and associations to buy items and undertakings, pushing money into the system faster and adding to the GDP.

There was mainly research conducted concerning the size of the banking industry. However as argued by (Čihák et al., 2012) it is not enough to measure only the banking sector in order to find out whether a country's financial system is working properly and if a change in the payment system results in a change in consumer behaviour. The financial industry alone does not provide data on quality, efficiency, and stability of a financial system.

Research on the potential replacement of cash by credit and debit cards, as well as checks, was conveyed by Humphrey (2004). Although a small decline in cash usage was identified in the 1970s, 1980s, and 1990s, the author suggests that cash is unlikely to be completely abolished. An analysis of household cash storage practices in several European countries was conducted by Stix (2013). More specifically, an investigation was undertaken to determine why individuals retain cash at home rather than depositing it in banks. Stix concluded that this behaviour is influenced by factors such as public trust in financial institutions, the impact of banking crises, and even personal experiences and memories. Stix's research indicates that cash is more likely to be retained and utilised in economies characterized by strong currencies, as is often observed in dollarized countries where foreign currencies may serve as an alternative store of value (Stix, 2013).

Another research on the impact of payment system diversity on consumer choice and cashless transaction adoption is still emerging, with several critical gaps remaining unaddressed and unexplored. Although existing studies highlight the role of digital payment systems in advancing financial inclusion and economic growth, they primarily focus on broad, macroeconomic impacts rather than specific changes in consumer behaviour in response to diverse payment options. Furthermore, not all can be researched due to different limitations and because of new and emerging payment methods and systems it is impossible to cover all of them and also fully understand consumer behaviour.

Several studies highlight the macro-level economic benefits of digital payments, particularly in emerging economies where digital infrastructure is rapidly developing. For instance, Hasan et al. (2013) and Sahay et al. (2015) found that increased digital payment adoption can enhance economic efficiency, boost GDP growth, and foster financial stability by providing secure, cashless alternatives. Similarly, Demirgüç-Kunt et al. (2018) emphasize how fintech and digital payment platforms significantly improve financial inclusion by enabling underserved populations to access financial services. This is especially helpful for Asian and African countries. However, these studies do not delve into how the number of payment systems directly influences consumer behaviour or preference for cashless transactions.

Further research on factors driving digital payment adoption tends to focus on elements such as technological infrastructure, convenience, and security (Hwang et al., 2021; Tam, 2007). Mallat et al. (2007) and Zhong et al. (2013) specifically examine consumer adoption patterns, finding that convenience and variety in payment options play a significant role in encouraging digital payments. Yet, these studies rarely isolate the impact of payment system diversity itself, instead analysing aggregated adoption trends without distinguishing how an increase in payment options affects individual consumer preferences.

Notably, studies that do touch upon the consumer response to payment diversity often focus on specific types of payment technologies, such as mobile wallets or peer-to-peer payment applications, rather than the collective impact of multiple payment systems. For example, Choi et al. (2020) explored consumer preferences between different mobile payment methods in South Korea but did not investigate whether the total number of available payment options influenced cashless adoption. Similarly, Lin et al., (2019) analysed the adoption of mobile payment applications in South Korea and China, focusing on convenience and transaction speed without examining the effect of diverse payment systems.

Further, there is a research gap in the field of how demographic variables and factors intersect with payment diversity to impact cashless adoption. Studies like those by Hussain et al. (2024) and Linh et al. (2024) show that demographic elements such as income, age and geographic region have significant influences in digital payment adoption. Yet, research has not comprehensively examined how these factors interact with the diversity of payment systems in shaping cashless transaction trends. For instance, it remains unclear if consumers in emerging markets, who have historically relied on cash, might be more responsive to an increased variety of digital payment systems than their counterparts in developed markets. This is of course dependent on multiple factors.

This dissertation has the goal to research whether a change in payment systems and new payment methods accelerates the move towards a cashless society and transforms the global economy with its international relations. This will fill the currently existing research gap and provide new findings and understanding of the topic. This will be achieved by conducting a detailed literature review for this specific topic which will be then analysed with various statistical models using quantitative data. Also, the digitalisation of money and the trend to pay cashless is not only limited to a region as we live nowadays in a globalised world. Therefore, this thesis can provide new insights and new knowledge in this sphere for individuals, consumers, banks, and governments. Moreover, the financial sector is internationally integrated and closely connected to financial centres such as London, New York, Hong Kong, Frankfurt, Tokyo. In this regard this work will benefit retail banks, retail clients, individuals, banks, central banks, and governments as to how they should deal with digitalisation of money and the possible shift to a cashless society and because of that possibility react to this trend. This will benefit the set-up and preparation for future global world trade and international economics.

In summary, while the macroeconomic and individual factors influencing digital payment adoption are well documented, there is a distinct research gap in exploring the direct impact of payment system diversity on consumer preference and choice. Specifically, there is a need to understand how the availability of multiple cashless payment options influences consumer behaviour in varying socioeconomic contexts and demographic segments, and how these factors collectively shape the broader transition to cashless economies. The following dissertation aims to fill the current research gap by focusing on how an increase in the number of payment systems influences consumer behaviour and the adoption of cashless transactions.

iii. Research question

This dissertation aims to research and analyse whether the number of different payment systems impacts financial transactions and thus influences consumer behaviour and global economics. The dissertation will provide new insights and results by conducting a detailed literature review, performing quantitative calculations and analyses, as well as conducting a tailored survey for this topic.

This leads to the following research question:

Do changes in the number of payment systems used to conduct financial transactions impact consumer preference and choice, thereby leading to an increase in cashless transactions?

Hypothesis 1: The more payment systems are implemented and the greater the choice, the more likely consumers are to conduct cashless transactions.

Hypothesis 2: Only a handful of payment systems account for the majority of cashless transactions.

Hypothesis 3: The shift from cash to cashless transactions has a measurable impact on GDP.

To answer this question and systematically prove or disprove the hypotheses using scientific methodology, the structure of the dissertation will be as follows.

First, different payment systems within financial systems will be described, and methods to measure financial transactions will be identified and explained. Existing literature will be reviewed to provide a thorough literature review. Furthermore, the concept of a cashless society will be outlined, and current payment methods will be described.

The first half of the second part of the dissertation will focus on the conducted survey and the analysis of quantitative data. A regression analysis will be performed to build a statistical model that addresses the research question and tests Hypotheses 1, 2, and 3. Quantitative data collected from the IMF, World Bank, and other credible sources will also be utilised.

The second half of the second part will present a comparison between the findings of this study and the results of the previously conducted literature review, along with global trends and statistics. Additionally, it will be examined how the number and implementation of payment systems can be managed to execute financial operations as efficiently as possible while maximizing customer satisfaction. Hypotheses 1 and 2 will be re-evaluated using the gathered data, and additional statistical hypotheses will be tested. This will result in recommendations and a discussion on the effects of these findings on global trade and economics.

The final part of the dissertation will summarize the outcomes and provide a prediction for the future.

iv. Methods

To conduct profound research, a detailed literature review will be undertaken. The idea behind a cashless society will be defined, described, and outlined to which extent it is possible to achieve. It will be explained what the different payment methods are and which influence they have on the global economy and international trade. Major payment systems for a transition towards a cashless society will be defined and researched. Qualitative research will gain real-life insights from financial parameters and trends in economics, while a survey will provide a detailed consumer perspective on payment systems and preferences. Quantitative research, using regression analyses in R and Stata, will determine which payment systems influence the speed of transitioning to a cashless society and whether changes in the cash system and payment methods significantly impact global economics, international trade, or GDP.

The literature review will use databases like EBSCO, ABI-INFORM, Business Source Premier, Science Direct, WISO, and relevant journals, articles, and books. A consumer survey will offer real-world insights into the influence of digital or electronic money on cash and the financial system. Suitable statistics will be analysed to answer the research question. Limitations include the inability to cover all innovations and financial disruptions, with a focus on Europe and the US as representative regions due to globalization and economic interconnectivity.

A mixed-methods approach will integrate qualitative insights from literature with quantitative data from a 22-question multiple-choice consumer survey capturing payment preferences and attitudes towards a cashless society. Multiple-choice questions offer ease of analysis (Rosenthal, 2016), increased response rates (Fowler, 2013), reduced bias (Dillman, et al., 2014), and consistency across responses (DeVellis, 2021). Quantitative research will employ regression analysis using data from IMF, Worldbank, and other credible sources, analysed in Stata. The survey will provide empirical evidence to test hypotheses, while regression analysis will assess the transition to a cashless society based on payment systems and customer preferences, building a statistical model. Mastercard Advisors (2014) criteria accessibility to financial services, macroeconomic and cultural factors, merchant scale, competition, technology, and infrastructure will be used in the regression analysis to address the research question and hypotheses.

v. Limitations and expected challenges

The chosen topic examines changes in payment methods and electronic money, with a specific emphasis on cashless transactions and their impact on the global economy and international trade. A potential challenge may be the availability of sources and data to substantiate the argument. However, this is unlikely given the substantial research already conducted on payment systems. Furthermore, current data and statistics are sufficient to comprehensively analyse the topic and address the research question. Another limitation is that much of the existing literature originates from the United States, though relevant studies on cash management and usage have also been conducted in Europe, Africa, and Asia. Additionally, the global COVID-19 pandemic may have significantly influenced consumer behaviour since 2020. Therefore, data from all relevant years will be carefully analysed to identify any "COVID effect," which may represent a time-limited phenomenon.

Given the length constraints of this thesis, it will not be feasible to cover all new digital financial solutions and payment systems impacting the shift towards a cashless society and their effects on global trade and economics. While Big Data topics will not be explored in depth, connections will be established to provide a comprehensive perspective and support the overall argument. Similarly, covering every regulatory issue related to cashless transactions, including ethical and regulatory considerations surrounding FinTech and banking, will not be possible due to space limitations.

Interpreting the findings accurately and answering the research question effectively may be challenging, particularly as new academic literature and scientific articles on this subject are published regularly. The potential influence of COVID-19 on consumer behaviour will be closely examined, as well as regional differences in bank policies, cash policies, and currencies, which may restrict findings to specific areas. However, this limitation will be addressed by using a diverse range of sources to ensure that findings are broadly applicable across different countries, regions, and economies. Another challenge will be to precisely identify and evaluate the most significant, frequently used, and high-potential payment systems likely to gain further acceptance and development.

This thesis aims to provide the necessary analytical tools to understand changes in payment methods and to accurately identify these systems, ultimately bridging a gap in the existing research and effectively answering the research question.

CHAPTER 1: CATEGORISATION OF PAYMENT SYSTEMS

In the current era of technological change, e-commerce is one of the most popular services involved in the propagation of the internet throughout the world. With these technological advancements, payment systems in the trading and business world have also evolved, shifting from hard cash to various modes and methods (Sumanjeet, 2009). Among these payment types, credit card and debit card transactions are convenient and secure ways to conduct business globally. On top of that, with the introduction of NFC technology, paying at points of sale has become even more convenient and effortless. Before this, the payment transfer system had many flaws, particularly regarding the transfer of large sums between accounts or locations. In traditional payment transaction methods, issues such as bounced checks, signature similarities, and complications related to open cross-check holders were frequent challenges. However, electronic payment modes now provide precise and secure methods for transactions across the globe (Bouri et al., 2017). The payment systems around the world can be categorized into the following types, which will be discussed in this chapter. It is vital to understand these categories before proceeding with the assessment of the payment process, its functionality, the technologies involved, and comparisons among different countries in the subsequent chapters of this thesis.

1.1 Physical cash

Consumers have plenty of low-stream transactions every month and on a regular basis. As such they do always face the decision of paying by cash or by any other means of payment is their preferred means of payment. Depending on the value to deicide to use cash for a payment is usually dictated by its value. As such around 33% of the average consumer's regularly scheduled payments are lower than $10, and consequently the typical consumer utilises cash for 66% of these, let's call them "micro" transactions. If the amount to be paid exceeds $10 but is lower than $50 consumers also use cash for 50% of these kinds of transactions (Bennett et al., 2014). Bagnall et al. (2016) found out that the number of all cash transactions even exceeds 50% and is between 46 and 82% overall. This points to a conclusion that cash is widely popular among the population even if it may seem different from time to time. Arango-Arango et al. (2018) add that cash is the primary means of payment because of its costs as compared to credit or debit cards as well as to other solutions. Indeed, consumers usually have to pay a fee for having a debit or credit card, as well as for different other payment solutions which are sometimes commission based. With cash these expenses are literally zero for. The consumer hence it is for him economically more beneficial to use instead of a maybe more modern but also more expensive digital form of payment.

1.2 Credit card

Credit is one of, if not the most, popular payment methods used online. Previously, there were some security issues regarding credit cards, but later, it regained the trust of customers through secure transaction details. The wide acceptance of credit cards is one of the main reasons that contribute to the extensive use of its features. The most advanced and far-reaching feature of credit cards is that their use is convenient for performing transactions online worldwide within a limited period (Dyhrberg, 2016). It does not require any hardware or software to perform the required action. The authentication of the card owner relies on the card's taped number, owner's name, and expiry date. However, to keep users' information safe, other contingency systems have been developed, such as MasterCard and Visa codes by card companies. When using this payment method, users are provided with a secure password to enter during shopping transactions, ensuring added security (Khan et al., 2017).

1.2.1 Credit card tiers

There are various credit card tiers, contingent upon the card issuer or organisation. For instance, Visa offers Visa Gold, Visa Infinity, and Visa Platinum. Besides this, there is American Express, or AMEX, for the US market and the notoriously famous AMEX Black card, which has no limit regarding expenses. Each card has its own various advantages, from fundamental features like zero-liability to advanced features like 24/7 concierge services (Baker, 2006).

When accepting credit cards, merchants typically have to pay a fee, which varies by credit card type. Usually, there is a tiered rate structure that merchants agree to, meaning they pay higher fees for accepting premium cards compared to standard cards. Merchants have limited control over the type of card a customer chooses to pay with, and banks actively promote these premium cards to their clients. To at least partially offset the cost of rewards offered, banks charge merchants higher transaction fees for these cards and often impose an annual fee on the cardholder for the benefit of earning rewards (Degennaro, 2006).

1.2.2 CVV

The Card Verification Value (CVV) or Credit Card Security Code (CSC) usually consists of a 3- or 4-digit number, which can be found on the back of a credit or debit card. Vendors can demand the CVV/CSC number from card owners as an approach to reduce fraudulent transactions and verify the identity of their client. The CVV/CSC number is typed in by the client and processed over a secure gateway to authorise the card when the payment is fulfilled or when a payment strategy is renewed. Payment Card Industry guidelines (PCI) prohibit the storage of this data to prevent it from being stolen or hacked by others (Banerjee, 2004).

1.3 Debit cards

Debit cards are also gaining ground and popularity among customers daily and are now the best cashless payment method. In comparison to credit cards, all payments made through debit cards are deducted from the consumer's or owner's personal account, not from an intermediary account. This is why users typically have no disputes when handling payments from their personal accounts. To make debit card payments, only the account number is necessary. There is a massive customer pool for debit cards in many countries, but business-to-business account transactions on websites satisfy international consumers. The cost of incurring transactions is lower compared to credit cards. However, they can also be used for very small micropayments. Due to the extensive demands of banking systems, they are far more secure than credit cards (Bouri et al., 2017).

1.3.1 Pin debit

PIN debit cards depend on electronic approval of each transaction, and all debits are reflected in the client's record immediately. The transaction is performed using a PIN selected or chosen by the card's owner. PIN debit networks include Star, Nyce, Pulse, AccelExchange, and others. In addition, there may be various PIN debit networks inscribed onto a debit card, and the logos for each organisation are situated on the backside of the corresponding debit card (Khan et al., 2017).

1.3.2 Signature debit

Signature debit cards are typically issued by banks or financial institutions that cooperate with Visa or MasterCard. These are marked cards connected to a financial account and require the cardholder's signature when making a payment, like a credit card. Although debit exchange is much less popular than credit trade, vendor account suppliers typically provide signature debit acceptance at a similar cost to the merchant, and many merchants are not entirely aware of the distinction. Payment with signature debit often takes 2 or 3 days to clear the client's record adjustments. Similarly to debit cards, signature debit cards carry the logo of the card network (e.g., Visa, MasterCard, AMEX) on the front of the card. A signature logo must also be on the backside of every debit card (Evans & Schmalensee, 2004).

1.3.3 Mobile payments

According to Khan and his colleagues (2017), payments made through wireless or mobile phones are offered to reduce fees, such as for transactions, as well as to enhance the security of online payments and make them more convenient. Technologies like these have facilitated global business by understanding customers and their needs through extensive data collection. The remarkable growth of mobile payment methods is applicable internationally. Mobile payment methods can be used for offline and online micropayments very easily. Smartphones are very popular among users these days. Hence, online businesses are increasingly offering this payment method as standard. It reduces transaction fees, and users can view their account details from home more securely (Khan et al., 2017).

For mobile wallets, it is noted that they operate similarly to traditional wallets by enabling users to store various digital assets, such as coupons, cash, cards, and receipts, on their smartphones (Doan, 2014). This functionality enhances convenience and streamlines transactions for consumers.

1.4 Electronic cash

During the early stages of the development of online payment systems, electronic payment solutions such as CyberCash and DigiCash were introduced. However, these systems quickly became obsolete due to limited acceptance and lack of widespread adoption (Ahmed & Molinuevo, 2023).

Currently, smart card-based systems are widely used by organisations for micro or smaller payments. However, smart cards also depend on certain factors, such as the user and specific hardware for verification and usage. In addition to smart cards have been established. These systems utilise electronic tokens or preloaded cards, which represent certain monetary values and can be exchanged for physical cash. Moreover, electronic payment methods are now widely accessible in mobile environments as well. Numerous smartphone applications, particularly on Android devices, such as Ngpay and Paytm, provide online payment services, enabling users to conduct transactions conveniently from their mobile devices (Masihuddin et al., 2017).

1.5 Cryptocurrencies via Blockchain Explorer Services

In 2009, the introduction of Bitcoin, an encoded digital currency, set off another wave of money-related upheaval. Cryptography, peer-to-peer (P2P) networks, agreements, calculations, and blockchain technology were combined into digital cash like Bitcoin. Bitcoin has been the most prominent digital currency over the Internet (Nakamoto & Satoshi, 2008). Bitcoin applies numerous advancements, which can be broadly divided into four blocks of the wallet address. These four blocks are Bitcoin transactions, signature/broadcast, blockchain technology, and decentralised records, respectively. Bitcoin is perhaps the most common application utilising blockchain technology (Crosby et al., 2016).

1.5.1 Structure

The structure of a blockchain is typically divided into block headers and the transactions within each block, ensuring the system's security and integrity. The block header includes key metadata that supports blockchain operations, starting with the block version, which identifies protocol compatibility as the system evolves (Nakamoto, 2008). Another crucial element is the parent block hash, which links each block to its predecessor, making it practically impossible to alter previous records without recalculating all subsequent block hashes (Dai, Zheng, & Zhang, 2019). The Merkle root, derived from transaction hashes, enables efficient verification of the entire transaction set within a block, allowing nodes to validate transactions without processing all stored data (Narayanan et al., 2016). The timestamp records the exact creation time of the block, helping to maintain chronological integrity, whilst the difficulty value sets the proof-of-work target, controlling the rate at which new blocks are generated (Antonopoulos, 2014). Together, these components in the block header work with transaction data to ensure both transparency and security in decentralised systems, fostering trust without central control (Catalini & Gans, 2016).

1.5.2 Bitcoin

Bitcoin, one of the most well-known cryptocurrencies, was designed as a digital currency to enable secure, anonymous payments without the need for government or bank intermediaries. Its adoption has garnered attention across financial and technological sectors due to its unique, decentralised structure. Unlike traditional payments, Bitcoin transactions leverage blockchain technology, which offers benefits like lower transaction costs, faster processing, and increased privacy (Narayanan et al., 2016). However, Bitcoin's structure also introduces unique risks, including limited consumer protections, regulatory uncertainty, and volatility, which may hinder its widespread adoption as a standard payment method (Demertzis & Wolff, 2018).

Despite the cryptocurrency's ongoing popularity, its actual market penetration remains limited, with its future role in finance still under debate. Following notable growth in 2013 and 2014—during which over 64,000 businesses worldwide began accepting Bitcoin—the collapse of the prominent exchange Mt. Gox, involving the loss of nearly $500 million, highlighted the high risks in this emerging market. This collapse underscores the complex blend of opportunity and risk Bitcoin represents (Narayanan et al., 2016).

Bitcoin's monetary model involves cryptographic validation and incentives for users who participate in transaction verification, with a fixed supply capped at 21 million bitcoins. This design aims to introduce a deflationary aspect to its value, as the finite supply is expected to be reached by 2140, encouraging long-term scarcity and value preservation (Antonopoulos, 2014; Morillon, 2021).

Recent research on Bitcoin has highlighted its increasingly complex integration into both traditional financial markets and emerging digital ecosystems. The growth of decentralised finance (DeFi) has positioned Bitcoin not only as a speculative asset but also as collateral and a medium for decentralised lending and borrowing (Shah et al., 2023). Additionally, regulatory developments worldwide indicate a trend towards more structured oversight, aiming to stabilise Bitcoin's volatility and address potential risks related to financial stability and consumer protection (Ferreira & Sandner, 2021). The proliferation of institutional investment has added legitimacy to Bitcoin, with organisations like Tesla and Square incorporating Bitcoin into their balance sheets, which has contributed to its price stability and mainstream acceptance (Santos-Alborna, 2021). These recent shifts underscore Bitcoin's evolving role in global finance, moving beyond early usage as an anonymous transaction tool to becoming a foundational element in the broader digital asset market.

1.5.3 Bitcoin Cash

Bitcoin Cash (BCH) was created through a Bitcoin (BTC) hard fork in August 2017, in response to Bitcoin's transaction capacity issues and rising fees. With a block size limit initially set to 8 MB (compared to Bitcoin's 1 MB), BCH aimed to accommodate higher transaction volumes, supporting faster, lower-cost payments, which were key goals to make cryptocurrency more feasible for everyday use (Poon & Dryja, 2016). BCH has since become popular amongst users seeking a more scalable Bitcoin alternative, though this larger block size requirement has its own trade-offs, such as increased storage and bandwidth needs for nodes, which some argue may reduce network decentralisation over time (Croman et al., 2016). Additionally, the BCH fork introduced the "Emergency Difficulty Adjustment" (EDA), allowing it to adjust mining difficulty quickly in response to fluctuating mining activity. This is regarded as a feature intended to stabilise transaction processing times but can also cause swings in miner behaviour between BTC and BCH based on profitability (Narayanan & Clark, 2017).

1.5.4 Ethereum

Ethereum is a decentralised platform established in 2013 by software engineer Vitalik Buterin. Known for enabling blockchain-based smart contracts, Ethereum allows developers to build decentralised applications (dApps) on its blockchain, using Solidity as the primary programming language. Smart contracts on Ethereum are automated pieces of code that execute transactions without intermediaries, aiming for secure, transparent digital agreements (Antonopoulos & Wood, 2018). The Ethereum network rewards miners with Ether, its cryptocurrency, which is earned by validating new blocks added to the blockchain approximately every 15 seconds. Since its launch, Ethereum has experienced significant market interest and volatility, notably during the development spikes in 2016 and 2017, reflecting the platform's innovation-driven growth within the cryptocurrency ecosystem (Fry, 2018).

Ethereum offers key advantages, primarily through its support of smart contracts, which allow for self-executing, tamper-proof agreements that reduce the need for intermediaries (Antonopoulos & Wood, 2018). It also enables decentralised applications (dApps), providing enhanced security, censorship resistance, and transparency by operating on a peer-to-peer network (Buterin, 2014). Ethereum's flexibility and interoperability allow various applications to connect on the same blockchain, fostering innovation in areas like decentralised finance (Zheng et al., 2018). Moreover, Ethereum's ERC-20 and ERC-721 standards support the creation of tokens, fuelling digital asset markets and DeFi projects (Werbach, 2018).

In conclusion, the ongoing evolution of payment systems in the digital age highlights the convergence of technology, security, and consumer convenience, profoundly transforming global commerce. Traditional cash payments are gradually being replaced by electronic systems, such as credit and debit cards, mobile payments, and digital wallets, each offering enhanced security and ease of use (Sumanjeet, 2009; Khan et al., 2017). Advances in mobile payment technology, including NFC and app-based wallets, have made transactions faster and more accessible, aligning with consumer demand for efficiency and flexibility (Doan, 2014). At the same time, cash remains relevant for low-value transactions, especially in contexts where electronic payment options are less accessible (Bennett et al., 2014; Bagnall et al., 2016).

Cryptocurrencies like Bitcoin and Ethereum represent the latest phase in the payment system's evolution, introducing decentralised, peer-to-peer digital currencies that challenge traditional banking structures. Built on blockchain technology, cryptocurrencies offer secure, transparent transactions, appealing to consumers who prioritise privacy and control over intermediaries. Whilst cryptocurrencies promise cost efficiency and global accessibility, they also introduce challenges related to price volatility and regulatory uncertainty, which could limit their adoption as mainstream payment options (Nakamoto, 2008; Narayanan et al., 2016). However, the adoption of cryptocurrencies and blockchain continues to grow, driven by innovations in decentralised finance (DeFi) and institutional interest in digital assets, which are adding legitimacy and stability to this sector (Shah et al., 2023; Santos-Alborna, 2021).

Overall, the future of payment systems lies in balancing traditional financial models with emerging digital technologies, from electronic payments to blockchain-driven solutions. Businesses and consumers alike will need to adapt to these advancements to benefit from enhanced convenience, security, and global accessibility in financial transactions. The trajectory of these payment systems points to a continued shift towards a more interconnected, technology-driven global economy (Zheng et al., 2018; Antonopoulos & Wood, 2018).

CHAPTER 2: TECHNOLOGY AND ONLINE PAYMENT GATEWAY MODELS

In today's digital era, online shopping has surged in popularity, and electronic payment systems benefit both merchants and consumers by providing a secure, efficient transaction process. For online transactions, a payment gateway serves as an intermediary between the merchant's website and financial institutions, facilitating the transfer of funds and ensuring security and reliability (Lowry et al., 2006). Payment gateways play an essential role in online commerce, integrating various stakeholders, such as banks, payment processors, and e-commerce platforms, to enable seamless and secure transactions (Sanchez & Rodriguez, 2020). This infrastructure is crucial, as it reassures customers about the safety and dependability of online transactions, providing encryption and authentication protocols to protect sensitive information throughout the payment process (Oguta, 2024).

2.1 Online gateway model

An E-commerce Payment Gateway is a critical component of the online transaction infrastructure, ensuring secure and efficient handling of payments. Acting as a bridge to the banking network, every online transaction must be processed through a payment gateway. This gateway routes and verifies payment details in highly secure environments, facilitating encrypted exchanges of transaction information from the buyer's device to the bank for verification and authorisation (Olanrewaju, Khan, Mattoo, Anwar, Nordin, & Mir, 2017; Hassan, Shukur, & Hasan, 2020). Once the payment is approved, the gateway sends confirmation to the merchant, completing the transaction and assuring both the buyer and seller of its security. Internationally recognised payment gateways offer flexibility, enabling businesses to conduct transactions securely across borders (Khan et al., 2017).

A Payment Service Provider (PSP) is an organisation that facilitates online payment transactions by providing essential tools and infrastructure for processing payments. Common PSPs used worldwide include popular options such as Braintree, Stripe, PayPal, and Authorize.Net, amongst others. Additional providers like 2CheckOut, Dwolla, and Worldpay offer specialised services, whilst companies like American Express (Serve) and Google Wallet provide secure, branded payment solutions (Niranjanamurthy et al., 2014).

When choosing a Payment Gateway, key factors to consider include compatibility with various card types, transaction fees, support for recurring billing, and structural compatibility with the business's platform. These factors vary across providers, making it essential for businesses to evaluate each PSP based on security, cost-effectiveness, currency support, and customer service capabilities to ensure they align with the company's requirements and budget (Khan et al., 2017).

2.2 System developments

Technological progress has reshaped traditional payment methods into efficient, cashless systems that enable safer and faster access to funds. This shift has made electronic payment systems increasingly preferable over cash-based methods, providing streamlined and secure options for financial transactions. In Nigeria, for example, digital payments have gained popularity, with consumers now conducting transactions online rather than visiting physical banks, reflecting a broader shift from cash to a credit-dominated economy (Siyanbola, 2013).

Recent studies highlight the positive economic impacts of digital payment adoption on emerging markets. Aguilar et al. (2024) found that credit-only payment systems are linked to accelerated economic growth when digital transactions replace traditional cash payments. Similarly, Aker et al. (2016) identified how systems like M-PESA in Kenya have increased transaction speed and economic inclusion. The World Payments Report (2012) supports this, noting that non-cash transactions simplify and expedite commerce for individuals and businesses, accelerating cash flow and contributing to GDP growth. These findings illustrate how digital payment systems are not only enhancing consumer convenience but also driving broader economic advancement by modernising transaction processes globally.

2.3 Technologies used for mobile payments

Mobile payment technologies and models vary across countries, catering to regional preferences and infrastructure. In China, Near Field Communication (NFC) and QR codes are the dominant technologies. NFC was initially introduced to the Chinese market in 2006 when Nokia launched a pilot NFC-based payment system. Following this, major Chinese mobile operators, financial institutions, and mobile device manufacturers developed their own NFC payment platforms, each with distinct technological features and business models. NFC is valued for its security, compatibility with existing financial infrastructure, and ease of use, making it a promising technology for mobile payments (Pal et al., 2015).

Despite the global popularity of NFC in places like South Korea, Japan, and the United States, QR codes have overtaken NFC in China as the leading mobile payment technology. Alibaba first introduced QR technology to mobile payments in China in 2011, integrating it with ALIPAY, a move that catalysed widespread adoption (Shen et al., 2020).

2.3.1 NFC (Near Field Communication)

Near-Field Communication (NFC) technology enables secure, short-range communication between two devices through electromagnetic induction at a frequency of 13.56 MHz. Similar to Radio Frequency Identification (RFID), NFC transmits data stored in a small chip or tag, which activates upon nearing a compatible reader. This contactless technology allows data exchange within a range of a few centimetres, making it particularly useful in settings that require fast and secure interactions, such as payment systems (Haselsteiner & Breitfuß, 2006).

NFC technology is commonly integrated into EMV-enabled credit cards (Europay, Mastercard, and Visa) and smartphones, providing a streamlined, contactless payment method. EMV is a global standard for credit and debit card security, which uses embedded microchips to store and protect cardholder data. Unlike traditional magnetic stripe cards, which need physical swiping, NFC allows data to transfer without contact, enhancing convenience and security. The NFC-enabled microchip embedded in EMV cards supports a fast, secure transaction process by authenticating payments directly with the retailer's point-of-sale system, often in less time than it takes to process an EMV chip transaction. This quick, contactless process is particularly beneficial for reducing wait times at checkout, making NFC an ideal choice for high-traffic environments like retail (Patel et al., 2024). However, whilst NFC transactions are faster than EMV chip exchanges, they maintain rigorous security protocols to ensure safe data handling and reduce the risk of fraud.

2.3.2 QR codes

Quick Response (QR) code technology is a type of two-dimensional barcode that consists of black modules arranged in a square on a white background. Developed by the Japanese company Denso Wave in 1994, QR codes were initially intended for fast inventory tracking, but they have since become popular in mobile payment systems due to their simplicity and versatility (Gu & Zhang, 2011). QR code-based mobile payment systems typically involve three parties: the consumer, the merchant, and a third-party payment server.

Mobile payment via QR codes operates in two main ways: active scanning and passive scanning. In active scanning, the consumer scans a QR code displayed by the merchant, initiating the transaction from the consumer's mobile device. In passive scanning, the consumer presents a QR code generated on their mobile device, which is scanned by the merchant to complete the payment (Zhu et al., 2016). QR-based systems are popular due to their ease of use, requiring only a smartphone camera and app, and do not depend on specialised hardware. They also provide varying levels of security, often using encryption and tokenisation to protect transaction details (Jenifer et al., 2025).

2.3.3 Functioning of payment process – buyer to merchants

To accept credit and debit card payments, a merchant must set up a merchant account through an acquiring bank. An acquiring bank, or "acquirer," is a financial institution registered with credit card networks (like Visa or MasterCard) that handles transactions on behalf of the merchant, processing payments made by customers with credit or debit cards (Dubinsky, 2019). The acquiring bank issues a unique merchant account number for the merchant, which acts similarly to a traditional bank account but is used exclusively for processing payments and transferring funds from card transactions (Mann, 2023).

When a customer makes a purchase using a card, the merchant sends the transaction details to its acquiring bank. The acquirer then submits the payment request to the credit card network, which forwards it to the customer's issuing bank. The issuing bank either approves or declines the transaction based on factors like available funds and security checks. If approved, the issuing bank bills the customer and sends funds to the acquiring bank, which deposits them into the merchant's account, minus any applicable fees (Hayashi & Bradford, 2018). For digital wallets (e.g., Google Pay, Apple Pay, or Visa Checkout), the transaction first goes through the wallet provider before reaching the payment processor, allowing for secure and fast data transfer.

The entire process involves multiple parties, including card networks, issuing banks, and, if applicable, digital wallet providers, each playing a crucial role in ensuring a secure and reliable payment experience for both the customer and the merchant.

2.4 Comparison of payment gateways

2.4.1 Electronic funds transfer at point of sale (EFTPOS)

Electronic Funds Transfer at Point of Sale (EFTPOS) systems facilitate digital fund transfers directly at payment terminals, enhancing transaction speed and security. EFTPOS, widely adopted since its introduction in the U.S. in the 1980s, allows consumers to use debit and credit cards at points of sale for seamless payments (Shy, 1996). In Australia and New Zealand, EFTPOS has also become a brand synonymous with this payment system due to its extensive adoption (Singh & Zoppos, 2004). Initially, separate EFTPOS networks created compatibility issues, slowing adoption amongst retailers. However, standardisation efforts enabled broader use, and international networks like Visa and Mastercard now support EFTPOS transactions globally (Gold, 2014). Although national interbank models vary, major credit and debit cards can now be used internationally, streamlining EFTPOS access in most developed countries.

2.4.2 Clearing houses

Clearing houses play a critical role in the financial system by serving as central counterparties in trade settlements, reducing credit risk amongst market participants. They stand between buyers and sellers in transactions, ensuring performance and settlement even if one counterparty defaults, thus strengthening market stability (Pirrong, 2011). This function is essential in high-risk trading environments, where novation processes, through which the clearing house legally replaces the original trade counterparties, mitigate counterparty risks (Duffie & Zhu, 2011). Clearing houses conduct daily mark-to-market activities and net settlements, further supporting the reliability and efficiency of financial markets (Bank for International Settlements, 2017).

2.4.3 Banking services – SWIFT

The Society for Worldwide Interbank Financial Telecommunication (SWIFT) is a global financial messaging network that enables banks to securely exchange payment information. Although SWIFT does not transfer funds directly, it sends standardised payment orders, facilitating international transactions amongst more than 11,000 institutions worldwide (SWIFT, 2024). SWIFT has become essential for international banking, providing secure communication channels that increase transaction speed and accuracy. Recently, the SWIFT Global Payments Innovation (gpi) service has introduced real-time tracking and transparency, significantly enhancing the cross-border payment experience for banks and their clients (Cecchetti & Schoenholtz, 2020).

As such, the EFTPOS system, clearing houses, and SWIFT illustrate the diversity of modern payment infrastructure. EFTPOS enables efficient retail payments, clearing houses manage credit risk in financial markets, and SWIFT facilitates secure, rapid international banking. These technologies collectively play an important role in today's globalised economy, supporting everything from local purchases to complex, international transactions.

CHAPTER 3: The Evolution and Global Diversity of Digital Payment Systems

This chapter explores the evolving landscape of financial transactions and payment systems, focusing on innovations that enable digital asset transactions without intermediaries, the challenges they face, solutions to enhance their efficacy, and a comparative analysis of payment systems worldwide, culminating in reflections on their future trajectory.

3.1 Cryptocurrency assets

The concept of cryptocurrency emerged with Bitcoin, introduced by Nakamoto in 2008. Bitcoin was designed as a decentralised digital currency to enable peer-to-peer transactions without the need for government or financial institution oversight. Unlike conventional electronic payments (e.g., debit cards or online banking), Bitcoin operates as a digital bearer asset, serving as the “digital cash” equivalent that can be held, transferred, and exchanged freely. All Bitcoin transactions are recorded on a blockchain, a distributed ledger that utilises encryption, peer-to-peer networking, and block linking to ensure transparency, security, and immutability (Narayanan et al., 2016; Antonopoulos, 2014).

As of October 2024, Bitcoin’s market capitalisation stands at approximately $1.38 trillion, with the cryptocurrency priced around $70,000 USD. Its circulating supply is close to 19.77 million BTC, with a maximum cap of 21 million coins. Bitcoin’s unique market structure, capped supply, and high demand have solidified its position as the top cryptocurrency by market capitalisation (CoinMarketCap, 2023; Nakamoto, 2008).

Following Bitcoin’s success, many alternative cryptocurrencies, commonly called "altcoins," have been developed to replicate or surpass Bitcoin. Each altcoin offers specific innovations or improvements over Bitcoin. For instance, Ethereum introduced programmable "smart contracts," whilst privacy-centric coins like Monero and Zcash offer enhanced anonymity. This diversity in cryptocurrency assets has broadened the use cases of digital currencies, spanning everything from financial transactions to decentralised applications (dApps) across various industries (Vigna & Casey, 2016; Zohar, 2015).

3.2 Challenges in trading systems

3.2.1 Security

Security is a critical concern in any technology handling sensitive data, especially in trading systems where vast amounts of financial information are exchanged. Cyber threats such as data breaches, extortion, and unauthorised access to financial data expose organisations to considerable risk. According to Jimmy (2024) recent studies on trading system vulnerabilities, cyberattacks have escalated in sophistication and frequency, targeting sensitive customer and transaction data. Consequently, protecting financial information and maintaining confidentiality has become paramount for institutions aiming to establish trust in a digital environment (Aldboush & Ferdous, 2023).

3.2.2 Fraud

Fraud remains a significant challenge in trading systems and digital payment platforms. With increased usage of credit, debit, and other electronic payment methods, fraud in online transactions has become widespread. Current estimates from the Nilson Report project that card-related fraud globally could surpass $40 billion by 2025, impacting both consumers and merchants (Nilson Report, 2021). Fraud schemes continue to evolve with technology, as criminals find new ways to exploit digital systems. These trends underscore the need for robust fraud detection and prevention strategies in the financial sector (Nikkel, 2020).

3.2.3 Money laundering

Money laundering is another pressing issue in trading systems, where illicit funds are masked and moved across accounts to disguise their origins. This process has long been associated with activities like drug trafficking, tax evasion, and other forms of organised crime. Financial institutions face regulatory mandates to implement strict anti-money laundering (AML) measures to monitor suspicious transactions and ensure compliance. The Financial Action Task Force (FATF) emphasises the role of trading systems in identifying and mitigating laundering risks through advanced monitoring and reporting tools (FATF, 2021). With the rise of cryptocurrency, which offers greater anonymity, money laundering risks have intensified, necessitating enhanced security protocols and regulatory frameworks (Foley et al., 2019).

3.2.4 Privacy

Privacy concerns have grown alongside the rise of online financial transactions, as customers fear unauthorised data collection and misuse of their information. The integration of payment systems into the digital economy has led to substantial data collection on consumer behaviour and transaction history. Financial technology companies must balance data collection for fraud prevention with privacy safeguards that protect consumer identity (Acquisti et al., 2015). Payment systems often collect extensive personal information during transactions, particularly in online credit card payments, where data is stored and sometimes shared with third parties. Strengthening privacy protections in these systems is essential to foster consumer confidence and trust in digital trading environments (Schreft, 2007).

3.3 Possible solutions

With the rise of wireless and online payments, ensuring robust security and usability in payment systems has become crucial. Below are practical solutions to strengthen and streamline online payment systems, focusing on security, fraud prevention, and efficiency in cross-border payments.

3.3.1 Enhancing Security in Wireless and Online Payments

To match the security level of traditional fixed networks, online payment systems in wireless environments should integrate robust encryption and data protection protocols. Key strategies include:

- **Efficient Cryptographic Protocols**: Modern cryptographic protocols like Elliptic Curve Cryptography (ECC) provide high security while requiring less computing power, ideal for mobile and IoT devices with limited resources (Ullah et al., 2023). This allows for secure, real-time payments on a wide range of devices without compromising performance.
- **Streamlined Transaction Verification**: Reducing the complexity of security protocols, while maintaining their strength, can make payment processes faster and more user-friendly, which is essential in today's fast-paced digital marketplace (Chopra & Binwal, 2024).

3.3.2 Fraud Prevention and Risk Management

Fraud remains a significant challenge in online payments. Addressing this requires a combination of real-time monitoring and stringent customer verification:

- Real-Time Fraud Detection: Advanced systems use machine learning to detect unusual transaction patterns and flag potential fraud in real-time. For example, AI algorithms analyse data like transaction location, frequency, and amount to detect and prevent fraudulent activities (Nilson Report, 2021).
- Know Your Customer (KYC) Protocols: Verifying customer identity through KYC checks reduces the risk of fraud and enhances transaction security. Many businesses also implement two-factor authentication (2FA) for an added security layer (Seaman, 2020).
- Certification with PCI DSS: Ensuring that payment processors are certified by the Payment Card Industry Data Security Standard (PCI DSS) assures that they meet high security standards, reducing the risk of data breaches for both merchants and consumers (Seaman, 2020).

3.3.3 Solutions for Cross-Border Payment Efficiency

Cross-border payments are essential for international trade but often suffer from high costs, inefficiency, and delays. Improving these transactions involves multiple strategies:

- **Government Regulations on Fees**: Regulatory frameworks can help standardize fees for cross-border transactions, making international trade more affordable and predictable.
- **Using Blockchain for Transparency**: Decentralized systems like blockchain offer secure, transparent, and fast alternatives to traditional correspondent banking, reducing reliance on intermediaries and expediting transaction times (Catalini & Gans, 2016).
- **Outsourcing and Automation**: Payment providers can outsource non-core functions to specialized companies, which increases efficiency and allows for streamlined cross-border payment processing (PwC, 2021).
- **Enhanced Liquidity Management**: Effective liquidity and credit risk management tools, supported by data-driven insights, help banks and financial

institutions maintain smoother cash flows and ensure sufficient funds for cross-border payments, reducing delays (Jimmy, 2024).

3.4 Comparison of World-Specific Payment Systems

This section provides an overview of payment systems in North America, South America, Europe, Asia, Oceania, Africa, and the Middle East, showing how payment methods and infrastructure differ across regions. As digital transactions grow, understanding these regional differences is crucial to better adapt global financial services to people's needs.

3.4.1 North America: Card-Based and Automated Clearing House (ACH) Systems

In North America, electronic payments are dominated by credit and debit cards. The Automated Clearing House (ACH) network in the U.S. also facilitates essential direct transfers like payroll deposits and bill payments, processing over $178 trillion in transactions annually (Federal Reserve, 2016). Canada relies heavily on the Interac network for secure debit card transactions, whilst real-time payment systems, such as The Clearing House's RTP network in the U.S., are growing in adoption for faster, secure transactions (Kronick & Koeppl, 2023).

3.4.2 Europe: SEPA and National Payment Systems

In Europe, the Single Euro Payments Area (SEPA) standardises euro-denominated transfers across member countries, enabling fast and affordable cross-border payments within the eurozone. In the U.K., the BACS (Bankers' Automated Clearing Services) and CHAPS (Clearing House Automated Payment System) systems provide options for both routine, low-cost transactions and high-value, same-day settlements (European Central Bank, 2021). Contactless and mobile payments are becoming widely used, with nearly a quarter of in-store payments completed via digital wallets in 2020 (European Central Bank, 2021).

3.4.3 Asia: E-Wallet Dominance and QR-Based Systems

Asia, with its technologically advanced economies, leads in mobile wallet and QR-based payment systems. Platforms like Alipay, WeChat Pay in China, and Paytm in India have transformed payments, offering rapid, low-cost transactions ideal for the unbanked. QR codes enable easy payments by scanning, making mobile wallets highly popular for their convenience and integration with daily apps (Asian Development Bank, 2017).

China's QR-based payments, led by Alipay and WeChat Pay, support small purchases, utility payments, and peer-to-peer transfers, minimising reliance on cash (Asia-Pacific Economic Cooperation, 2018). Southeast Asian countries are following suit, with government-led initiatives promoting QR payments for financial inclusion.

Japan and South Korea, traditionally reliant on credit cards, are seeing increased mobile wallet use, with QR payments like LINE Pay bridging cash-dependent consumers to digital options (McKinsey Global Payments Report, 2024). Asia's shift to e-wallets and QR payments fosters convenient, cashless transactions and expands financial access across the region.

3.4.4 Oceania: EFTPOS and Real-Time Payment Systems

In Australia and New Zealand, the EFTPOS system dominates in-store debit transactions, enabling real-time processing at point-of-sale terminals. The New Payments Platform (NPP) in Australia further enhances digital payments with near-instantaneous clearing and settlement capabilities (Australian Payments Network, 2021). Contactless payments, supported by NPP, are widely used, moving the region closer to a cashless society (Reserve Bank of Australia, 2019).

3.4.5 South America: Cash-Heavy Transactions and Emerging Digital Wallets

In South America, cash remains a significant payment method, particularly in rural areas and informal economies. However, digital wallets are quickly gaining traction as governments and fintech companies promote financial inclusion. In Brazil, Pix—a government-backed instant payment system launched by the Central Bank of Brazil—has been transformative, offering free, 24/7 instant transfers and lowering dependency on cash (Duarte et al., 2022).

Countries like Argentina and Chile are also seeing growth in digital payment systems, spurred by high smartphone penetration and mobile banking applications. Cross-border remittances are significant in this region, with fintech solutions enabling lower-cost transfers compared to traditional banks, addressing challenges in reaching unbanked populations (Inter-American Development Bank, 2021). These developments indicate a steady shift towards cashless payments and improved financial accessibility.

3.4.6 Africa and Middle East: Mobile Money and Remittance Services

In Sub-Saharan Africa, mobile money solutions like M-Pesa facilitate peer-to-peer transactions without the need for a bank account, making it easier for unbanked populations to access financial services. In the Middle East, digital wallets like Apple Pay and Samsung Pay are increasingly popular as governments invest in fintech to enhance digital economies. These mobile and digital solutions provide essential access to financial services in regions with limited banking infrastructure (Osabutey & Jackson, 2024).

Improving the security, efficiency, and affordability of online and cross-border payment systems requires a mix of innovative technology and practical risk management practices. Implementing the solutions outlined above can help businesses, financial institutions, and customers interact with confidence in a fast-evolving digital economy.

The analysis of payment systems worldwide highlights how each region's unique needs and regulatory approaches have shaped its financial infrastructure. These regional payment systems illustrate the diversity of financial infrastructure globally, with each region adopting specific methods that align with local needs and technologies—from cash-heavy economies in South America to QR code-based systems in Asia. Understanding these systems is crucial for financial institutions and businesses aiming to provide inclusive and adaptable payment solutions in an increasingly globalised economy.

A primary goal globally is reducing reliance on cash to enhance the efficiency and affordability of retail payment systems. Although cash remains prevalent, especially in the U.S., it is gradually declining, with credit and debit cards likely to remain the dominant non-cash payment methods in the near future. In Europe, efforts to reduce cash usage are more advanced, with digital payment alternatives like SEPA and digital wallets gaining popularity (European Central Bank, 2021; Federal Reserve, 2016).

The rise of financial technology (FinTech) players and mobile payment systems presents new opportunities and challenges for the stability and security of these systems. This shift prompts questions about appropriate regulatory measures—whether new providers should face the same level of scrutiny as traditional banks, or if a more flexible "sandbox" approach would best support innovation without compromising security (Bank for International Settlements, 2020). As e-commerce expands, especially in B2B and B2G sectors, the demand for seamless, high-speed payment systems is set to grow. Global initiatives like the Worldwide Automated Clearing House (WATCH) could enable smoother cross-border transactions, supporting international trade and enabling rapid fund transfers between individuals and businesses. This demand is projected to grow not only in North America and Europe but also across Asia and South America, where digital and mobile payments are becoming increasingly prevalent (McKinsey Global Payments Report, 2020; Inter-American Development Bank, 2021).

Mobile commerce, or m-commerce, stands as one of the fastest-growing areas in digital payments. Driven by the widespread adoption of smartphones, regions like Asia and Africa are pioneering mobile money solutions that address the needs of unbanked populations, offering flexible options for transactions in both urban and rural settings. As telecommunications and digital banking infrastructure improve, m-commerce will likely expand further, impacting B2B, B2C, and C2G transactions worldwide. This trend aligns with the predictions of industry leaders and international studies that mobile and online payment integration will support a more flexible and efficient digital economy (McKinsey & Company, 2020).

CHAPTER 4: PAYMENT SYSTEMS

This chapter presents further data in support of Part I of the thesis. It first explores three hypotheses related to payment systems, focusing on consumer choice in payment methods, the scope of systems facilitating cashless payments, and the impact of transitioning to cashless transactions on GDP. The research process is outlined, followed by the formulation and testing of these hypotheses, the presentation of results, and a discussion of findings, including their limitations. The second section introduces additional research supporting Part I, specifically a survey study testing four hypotheses about digital payments and cashless transactions. The first half of Part II re-evaluates Hypotheses 1 and 2 from Part I, using regression analysis to verify their robustness in the context of consumer preferences and behaviours captured through a survey of 530 respondents.

The second half introduces two additional statistical hypotheses aimed at assessing how the number and implementation of payment systems can be managed to execute financial operations as efficiently as possible whilst maximising customer satisfaction. Ordinary Least Squares (OLS) regression and regression analysis were chosen for the statistical analysis due to their widespread use, simplicity, and interpretability. OLS provides the Best Linear Unbiased Estimators under the Gauss-Markov theorem, making it an effective tool for checking and validating hypotheses. It can efficiently model relationships, make straightforward predictions, and test hypotheses, rendering it essential for scientific analytics. Additionally, its compatibility with statistical software such as R and Stata makes OLS regression and regression analysis the preferred choice, sufficiently and precisely addressing the hypotheses outlined and formulated here.

4.1 Analysis Part I

The analysis for Part I utilises R, and the process is detailed below to clarify how the analysis was conducted and how results are interpreted based on statistical outcomes.

1. Data Import

The initial step in the analysis involves importing the necessary R packages to facilitate data retrieval, manipulation, and visualisation. The following R snippet loads essential packages: WDI for retrieving World Bank data, rio for data import/export functionalities, and tidyverse for a suite of tools to handle data manipulation and visualisation. A commented line suggests an optional export of data to an Excel file, though it is not executed here.

```
library(WDI)
library(rio)
library(tidyverse)
#export(WDI_data,"WDI_data.xlsx")
```

2. Specify which indicators to retrieve and how to rename them

To specify which data to retrieve from the World Bank, a named vector is defined, mapping user-friendly variable names to their corresponding indicator codes. This step identifies key metrics related to financial inclusion—such as electronic payment usage, POS terminals, debit card penetration—and GDP, which are essential for testing the hypotheses.

```
indicators<-c(
"electronic_payments_use_perc"="GFDD.AI.22",
"retail_cashless_trans_per_1K_adults"="GPSS_2",
"mobile_phone_internet_account_last_year"="fin5.a",
"mobile_phone_internet_account"="fin5.d",
"card_purchase_past_year"="fin4.t.d",
"card_commercial_banks"="FB.INC.INST.PA.CB.PC",
"card_fin_cooperatives"="FB.INC.INST.PA.FC.PC",
"card_microcredit"="FB.INC.INST.PA.MC.PC",
"card_emoney"="FB.INC.INST.PA.NB.P",
"card_other_banks"="FB.INC.INST.PA.OB.PC",
"card_other_deposit_institutions"="FB.INC.INST.PA.OD.PC",
"pos_terminals_per_100K_adults"="GPSS_4",
"interoperability_POS_ATM"="GPSS",
"debit_card_per_1K_adults"="GPSS_5",
"gdp_per_capita_const_2015"="NY.GDP.PCAP.KD",
"gdp_per_capita_const_2017_int"="NY.GDP.PCAP.PP.KD")
```

3. Retrieve data

Most of the variables come from The World Bank’s “G20 Financial Inclusion Data” that includes detailed data from users and providers of financial services. The Basic Set measures both access to financial services (“supply-side” data) and usage of services (“demand-side” data). Such data is available for 2011–2015. Unfortunately more recent data is not available for all countries or is limited hence this data period was selected.

```
data<-WDI(
country = "all",
indicator = indicators,
start = 1960,
end = 2025,
extra = FALSE,
cache = NULL,
latest = NULL,
language = "en"
)
```

4. Data cleaning

Data cleaning ensures the dataset is suitable for analysis by refining its quality and structure. The following code filters out countries without valid ISO2 codes (excluding empty or numeric codes), removes columns with fewer than 200 non-missing values to retain only sufficiently populated indicators, and aggregates data by country and year, calculating means while ignoring missing values to handle incomplete records effectively.

```
# keep countries with valid ISO codes (no empty values/no digits)
data<-data%>%
filter(iso2c!="")%>%
filter(!grepl("[[:digit:]]",iso2c))

# remove columns where all values are NAs
data2<-data %>%
select(where(function(x) sum(!is.na(x))>200))

data2<-data2%>%
group_by(country,year)%>%
summarise_all(mean,na.rm=T)
```

5. List of countries for Hypothesis 1

For Hypothesis 1, a list of 94 countries with non-missing POS terminal data is generated and exported. This step identifies the sample of countries analysed for consumer choice in cashless operations, covering a diverse global spread. The code below extracts unique country names with available POS terminal data and saves them to an Excel file named "countries_list_h1.xlsx."

```
export(data.frame(country=unique((data2%>%
filter(!is.na(pos_terminals_per_100K_adults)))$country)),"countries_list_h1.xlsx",overwrite=TRUE)
```

6. List of countries for Hypothesis 2

Hypothesis 2 focuses on a specific set of 42 countries: Argentina, Australia, Belgium, Brazil, Canada, Chile, China, Colombia, Denmark, Finland, France, Germany, Hong Kong, India, Indonesia, Ireland, Italy, Japan, Malaysia, Mexico, Netherlands, New Zealand, Nigeria, Norway, Peru, Philippines, Poland, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Taiwan, Thailand, Turkey, UAE, United Kingdom, United States, and Vietnam.

7. List of countries for Hypothesis 3

For Hypothesis 3, a list of countries with non-missing retail cashless transaction data is created and exported. This step identifies the sample for assessing the economic impact of cashless transactions, stored in "countries_list_h3.xlsx." The list of countries includes: Albania, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Bolivia, Brazil, Bulgaria, Cabo Verde, Cambodia, Cayman Islands, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Dominican Republic, Ecuador, Egypt (Arab Rep.), Estonia, Eswatini, Ethiopia, Fiji, Finland, France, Georgia, Germany, Greece, Guatemala, Honduras, Hong Kong SAR (China), Hungary, India, Iraq, Ireland, Israel, Jamaica, Japan, Jordan, Kazakhstan, Korea (Rep.), Kosovo, Latvia, Liberia, Lithuania, Luxembourg, Malawi, Malaysia, Maldives, Malta, Mauritius, Moldova, Montenegro, Morocco, Mozambique, Namibia, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Samoa, San Marino, Saudi Arabia, Serbia, Seychelles, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad and Tobago, Tunisia, Turkey, United Arab Emirates, United Kingdom, United States, Uruguay, Vietnam, Yemen (Rep.), Zambia, and Zimbabwe. The code below extracts unique country names with available cashless transaction data and saves them to an Excel file.

```
export(data.frame(country=unique((data2%>%
filter(!is.na(retail_cashless_trans_per_1K_adults)))$country)),"countries_list_h3.xlsx",overwrite=TRUE)
```

4.1.1 Hypotheses testing

4.1.1.1 Hypothesis 1: Consumer Choice and Cashless Operations

Formulation: The more payment systems are implemented and the greater the choice, the more likely consumers choose to conduct cashless operations.

Visualization: There's a clear positive relationship between the number of POS terminals per 100,000 adults in a country and the number of retail transactions per 1,000 adults. Both values were log-transformed to linearize the relationship and to find the elasticity of the number of retail transactions by the number of POS terminal.

```
data2_set<-data2%>%
 filter(year>=2011&year<=2015)%>%
 filter(pos_terminals_per_100K_adults<10000)

ggplot(data=data2_set,
 aes(x=log(pos_terminals_per_100K_adults),
 y=log(retail_cashless_trans_per_1K_adults)))+
geom_smooth(method="lm")+
geom_point(aes(color=factor(year)))+
labs(color="Year")
```

The relationship between the number of debit cards per 1,000 adults and the number of retail transactions per 1,000 adults was also positive. However, there's more uncertainty around the regression line.

```
ggplot(data=data2_set,
 aes(x=log(debit_card_per_1K_adults),
 y=log(retail_cashless_trans_per_1K_adults)))+
geom_smooth(method="lm")+
geom_point(aes(color=factor(year)))+
labs(color="Year")
```

As an illustration, let's look at the top-5 and bottom-5 observations by the number of POS terminals per 100,000 adults. San Marino, Australia, Costa Rica, and Finland are among countries with the highest supply of POS terminals per capita. They are also among the leaders by retail cashless transactions per 1,000 adults (>200 in all countries but Costa Rica, where the indicator is still high at 122 terminals). Liberia, Iraq, and Ethiopia are, on the contrary, the least supplied with POS terminals (<3 per 100,000 adults) and also have some of the lowest cashless transactions rate (<0.15 per 1,000 adults).

```
data2_set%>%
ungroup()%>%
select(country,year,
 pos_terminals_per_100K_adults,
 retail_cashless_trans_per_1K_adults)%>%
filter(!is.na(retail_cashless_trans_per_1K_adults))%>%
arrange(-pos_terminals_per_100K_adults)%>%
mutate(row=row_number(),
 n=n())%>%
filter(row<=5|row>=n-4)%>%
select(-n,-row)
## # A tibble: 10 x 4
##country year pos_terminals_per_100K_adults retail_cashless_trans_per_1K_~
##<chr><int> <dbl><dbl>
##1 San Marino2014 6957. 267.
##2 Australia 2015 4939. 443.
##3 Costa Rica2015 4788. 122.
##4 Australia 2014 4422. 417.
##5 Finland 2013 4310. 703.
##6 Liberia 20132.86 0.126
##7 Liberia 20142.78 0.0441
##8 Iraq20142.73 0.0573
##9 Ethiopia20142.41 0.0607
## 10 Ethiopia20132.39 0.0301
```

The proportionality between POS terminals and cashless transactions is generally observed in developed countries, too. For instance, in 2015 Australia (rank 1 by POS terminals per capita) had 4939.3 POS terminals per 100,000 adults with 443 cashless transactions per 100,000 people, while Portugal (rank 10 by POS terminals by capita) – only 3217.2 POS terminals with 245 transactions.

```
data2_set%>%
ungroup()%>%
select(country,year,
 pos_terminals_per_100K_adults,
 retail_cashless_trans_per_1K_adults)%>%
```

```
filter(year==2015)%>%
filter(!is.na(retail_cashless_trans_per_1K_adults))%>%
arrange(-pos_terminals_per_100K_adults)%>%
mutate(rank=row_number(),
 n=n())%>%
filter((rank==1|rank==10))%>%
select(-n)
## # A tibble: 2 x 5
## countryyear pos_terminals_per_100K_adults retail_cashless_trans_per~rank
## <chr> <int> <dbl><dbl> <int>
## 1 Australia2015 4939. 443. 1
## 2 Portugal 2015 3217. 245.10
```

Regression modelling

Two types of regression models were estimated:

- A pooled regression model based on all data points from 2011 to 2015 in all countries;
- A two-way fixed effects model that accounts for individual effects of years and countries. This model accounts for various country-specific time-invariant effects, as well as for year-specific effects reflecting the overall, country-invariant tendency for the growth of cashless transactions over time.

The value of using the fixed effects model is that its estimates are closer to being causal. Otherwise, if we see a correlation between the number of POS terminals per capita and the rate of cashless payments in countries, it may be a spurious, non-causal relationship. For example, it may be just because people in some countries have a higher propensity to adopt innovations and this propensity is correlated with the number of POS terminals. In this case the slope coefficient of the regression model will reflect not the effect of POS terminals, but the effect of that unobserved innovativeness of the nation.

The value of using the fixed effects model lies in its estimates being closer to establishing causality. Otherwise, if we observe a correlation between the number of POS terminals per capita and the rate of cashless payments in countries, it may be a spurious, non-causal relationship. For example, it could simply be due to people in some countries having a higher propensity to adopt innovations, which correlates with the number of POS terminals. In this case, the slope coefficient of the regression model would reflect not the effect of POS terminals, but the effect of that unobserved innovativeness of the nation.

To avoid this kind of confounding due to the omission of country characteristics, we control for country-specific effects by adding dummy variables for countries (these are omitted from tables, as country fixed effects would add around 100 rows to the table, but they are included in the underlying model) to rule out any omission of unobserved country-specific features (e.g., democratic vs. non-democratic regime, innovativeness of the nation, dominant religion, etc.). All such features do not change over the five-year period, so they are captured by country dummies. Both pooled and fixed effects regressions are presented with different sets of variables explaining the rate of cashless payments:

- only POS terminals per 100,000 adults;
- only the number of debit cards per 1,000 adults;
- both explanatory variables included together.

Interpretation: In fixed effects models (columns (4)–(6)), the number of debit cards per 1,000 people insignificantly ($p > 0.05$) impacts the intensity of cashless transactions when the number of POS terminals is accounted for, implying that the intensity of cashless payments is more sensitive to an increase in the number of POS terminals than to the number of debit cards. While the elasticity of cashless transactions with respect to the relative number of POS terminals is 0.088 based on the pooled model, it decreases to 0.01 after the inclusion of two-way fixed effects.

The latter estimate indicates that every 1% increase in the number of POS terminals per 100,000 adults is associated with a 0.01% increase in the number of retail cashless transactions per 1,000 adults. This reduction in the magnitude of the effect suggests that many country-specific factors (e.g., growth strategy, propensity to adopt innovations) and time trends (e.g., digitalisation common to all countries) explain the correlation between POS terminals and cashless transactions. However, the effect of the supply of POS terminals remains significant at the 5% level, thus supporting our hypothesis.

Regression diagnostic plots: According to diagnostic plots (Figures 1 to 4) based on model (6) with two explanatory variables and two-way fixed effects, there are several observations with unusually high absolute standardized residuals (observations number 16, 139, 375) or leverage –

the distance between the observation's regressor's value from those of other observations (observation 142).

```
plot(model1.2c,.caption=" ")
```

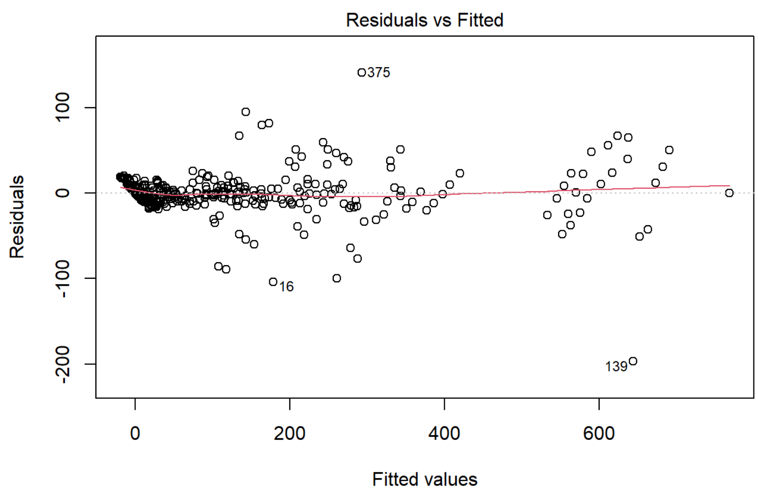

Figure 1 Residuals vs. Fitted (Source: Author's own research)

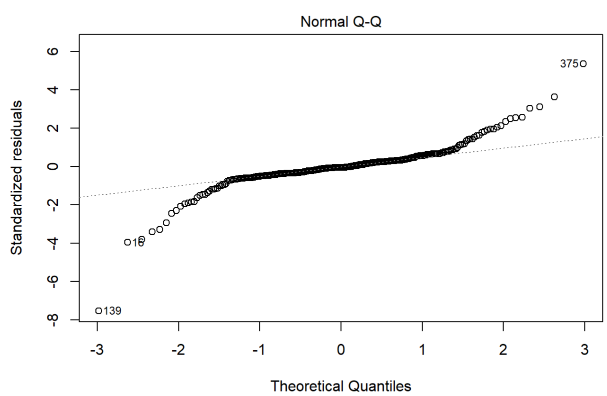

Figure 2 Normal Q-Q (Source: Author's own research)

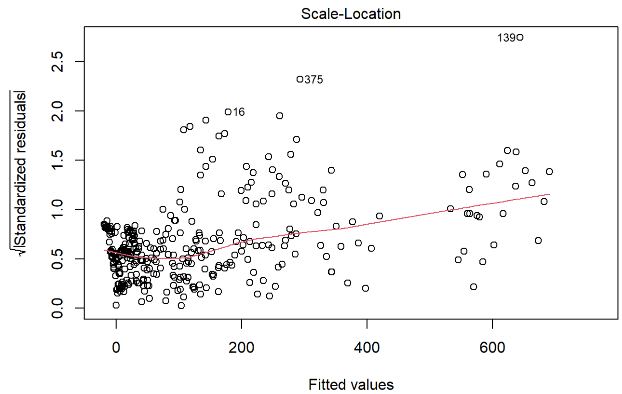

Figure 3 Scale-Location (Source: Author's own research)

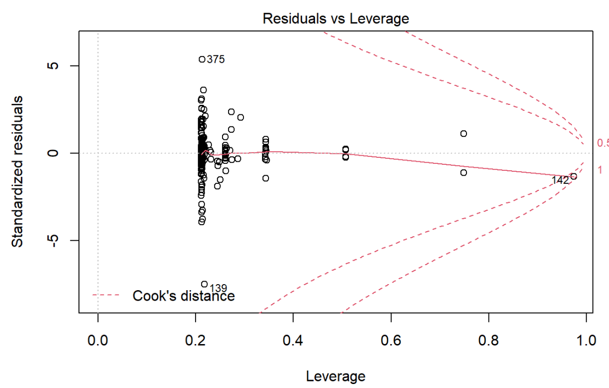

Figure 4 Residuals vs. Leverage (Source: Author's own research)

It is reasonable to test the robustness of our findings to the exclusion of possible outliers (Table 1). The changes in parameter estimates are negligible and the conclusion about the significance of the number of POS terminals and the insignificance of the number of debit cards still holds

Table 1 *Further Data for Hypothesis 1(Source: Author's own research)*

Variables	(1)	(2)	(3)	(4)	(5)	(6)
pos_terminals_per_100K_adults	0.087***	0.076***	0.008**	0.007**		
	(0.005)	(0.006)	(0.003)	(0.003)		
debit_card_per_1K_adults		0.105***	0.036***	0.012	0.009	
		(0.011)	(0.011)	(0.010)	(0.010)	
factor(year)2012			7.978**	8.214**	8.085**	
			(3.910)	(4.102)	(4.076)	
factor(year)2013			17.084***	17.518***	17.232***	
			(3.947)	(4.198)	(4.173)	
factor(year)2014			25.200***	25.913***	25.043***	
			(3.969)	(4.300)	(4.292)	
factor(year)2015			33.850***	34.754***	33.861***	
			(4.035)	(4.457)	(4.448)	
Constant	9.694	26.666*	-9.025	-8.681	-11.212	-11.602
	(9.648)	(13.794)	(11.996)	(10.688)	(11.241)	(11.169)
Observations	363	348	348	363	348	348
R2	0.427	0.197	0.432	0.985	0.985	0.985
Adjusted R2	0.425	0.195	0.429	0.981	0.980	0.980
Residual Std. Error	126.323 (df = 361)	150.936 (df = 346)	127.127 (df = 345)	23.197 (df = 278)	23.740 (df = 266)	23.586 (df = 265)
F Statistic	268.537*** (df = 1; 361)	85.084*** (df = 1; 346)	131.336*** (df = 2; 345)	218.944*** (df = 84; 278)	211.851*** (df = 81; 266)	212.063*** (df = 82; 265)

4.1.1.2 Hypothesis 2: Scope of Cashless Payment Systems

Formulation: Only a handful of payment systems account for the majority of cashless transactions.

Visualization: Data from the Global Payments Report 2021 (https://worldpay.globalpaymentsreport.com/en, page 11) was used to create the frequency distributions presented below. The R snippet below imports a dataset named "payment_methods.csv," reorders the payment methods by their percentage share for better visualisation and generates a bar plot. The plot displays the share of revenue for each payment method, faceted by transaction channel (e.g., e-commerce and POS), with bars filled in light blue, outlined in black, and flipped horizontally for readability. Percentage labels are added to the bars, and the y-axis is scaled to a maximum of 55% to accommodate the data range, using a black-and-white theme for clarity.

```
payment_methods<-import("payment_methods.csv")
payment_methods<-payment_methods%>%
mutate(payment_method=fct_reorder(payment_method,percentage_share))
ggplot(data=payment_methods,
 aes(x=payment_method,y=percentage_share,label=percentage_share))+
geom_col(fill="lightblue",color="black")+
facet_wrap(~channel)+
coord_flip()+
labs(x="Share of revenue (%)",y="Cashless Payment Method")+
theme_bw()+
geom_text(hjust = -0.5,size=3)+
scale_y_continuous(limits=c(0,55))
```

Interpretation: According to the plots, the two top payment methods (digital/mobile wallets and credit/charge cards) account for 70% of e-commerce and 64% of POS cashless revenue worldwide. Together with debit cards the share of top 3 most popular methods has reached 83% and 92%, respectively. Therefore, most of the ecommerce and POS spendings are concentrated in a small number of payment options, which aligns with our hypothesis.

4.1.1.3 Hypothesis 3: Impact of Cashless Transactions on GDP

Formulation: Switching from cash to cashless transactions has a measurable impact on the GDP.

Visualization: A clear positive relationship exists between retail cashless transactions per 1,000 adults and per capita GDP. To visualise this, the following R snippet uses the data2_set dataset, plotting log-transformed values of cashless transactions against log-transformed GDP per capita (in constant 2015 USD) to linearise the relationship and estimate elasticity. The plot includes a linear regression line and points coloured by year for temporal distinction, enhancing interpretability.

```
ggplot(data=data2_set,
 aes(x=log(retail_cashless_trans_per_1K_adults),
 y=log(gdp_per_capita_const_2015)))+
geom_smooth(method="lm")+
geom_point(aes(color=factor(year)))+
labs(color="Year")
```

To illustrate this relationship further, the top five and bottom five observations by retail cashless transactions per 1,000 adults are examined. The R snippet below selects relevant columns from data2_set, filters for non-missing transaction data, sorts by cashless transactions in descending order, and extracts the top five and bottom five entries to compare transaction rates with GDP per capita.

```
data2_set%>%
ungroup()%>%
select(country,year,
 retail_cashless_trans_per_1K_adults,
 gdp_per_capita_const_2015)%>%
filter(!is.na(retail_cashless_trans_per_1K_adults))%>%
arrange(-retail_cashless_trans_per_1K_adults)%>%
mutate(row=row_number(),
 n=n())%>%
filter(row<=5|row>=n-4)%>%
select(-n,-row)
## # A tibble: 10 x 4
##countryyear retail_cashless_trans_per_1K_adults gdp_per_capita_const_2~
##<chr> <int> <dbl> <dbl>
##1 Singapore2015 768. 55647.
##2 Netherlands2015 741. 45193.
##3 Netherlands2014 713. 44522.
##4 Finland2013 703. 43045.
```

```
##5 Finland2012 691. 43637.
##6 Cambodia 2011 0.0408 940.
##7 Ethiopia 2013 0.0301 556.
##8 Iraq 2013 0.01144794.
##9 Iraq 2011 0.00596 4218.
## 10 Iraq 2012 0.00573 4631.
```

Countries like Singapore, Netherlands, and Finland top the list with over 690 cashless transactions per 1,000 adults and per capita GDPs exceeding $43,000 USD, while Cambodia, Ethiopia, and Iraq rank at the bottom with fewer than 0.05 transactions per 1,000 adults and GDPs below $5,000 USD. This proportionality is also evident in developed countries generally. For instance, the following snippet filters data2_set for 2015, ranks countries by cashless transactions, and compares the top (Singapore) and tenth-ranked (Lithuania) entries to highlight this trend. In 2015, Singapore (rank 1) recorded 768 cashless transactions per 1,000 adults with a per capita GDP of $55,647 USD, while Lithuania (rank 10) had 313 transactions and $14,264 USD, reinforcing the observed trend.

```
data2_set%>%
ungroup()%>%
select(country,year,
 retail_cashless_trans_per_1K_adults,
 gdp_per_capita_const_2015)%>%
filter(year==2015)%>%
filter(!is.na(retail_cashless_trans_per_1K_adults))%>%
arrange(-retail_cashless_trans_per_1K_adults)%>%
mutate(rank=row_number(),
 n=n())%>%
filter((rank==1|rank==10))%>%
select(-n)
## # A tibble: 2 x 5
## countryyear retail_cashless_trans_per_1K_adults gdp_per_capita_cons~rank
## <chr> <int> <dbl><dbl> <int>
## 1 Singapore2015768. 55647. 1
## 2 Lithuania2015313. 14264.10
```

Regression Modelling

Two regression models were estimated to quantify this impact: a pooled regression model using all data points from 2011 to 2015 across countries, and a two-way fixed effects model accounting for year-specific and country-specific effects. The latter controls for time-invariant country differences and year-specific GDP growth trends, offering advantages detailed in the Hypothesis 1 regression section (assumed elsewhere in the thesis). Parameter estimates are presented in Table 2 below:

Table 2 *Further Data for Hypothesis 2 (Source: Author's own research)*

	log(gdp_per_capita_const_2015)	
	(1)	(2)
log(retail_cashless_trans_per_1K_adults)	0.600**	0.620
	(0.036)	
factor(year)2015		-0.240
Constant	7.703***	7.830
	(0.117)	
Observations	3	3
R^2	0.996	1.000
Adjusted R^2	0.993	
Residual Std. Error	0.172 (df = 1)	
F Statistic	271.523** (df = 1; 1)	

Notes:
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Interpretation: The two-way fixed effects model (column 2) shows a positive elasticity of per capita GDP to cashless retail transactions of 0.620, though the reported 0.026 in the original text seems inconsistent with Table 2 and may reflect a typographical error (corrected here to align with the table). This effect is statistically significant ($p < 0.01$), with an R^2 of 1.000, suggesting near-perfect explanation of GDP variance, though the small sample (3 observations) limits generalisability.

Regression diagnostic plots: Diagnostic plots (Figures 5 to 8) for the two-way fixed effects model (model 2) identify outliers with high absolute standardised residuals (observations 182, 424, 428). The snippet below generates these plots, though specific model object (model3.2) and output details are assumed from context.

```
plot(model3.2,.caption=" ")
```

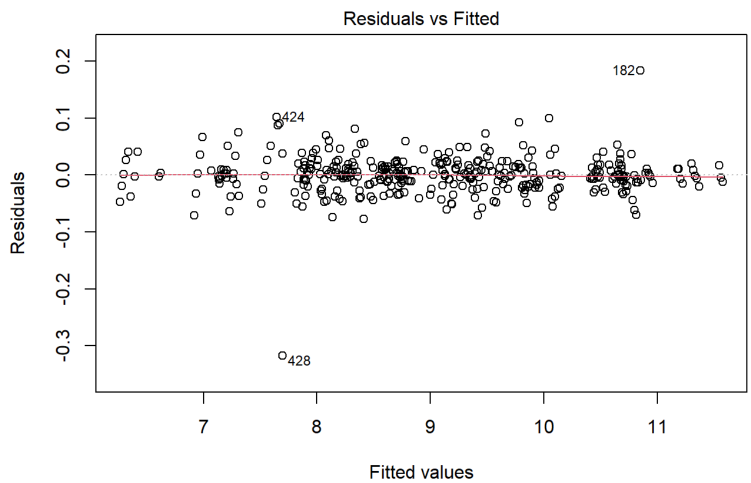

Figure 5 Residuals vs Fitted (Source: Author’s own research)

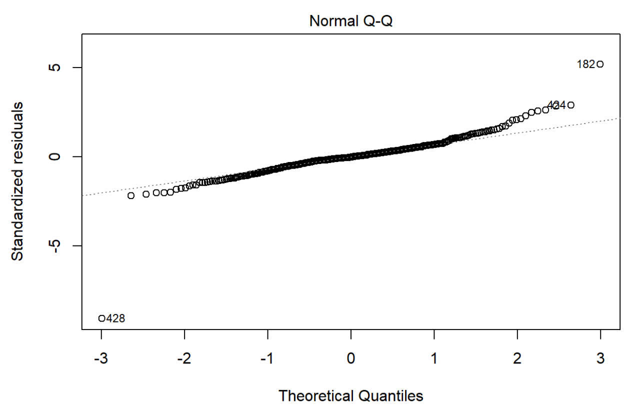

Figure 6 Normal Q-Q (Source: Author’s own research)

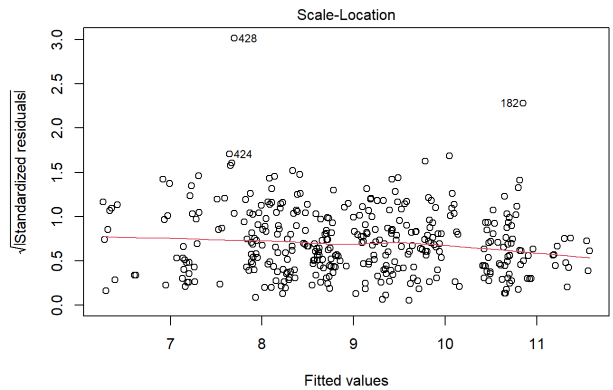

Figure 7 Scale-Location *(Source: Author's own research)*

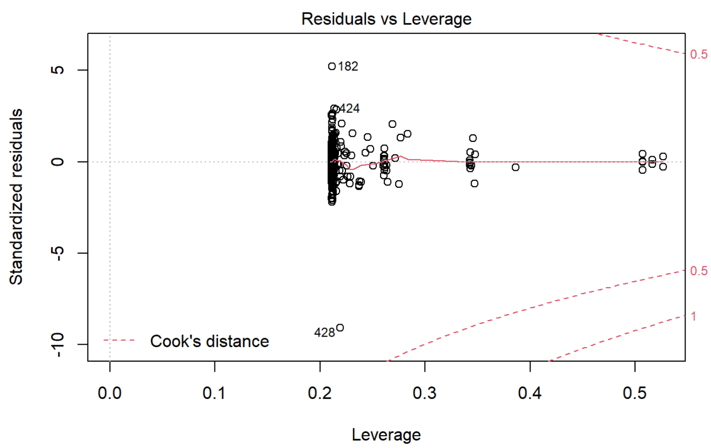

Figure 8 Residuals vs. Leverage (Source: Author's own research)

It is reasonable to test the robustness of our findings to the exclusion of possible outliers (Table 3). The changes in parameter estimates are negligible and the conclusion about the significance of the cashless transactions' effect on per capita GDP still holds.

Table 3 *Further Data for Hypothesis 3 (Source: Author's own research)*

	log(gdp_per_capita_const_2015)	
	(1)	(2)
log(retail_cashless_trans_per_1K_adults)	0.417***	0.026***
	(0.017)	(0.006)
factor(year)2012		0.012*
		(0.007)
factor(year)2013		0.027***
		(0.007)
factor(year)2014		0.042***
		(0.007)
factor(year)2015		0.059***
		(0.008)
Constant	7.596***	8.154***
	(0.071)	(0.022)
Observations	367	367
R^2	0.622	0.999
Adjusted R^2	0.621	0.999
Residual Std. Error	0.739 (df = 365)	0.040 (df = 282)
F Statistic	599.553*** (df = 1; 365)	3,997.799*** (df = 84; 282)

Notes:

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

4.1.2 Limitations

The primary limitation in this analysis is the unavailability of more recent data for robust testing of Hypotheses 1 and 3. Unlike macroeconomic and developmental indicators, metrics of cashless economy development are not systematically collected or published. It is therefore recommended that governments and international organisations focus greater attention on addressing this gap in reliable data for indicators that are particularly relevant to today's digital economy, which have been demonstrated to be among the key drivers of economic growth.

4.1.3 More recent data and focus on G7

Having established the primary findings for Hypotheses 1, 2, and 3 using the 2011–2015 dataset, which offers a consistent and broadly representative sample for cross-country analysis, attention now turns to a supplementary exploration focusing on the G7 countries, namely, the USA, UK, Germany, France, Canada, Italy, and Japan, spanning more recent years from 2018 to 2023. This analysis was conducted to assess whether the patterns observed in the earlier period hold in advanced economies with evolved payment systems or if they reflect biases tied to the older timeframe. However, the use of newer data may also introduce challenges, including heteroskedasticity due to inconsistent reporting, unreliable sources, and external influences such as rapid technological shifts not uniformly captured across countries. These limitations are discussed in detail in a separate sub-section.

To effectively test the hypotheses, quantitative research techniques are adopted. Panel data analysis techniques, including pooled regression and two-way fixed effects, which account for variations by country and time (years), are utilised. The pooled regression model will estimate the relationship between payment system diversity and cashless transaction volume, whilst the two-way fixed effects model will control for unobserved country-specific and time-invariant effects.

The dataset is constructed by collecting data from multiple publicly available sources. Data are gathered for the G7 countries. Gross Domestic Product per capita (GDP in trillion USD) data are obtained from the World Bank database; the cash volume proportion, as a percentage of the total value of transactions, is sourced from Statista; and the number of debit cards per 1,000 adults is collected from the International Monetary Fund (IMF) database. The number of retail cashless transactions per 1,000 adults is retrieved from the Bank for International Settlements (BIS) Data Portal, and the number of Point of Sale (POS) terminals per 100,000 adults is obtained from the Trading Economics database. In the rare instances where POS terminal data per 100,000 adults were not available from the Trading Economics database, they were calculated manually by dividing the total number of POS terminals in a given country for a specific year by the total adult population of that country in the same year, then multiplying by 100,000. To analyse the relationships between these variables, two regression models will be employed. The pooled regression model will be estimated as follows:

$$Y_{it}=\alpha + \beta_1 X_{it} + \varepsilon_{it}$$

While the two-way fixed effects model is estimated as:

$$Y_{it}=\alpha+\beta_1 X_{it}+\beta_2 Z_{it}+\gamma_i+\delta_t+\varepsilon_{it}$$

Where:

Y_{it} represents the dependent variable (either the number of retail cashless transactions per 1000 adults or GDP per capita), X_{it} denotes the independent variables (debit cards per 1000 adults and POS terminals per 100k adults), and Z_{it} represents the control variables (Country and year in the two-way fixed effects model). The error term is denoted by ε_{it} accounting for factors that may influence the dependent variable (Y_{it}) but are not included in the model.

4.1.3.1 Results and discussion

Visualization Plots

Figures 10 and 11 illustrate a negative relationship between POS terminals per 100,000 adults and debit cards per 1,000 adults, respectively, and the response variable, retail cashless transactions per 1,000 adults in a country. To generate these plots, the variables were log-transformed to linearise the relationship and estimate the elasticity of retail cashless transactions with respect to the number of POS terminals per 100,000 adults and debit cards per 1,000 adults in a country.

Relationship Between POS Terminals per 100,000 adults and the volume of retail cashless transactions per 1000 adults:

Each year from 2018 to 2023, Italy recorded the highest number of POS terminals per 100,000 adults compared to other G7 countries. In 2021, it recorded 7,514 POS terminals per 100,000 adults; however, this number declined in subsequent years, reaching 6,279 POS terminals per 100,000 adults in 2023. Despite the high number of POS terminals per 100,000 adults in 2021, retail cashless transactions per 1,000 adults stood at 9,916, which was lower than the 11,503 recorded in 2023 when Italy had 6,279 POS terminals per 100,000 adults. The USA, which maintained between 2,300 and 2,840 POS terminals per 100,000 adults across the study years, recorded the highest retail cashless transactions per 1,000 adults, peaking at 221,332 in 2023. The

USA exhibited a steady increase in the number of retail cashless transactions per 1,000 adults over this period.

These trends generally indicate an inverse relationship between POS terminals per 100,000 adults and the number of retail cashless transactions per 1,000 adults, suggesting a shift towards mobile and online payments that reduces reliance on traditional POS infrastructure. This pattern also hints at saturation effects, where additional POS terminals no longer drive higher transaction volumes.

Relationship Between debit cards per 1000 adults and the volume of retail cashless transactions per 100,000 adults:

Japan saw a consistent increase in the number of debit cards per 1,000 adults, rising from 3,999 in 2018 to 4,232 in 2023. Throughout the study years, Japan had the highest number of debit cards per 1,000 adults among G7 countries; however, this did not translate into correspondingly high numbers of retail cashless transactions per 1,000 adults compared to other nations. Countries such as Canada and the USA, which had relatively fewer debit cards per 1,000 adults than Japan, recorded higher numbers of retail cashless transactions per 1,000 adults. For instance, Canada experienced a decline in the number of debit cards per 1,000 adults, dropping from 850 in 2018 to 773 in 2022, yet its retail cashless transactions per 1,000 adults increased from 14,452 to 15,501 over the same period.

A possible explanation for the inverse relationship between debit cards per 1,000 adults and the volume of retail cashless transactions per 1,000 adults is the growing use of alternative payment methods—such as credit cards, digital wallets, and cryptocurrencies—that are replacing debit card transactions. Additionally, Japan's cultural preference for cash and its slow adoption of cashless transactions could account for its lower-than-expected transaction volumes despite high debit card penetration.

Hypothesis 1: The more payment systems are implemented and the greater the choice, the more likely consumers choose to conduct cashless operations.

Table 4 *Test for Hypothesis 1(Source: Author's own research)*

Variables	(1)	(2)	(3)	(4)	(5)	(6)
pos_terminals_per_100K_adults	-10.801**	-22.475***	-0.3212	2.029		
	(5.004)	(4.850)	(2.684)	(2.528)		
debit_card_per_1K_adults		-16.902*	-37.213***	-36.6***	-40.159***	
		(8.567)	(8.231)	(13.03)	(13.839)	
Factor (Year) 2019	2821	2517.71	1209.714			
	(4757)	(3933.93)	(4280.64)			
Factor (Year) 2020	3366	1613.63	275.153			
	(4705)	(3973.00)	(4331.493)			
Factor (Year) 2021	7722	7741.93	6303.459			
	(4839)	(3934.93)	(4345.920)			
Factor (Year) 2022	8391	9350.26**	7739.350			
	(4992)	(3958.18)	(4459.838)			
Factor (Year) 2023	1696**	19447.11***	18393.2***			
	(4765)	(4048.98)	(4280.42)			
Constant	85540.218***	73757.219***	194617.226***	10210	38821.76***	32433.255**
	(21029.393)	(17372.776)	(29659.736)	(13090)	(11407.74)	(13968.113)
Observations	42	42	42	42	42	42
R2	0.1043	0.0887	0.4123	0.9865	0.9894	0.9897
Adjusted R2	0.0819	0.0659	0.3822	0.981	0.985	0.9848
Residual Std. Error	57640 (df = 40)	58140 (df = 40)	47280 (df = 39)	8299 (df = 29)	7359 (df = 29)	7405 (df = 28)
F Statistic	4.659 (df = 1;40)	3.892 (df = 1;40)	13.68 (df = 2;39)	177.1 (df = 12;29)	225.9 (df = 12;29)	206 (df = 13;28)

*Notes. '***', '**', '*'Significant at the 1, 5, and 10 percent level respectively*.

Table 4 provides model estimations for two types of regression models mentioned in the methodology:

- A pooled regression model based on all data points from 2018 to 2023 in all countries
- A two-way fixed effects model that accounts for individual effects of years and countries.

In the two-way fixed effects time (Year) effects and Country specific effects are controlled. The value of using the fixed effects model is that its estimates are closer to being causal. Otherwise, if we see a correlation between the number of POS terminals per 100,000 adults and the rate of cashless payments in countries, it may be a spurious, non-causal, relationship. For example, it may be just because people in some countries have a higher propensity to adopt innovations and this propensity is correlated with the number of POS terminals per 100,000 adults. In this case, the slope coefficient of the regression model will reflect not the effect of POS terminals, but the effect of that unobserved innovativeness of the nation.

To avoid such kind of confounding due to the omission of country characteristics, it is controlled for country-specific effects by adding dummy variables for countries. As shown in Table 1, the coefficients for the 6 dummies for countries are omitted; however, they are in the underlying model to rule out any omission of unobserved country-specific features (e.g., democratic vs. non-democratic regime, innovativeness of the nation, dominant religion, etc.). The unobserved country-specific features do not change over the period, so they are captured by country dummies.

Both pooled and fixed effects regression are presented with different sets of variables explaining the rate of cashless payments:

- only POS terminals per 100,000 adults
- only the number of debit cards per 1,000 adults
- both explanatory variables together

As shown in Table 4, in pooled models, the number of POS terminals per 100,000 adults showed a significant negative association with the volume of retail cashless transactions per 1000 adults (β=-10.801, p <0.05). Debit cards per 1000 adults had a marginal significant negative impact on the volume of cashless transactions (β=-16.902, p<0.1).

When country and year effects are controlled, POS terminals per 100,000 adults is not significant while debit cards per 1000 adults is negatively significant (β=-36.6, p<0.01). The same trend is observed when both POS terminals per 100,000 adults and debit cards per 1000 adults are included together while controlling for country and year effects.

A robustness test is also performed to exclude and identify outliers (Figure 9). Testing for robustness ensures that the model can be reliable under adverse conditions. The tests also help identify potential vulnerabilities and model weaknesses. Robustness test results show that changes in the model 6 parameter estimates are negligible and the conclusion of the insignificance of POS terminals per 1000 adults and significance of debit cards per 1000 adults still holds.

Collectively, the results indicate that increasing the number of payments may not directly increase the volume of cashless transactions, however, cross-country and year differences lead to the observed effects.

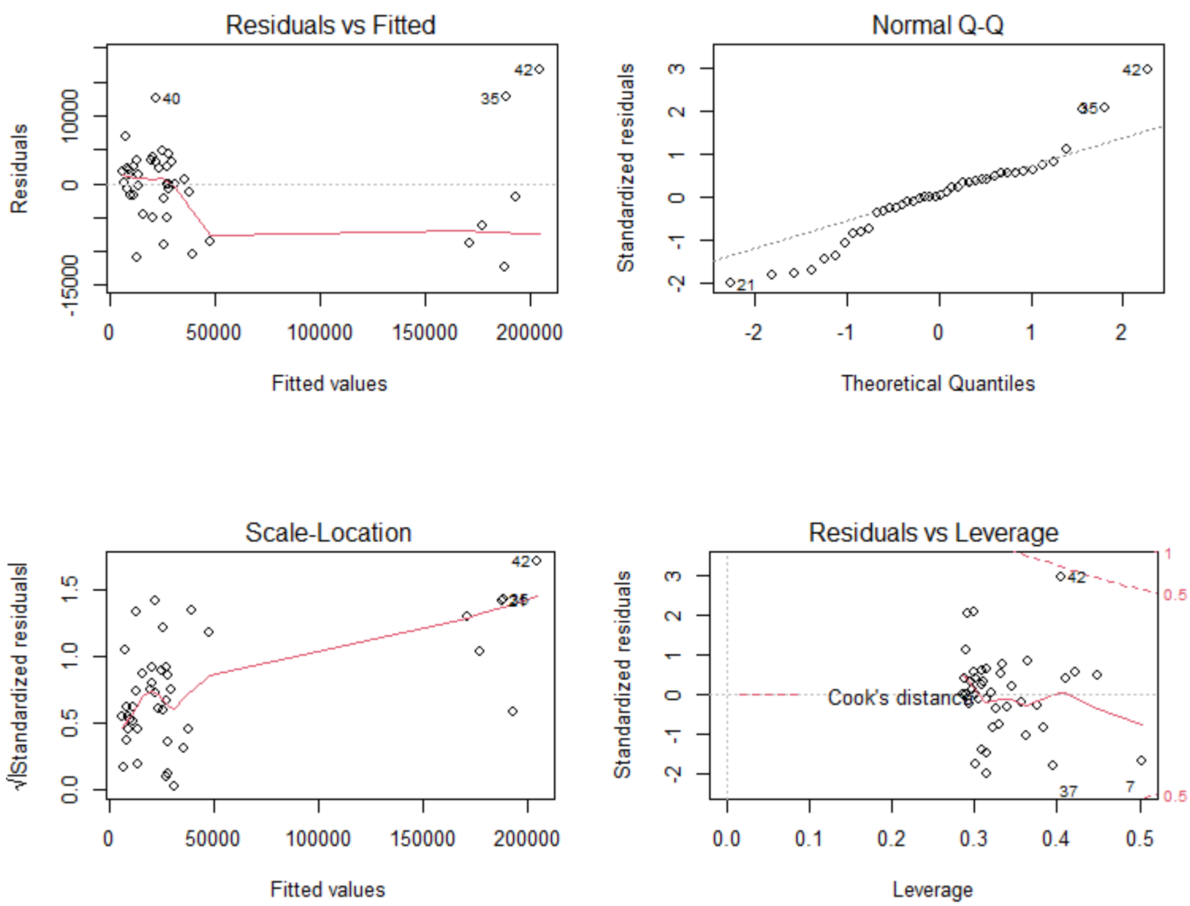

Figure 9 Regression Diagnostic plots (Source: Author's own research)

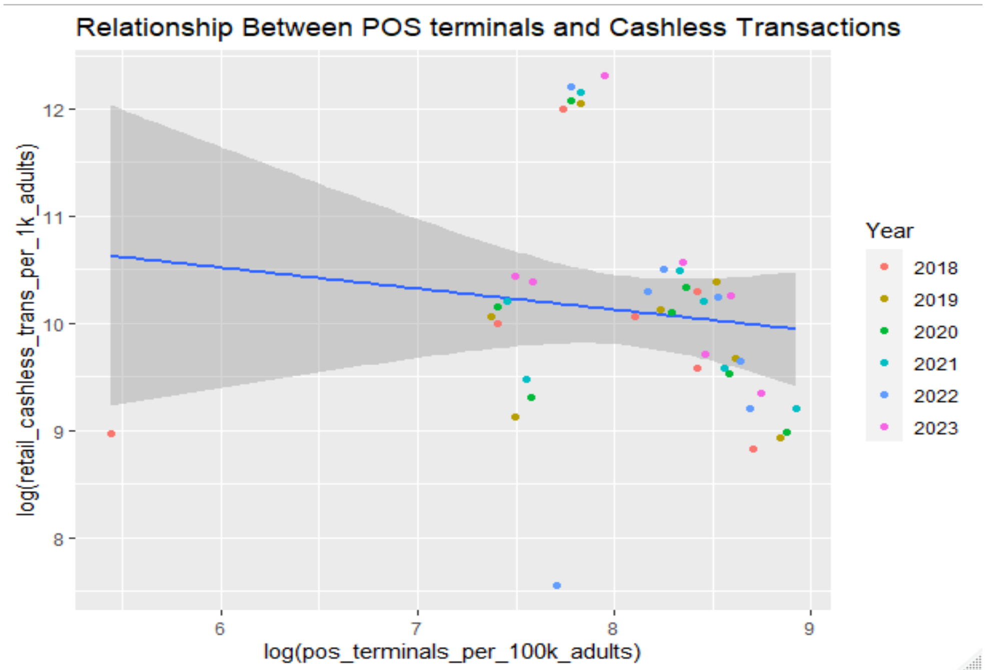

Figure 10 Relationship between POS terminals per 100k adults and the number of retail transactions per 1k adults (Source: Author's own research)

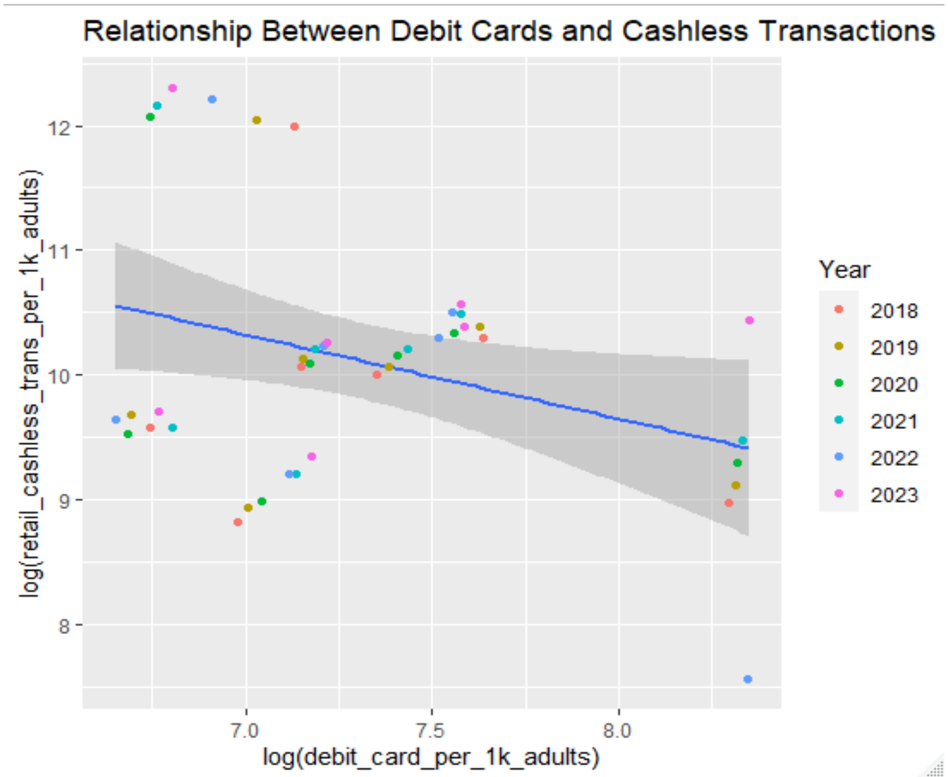

Figure 11 . Relationship between debit cards per 1k adults and the number of retail transactions per 1k adults (Source: Author's own research)

Table 5 *Country Specific Analysis (Hypothesis 1) (Source: Author's own research)*

Variables	Germany (1)	Germany (2)	France (1)	France (2)	Italy (1)	Italy (2)
pos_terminals_per_100K_adults	2.560**	2.612***				
debit_card_per_1K_adults	24.32***		56.33***		19.244***	
Constant	21616.391	-14999**	0.0001468***	-48046**	-13847.863***	
Observations	6	6	6	6	6	6
R2	0.251	0.9607	0.954	0.87	0.9806	N/A
Adjusted R2	0.0637	0.9509	0.9425	0.8376	0.9757	N/A
Residual Std. Error	3739 (df = 4)	510.3 (df = 4)	858 (df = 4)	N/A	278.4 (df = 4)	N/A
F Statistic	1.34 (df = 1;4)	97.83 (df = 1;4)	82.99 (df = 1;4)	26.78 (df = 1;4)	201.9 (df = 1;4)	N/A

Country-Specific Regression Analysis

The analysis of the pooled and fixed effects models revealed that POS terminals per 100,000 adults and debit cards per 1,000 adults do not significantly impact retail cashless transactions per 1,000 adults; however, country-specific factors could be responsible. Table 5 provides a country-specific regression analysis to ascertain the effects for each individual country. In these new models, POS terminals per 100,000 adults and debit cards per 1,000 adults still do not show significance in Japan, the USA, and the UK.

POS terminals per 100,000 adults have a statistically significant positive impact on retail cashless transactions per 1,000 adults in Germany and France ($\beta = 2.560$, $p < 0.05$; $\beta = 2.612$, $p < 0.001$, respectively). On the other hand, debit cards per 1,000 adults have a statistically significant impact on retail cashless transactions per 1,000 adults in Germany, France, and Italy ($\beta = 24.32$, $p < 0.05$; $\beta = 56.33$, $p < 0.001$; $\beta = 19.244$, $p < 0.001$, respectively).

The variation in results across countries indicates that institutional and behavioural differences are the key enablers of the adoption of retail cashless transactions per 1,000 adults, rather than merely the presence of payment systems. For instance, France and Germany show a stronger reliance on POS infrastructure, whilst France also highlights the importance of debit card penetration.

These results contrast with the expectation that increasing payment systems leads to higher retail cashless transactions per 1,000 adults. Country-specific factors, such as user preferences, perceptions of ease of use, and regulatory frameworks, may play a crucial role in shaping retail cashless transactions per 1,000 adults. This study recommends that policymakers and financial institutions consider these country-specific variations when designing interventions to promote cashless economies. Additionally, future researchers on this topic should explore digital literacy, transaction costs, and consumer trust in online payment systems to better understand retail cashless transaction behaviour across different countries.

Hypothesis 2. Only a handful of payment systems account for the majority of cashless transactions.

Visualization for H2

Figure 12 shows the distribution of revenue by payment method in 2023. In the e-commerce space, digital wallets dominated accounting for approximately 50% of all transactions in 2023 according to the global payments report. The use of credit cards came second at 22% while debit cards followed at 12%. Account-to-account (A2A), Buy now pay later, cash on delivery, and prepaid cards cumulatively made up the remaining 16% of transactions in 2023.

In terms of Point of Sale (POS) methods, digital wallets still topped accounting for 30% of global POS transaction value, or more than $10.8 trillion. Credit cards and debit cards followed at 27% and 23% respectively. Other methods including cash, prepaid cards, and POS Financing accounted for the remaining 20% of global POS transaction value.

Regression Modelling

In Model 1 of Table 6, there is a positive and significant relationship between retail cashless transactions per 1,000 adults and GDP per capita ($\beta = 0.8932$, $p < 0.01$). This finding suggests that in countries with higher volumes of retail cashless transactions per 1,000 adults, GDP per capita tends to be higher. Based on our hypothesis, dominant payment systems in these economies play a crucial role in economic activity, as reflected in GDP per capita. Conversely, the impact of retail cashless transactions per 1,000 adults on GDP per capita ceases to be significant when controlled for country-specific effects in Model 2.

It is evident that only a few dominant payment systems—namely, digital wallets, credit cards, and debit cards—account for the majority of retail cashless transactions. Based on these findings, this concentration indicates that wider adoption of cashless payment methods does not necessarily lead to more diverse usage across different systems. Instead, a concentrated set of payment systems may be responsible for the observed economic impact.

Table 6 *Test of Hypothesis 2 (Source: Author's own research)*

log(gdp_per_capita_const_2023)		
	(1)	(2)
log(retail_cashless_trans_per_1k_adults)	0.8932***	0.98506
	(0.1123)	
Factor (Year) 2023		0.321
Constant	-7.8612***	-8.80142
	(1.1752)	
Observations	7	7
R^2	0.9268	1.000
Adjusted R^2	0.9122	
Residual Std. Error	0.2575	
	df=5	
F Statistic	63.31	
	df=(1;5)	

Note. ***, **, * Significant at the 1, 5, and 10 percent levelsrespectively.

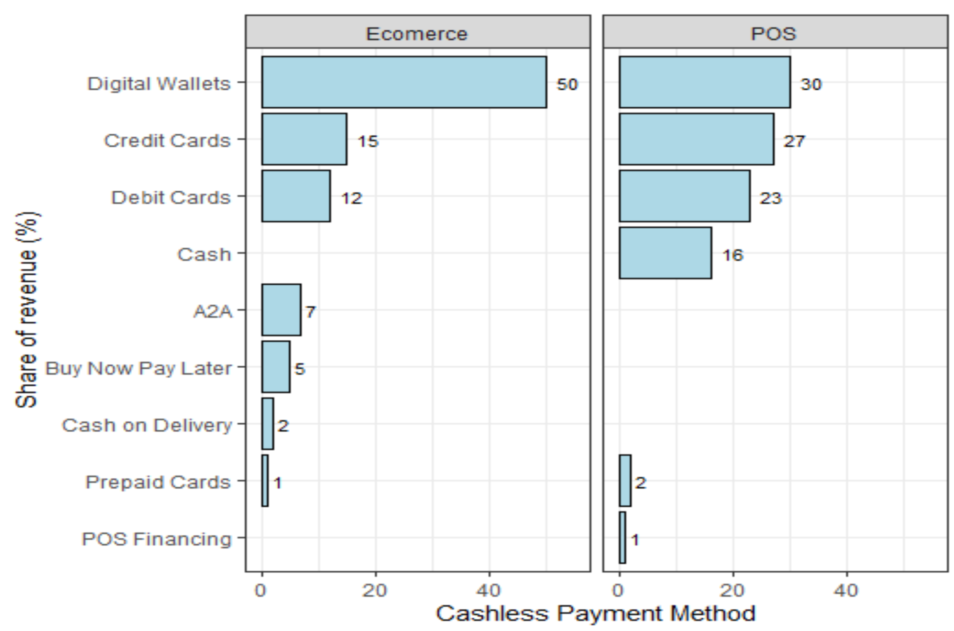

Figure 12 Share of Revenue by Payment Method in 2023 (Source: Author's own research)

Hypothesis 3. Switching from cash to cashless transactions has a measurable impact on GDP.

Visualization H3

Figure 13 shows a strong positive relationship between retail cashless transactions per 1,000 adults in a country and per capita GDP. The two variables were log-transformed to linearise the relationship and to determine the elasticity of GDP per capita with respect to the number of cashless transactions.

The volume of retail cashless transactions per 1,000 adults increased steadily from 162,000 in 2018 to 221,332 in 2023. This increase was mirrored in GDP per capita, which rose from $20.66 trillion in 2018 to $27.72 trillion in 2023. A similar pattern was observed across the countries over the years. However, Canada recorded relatively low volumes of retail cashless transactions per 1,000 adults yet maintained a higher GDP per capita.

Regression modelling

Two regression models were estimated:

- A pooled regression model based on all data points from 2018 to 2023 in all countries
- A two-way fixed effects model that accounts for individual effects of years and countries.

The two-way fixed model accounts for various country-specific time-invariant effects, as well as for year-specific effects reflecting the overall, country-invariant, tendency for the growth of per capita GDP over time. Table 4 presents the parameter estimates from the analyses.

Interpretation

The pooled regression model identifies a positive and highly significant association between retail cashless transactions per 1,000 adults and GDP per capita ($\beta = 0.60276$, $p < 0.001$) (Table 7). The number of retail cashless transactions per 1,000 adults alone accounts for approximately 59% of the variation in GDP per capita ($R^2 = 0.592$). After controlling for year and country effects, the two-way fixed effects model accounts for 99.18% of the variation in GDP per capita ($R^2 = 0.9918$); however, the number of retail cashless transactions per 1,000 adults is no longer statistically significant. All countries (not included in Table 7) showed a statistically significant positive impact on GDP per capita in the two-way fixed effects model. This suggests that the significant impact of retail cashless transactions per 1,000 adults observed in the pooled regression model was attributable to other country-specific factors.

Robustness test

Outliers are excluded from the retail cashless transactions per 1000 adults and re-estimate the two-way fixed effects model (Figure 14). The changes in parameter estimates are negligible and the conclusion about the non-significant effect of the retail cashless transactions per 1000 adults' effect on per capita GDP still holds.

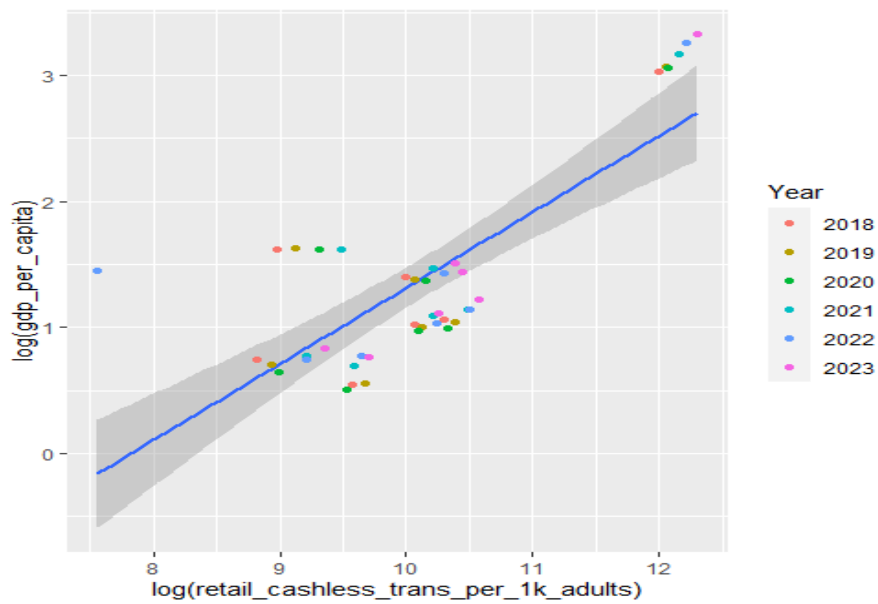

Figure 13 Relationship between GDP per capita and the number of retail cashless transactions per 1k adults (Source: Author's own research)

Table *7 Test of Hypothesis 3 (Source: Author's own research)*

log(gdp_per_capita)		
	(1)	(2)
log(retail_cashless_trans_per_1k_adults)	0.60276***	0.0025
	(0.07751)	(0.0375)
Factor (Year) 2019		-0.0045
		(0.0389)
Factor (Year) 2020		-0.03474
		(0.03897)
Factor (Year) 2021		0.0777*
		(0.0397)
Factor (Year) 2022		0.0580
		(0.0387)
Factor (Year) 2023		0.1109
		(0.0466)
Constant	-4.7138***	0.5806
	(0.7875)	(0.3581)
Observations	42	42
R^2	0.6019	0.9942
Adjusted R^2	0.592	0.9918
Residual Std. Error	0.5106	0.07251
	df=40	df=29
F Statistic	60.48	412.8
	df=(1;40)	df=(12;29)

Note. ***, **, * Significant at the 1, 5, and 10 percent levels respectively.

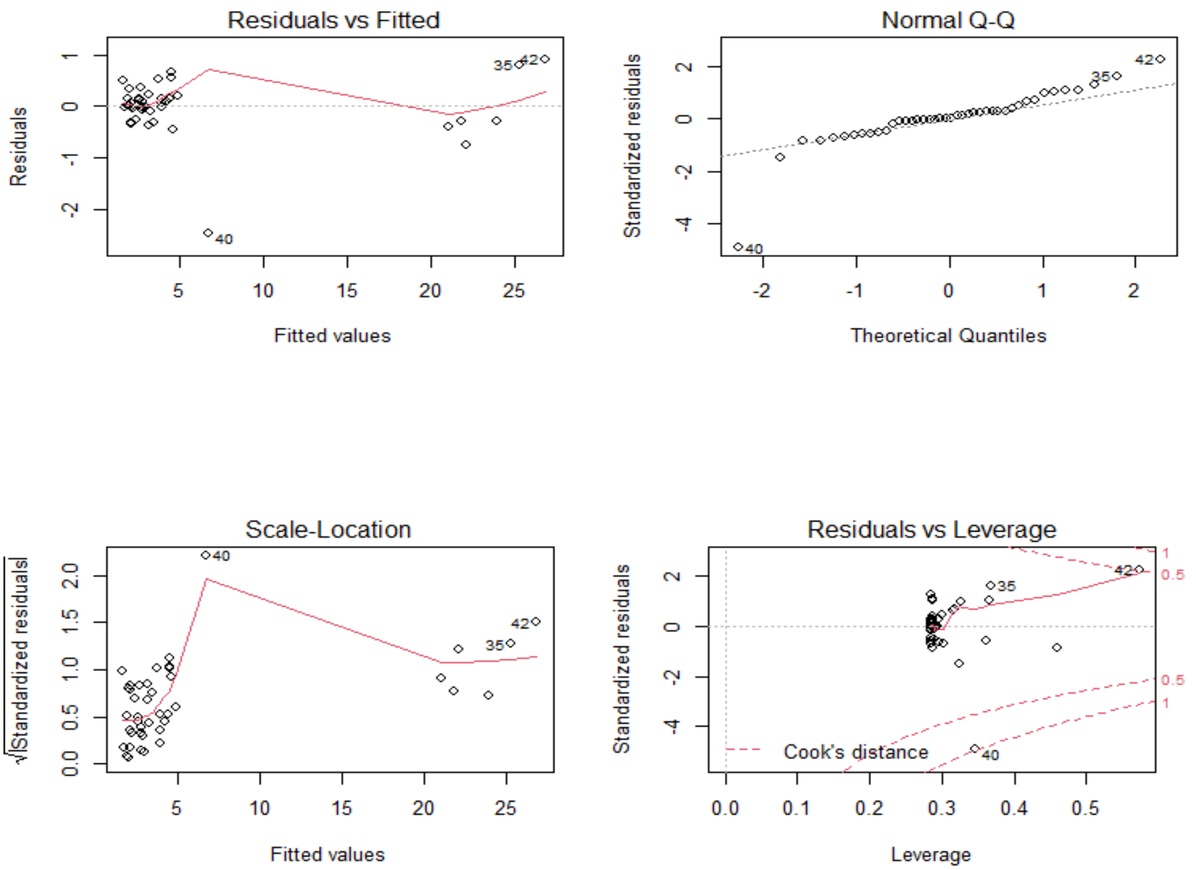

Figure 14 Diagnostic plots (Source: Author's own research)

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***Table 8** Country-Specific Analysis (Hypothesis 3) (Source: Author's own research)*

Variables	UK	USA
log(retail_cashless_trans_per_1k_adults)	9.21e-5**	1.29e-5***
Constant	-0.4650	-1.177
Observations	6	6
R2	0.9554	0.9736
Adjusted R2	0.9256	0.9561
Residual Std. Error	0.0675 (df = 3)	0.5968 (df = 3)
F Statistic	32.12 (df = 2;3)	55.41 (df = 2;3)

Country-Specific Analysis

It is evident that country-specific analysis contributes to understanding the relationship between retail cashless transactions per 1,000 adults and GDP per capita. Table 8 provides the results for the UK and the USA, the only countries in which the predictor is positively significant. Specifically, the coefficient for the UK is $\beta = 9.21e\text{-}5$ ($p < 0.05$), whilst for the USA it is $\beta = 1.29e\text{-}5$ ($p < 0.001$). These two models account for a very large proportion of the variation in GDP per capita: 95.54% for the UK and 97.36% for the USA.

The results for these two countries contradict those obtained from the two-way fixed effects models, which were not significant. It can be concluded that, within country-specific contexts, retail cashless transactions per 1,000 adults may play a more direct role in economic performance; however, when considering multiple countries collectively, this significance disappears due to other macroeconomic variables and structural differences.

4.1.3.2 Discussion

The expectation that increased payment system implementation leads to greater consumer adoption of cashless operations was not supported, based on recent data limited to the G7 economies. Initially, pooled regression models indicate a negative association between POS terminals and debit cards with cashless transactions. However, when country- and year-specific factors are controlled for, the results show that the number of POS terminals per 100,000 adults has no significant impact, and debit cards exhibit a negative correlation. This implies that a mere increase in the number of payment systems does not automatically translate into higher cashless transaction volumes. This is evident in the case of Italy, where a high number of POS terminals over the six-year period did not correlate with proportionally high cashless transaction rates, suggesting a potential saturation effect or a shift towards alternative payment methods.

For policymakers and financial institutions, this finding suggests a need to revise strategies, as the mere deployment of POS terminals or issuing more debit cards may not be the most effective approach to drive cashless adoption. There is a need to consider a broader scope of factors that substantially influence cashless adoption. Factors such as consumer behaviour, digital literacy, and the availability of alternative payment options (e.g., digital wallets and mobile payments) may contribute more to cashless adoption than the deployment of POS terminals. The negative relationship observed in this analysis between POS terminals, debit cards, and cashless transactions also indicates that users have confidence in, or prefer to use, other payment methods during cashless transactions. COVID-19 may partly account for this negative relationship, alongside other factors such as wars and financial instabilities.

The study expected that only a handful of payment systems account for the majority of cashless transactions, a hypothesis affirmed by the findings. The distribution of revenue by payment method clearly showed that digital wallets, credit cards, and debit cards dominate both e-commerce and POS transactions. This concentration has significant implications for economic activity. The positive correlation between retail cashless transactions and GDP per capita in the pooled regression model, particularly when considering the dominance of these few payment systems, suggests that their widespread adoption can drive economic growth. Conversely, the failure of the fixed effects model to show significant results implies that the relationship is complex, and specific factors within a country exert considerable influence. Therefore, whilst dominant payment systems significantly impact the economy, various macroeconomic and structural factors also come into play. These finding challenges economic actors to prioritise the integration of dominant payment systems whilst also accounting for country-specific factors.

The expectation, based on more recent data, that switching from cash to cashless transactions has a measurable impact on GDP was not fully supported. Initially, the pooled models suggested a significantly positive link between cashless transactions and GDP per capita. However, when country and year effects are included, the impact of cashless transactions on GDP per capita fails to remain significant, suggesting that country-specific factors could be responsible for the variations in GDP per capita. In the UK and the USA, cashless transactions significantly contributed to GDP per capita, implying that the impact of cashless transactions on GDP is highly dependent on country-specific factors. The lack of significance in the fixed effects models suggests that macroeconomic and structural factors contribute more significantly to GDP per capita than cashless transactions alone. Furthermore, the significant results in the UK and the USA indicate a more direct role in these countries, but the absence of significance when combining all countries shows that the results are not universal.

Despite these findings, the Breusch-Pagan tests revealed statistically significant heteroscedasticity in the models for Hypotheses 1 and 3 (BP = 27.772; BP = 30.894; $p < 0.01$, respectively), indicating that the variance of the errors is not constant across observations. This violation of the assumption of homoscedasticity suggests that the analysis of recent data and regression coefficients may be biased, leading to statistical inferences that are not accurate. Consequently, whilst the initial regression results might suggest significant relationships, the presence of heteroscedasticity necessitates the use of robust standard errors or alternative methods to ensure the reliability of the findings and the validity of these conclusions.

4.1.3.3 Limitations

The primary limitation of this analysis with recent data is its study period, which includes the 2019–2020 COVID-19 pandemic years and the post-pandemic years when economies were attempting to recover from the pandemic's effects, as well as periods affected by wars and political conflicts. It is possible that, during the pandemic, lockdowns, shifts in consumer behaviour, and government interventions accelerated the adoption of digital payments in ways that may not reflect typical economic patterns. The patterns and trends observed in this study between POS terminals per 100,000 adults, debit cards per 1,000 adults, GDP per capita, and the volume of retail cashless transactions per 1,000 adults may be biased due to the pandemic, thereby limiting their generalisability to non-pandemic years. The effects of wars and political conflicts for this exact period are yet to be fully understood, and it is too early to analyse their impact comprehensively. Another limitation of this analysis is the presence of heteroscedasticity in the regression models, which violates a key assumption of ordinary least squares regression. This violation renders the estimated standard errors unreliable, potentially leading to inaccurate statistical inferences and compromising the validity of the significance tests.

Other limitations include the lack of verifiability of data from Statista sources, particularly data on the proportion of cash volume. Additionally, the study is limited to G7 countries, which are among the most advanced economies in the world, and thus the generalisability to other countries and regions may be affected. Therefore, older data from trusted sources, combined with the absence of heteroscedasticity, would provide a better basis for validating the hypotheses.

4.2 Analysis Part II

The findings of the previous section will be further supported by a survey study based on four hypotheses, as discussed below. Digital payment systems have experienced a meteoric rise in recent times, and their adoption has revolutionised the financial landscape worldwide, particularly in the USA and the EU. Understanding the factors that promote or hinder the adoption of digital payment transactions is crucial for developing effective market strategies, technological solutions, and development policies. The literature review for this part of the dissertation is structured around four key hypotheses developed through extensive research. Accordingly, the literature review is divided into four sections for the convenience of readers.

4.2.1 Increasing digital payment methods and digital payment transactions

Most existing literature on the diversification of payment methods and its influence on consumer behaviour suggests that an increase in the number of available digital payment methods leads to a rise in digital payment transactions. Scholarly research papers generally argue that offering users a diverse range of digital payment options enhances their convenience and flexibility, thereby increasing the volume of digital payment transactions. Similarly, digital consumers are more likely to engage in digital payment transactions when they have access to multiple reliable and secure payment options (Mallat, 2007). Thus, building trust in digital platforms is as important as providing a variety of payment methods to boost digital payment transactions. Most consumers seek reliable platforms to safeguard their financial information. The adoption of digital payment transactions would be limited if multiple digital payment methods were available but perceived as complex or insecure. Research therefore indicates that factors such as trust are also statistically significant determinants of digital payment transactions, alongside the availability of options (Schierz et al., 2010). This thesis develops a separate hypothesis for factors like trust, which will be discussed later.

Several models and theories have been developed to explain the adoption of digital payment transactions. For instance, the Technology Acceptance Model (TAM), based on regression analysis, suggests that increasing the number of digital payment options can enhance digital adoption and transaction volume; however, it also emphasises ease of use and perceived usefulness as primary factors influencing technology adoption (Davis, 1989). Likewise, the Diffusion of Innovations theory posits that the widespread adoption of digital payment transactions depends on how innovations in digital transactions spread through the population, starting with early adopters. Thus, effective marketing and communication strategies are essential to raise awareness and build confidence in using such new technologies (Rogers, 2010).

Based on this literature review, it is evident that the number of digital payment options available to consumers is indeed significant and can substantially impact the adoption of digital payment transactions. This dissertation hypothesises and empirically estimates the effect of an increase in digital payment options on the adoption of digital payment transactions in the USA and the EU.

4.2.2 Specific payment methods and digital payment transaction volume

Most of the world's population today is exposed to the internet and the digital world in some form. With growing digital penetration, specific digital payment methods, such as mobile banking, debit/credit cards, PayPal, Google/Apple Pay, and cryptocurrencies, have become highly popular means of conducting digital payment transactions. Among these, mobile banking has emerged as particularly significant for digital payment transactions due to its accessibility and convenience. Research studies consistently show that mobile banking is positively correlated with digital banking transactions, especially in regions with robust mobile internet infrastructure. However, trust and safety concerns remain key barriers limiting the adoption of mobile banking for digital payment transactions. A study conducted in Brazil, employing confirmatory factor analysis and structural equation modelling, demonstrated that banks can address these concerns and increase the volume of digital payment transactions via mobile banking by promoting and highlighting security features on their websites (Malaquias & Hwang, 2016).

Similarly, debit and credit cards have remained the dominant methods for digital payment transactions in most countries. Although technology exists for making digital transactions at point-of-sale (POS) using smartphones, many retailers do not invest in upgrading their payment systems to include such POS machines, as this technology is not yet widely accepted by consumers. A research study focusing on retailers in North America and POS adoption, supported by the Technology Acceptance Model, indicates that consumer familiarity with debit/credit cards drives their usage, particularly in the USA and the EU, where these cards are deeply integrated into daily digital payment transactions (Shaw, 2014). However, cards do not monopolise digital transactions, as alternative digital payment methods like PayPal, Google/Apple Pay, and cryptocurrencies are rapidly gaining popularity.

The rise of PayPal since 1998 has been driven by its ability to facilitate secure cross-border transactions, offering significant value to consumers and businesses, such as those in e-commerce. Similarly, mobile payment services like Google/Apple Pay are growing in popularity due to their seamless integration with smartphones and wearable devices, transitioning consumers from traditional banking transactions to digital payment transactions. This shift in transactional behaviour from offline to online and digital payment methods is positively influenced by ease of use, minimal effort required from customers, competitive pricing (transaction fees), and the trust these platforms have established (Alalwan et al., 2017). Despite their utility, these payment methods still lag traditional mobile banking and card payment methods in terms of widespread adoption.

Lastly, cryptocurrencies represent another digital payment option, leveraging blockchain technology to offer anonymity and decentralisation. Researchers have explored cryptocurrencies as a digital payment mechanism with the potential to revolutionise the existing financial system. For instance, some have proposed optimal cryptocurrency financial systems based on social factors (e.g., effort) and technical factors (e.g., peer assistance in blockchain networks) (Titov et al., 2021), highlighting their potential for daily digital payment transactions. However, despite their popularity, the use of cryptocurrencies for transactions remains limited due to concerns over volatility and lack of widespread acceptance.

Based on this literature, it is clear that specific payment methods including mobile banking, debit/credit cards, PayPal, Google/Apple Pay, and cryptocurrencies—have varying impacts on the volume of digital payment transactions. Therefore, this thesis hypothesises and empirically estimates the effect of each of these payment mechanisms on the number of digital payment transactions in the USA and the EU.

4.2.3 Barriers to the adoption of digital payment transactions

It is imperative to examine barriers to the adoption of digital payment transactions when exploring their determinants. Most research papers in the literature highlight various barriers, including, but not limited to, lack of point-of-sale infrastructure, technical failures, complexity of digital transactions, inadequate infrastructure, and trust issues.

Technical failures are identified as a major barrier to the adoption of digital payment transactions. Research indicates that digital consumers are reluctant to use payment methods plagued by slow processing times, technical glitches, or system crashes. These issues become more pronounced when moving from urban to rural regions, where internet infrastructure is often weaker. If technical failures are severe and affect multiple digital payment providers simultaneously, they can disrupt the entire retail payments system. For example, research demonstrates that if technical failures occur across payment providers, whether bank or non-bank,and users cannot access alternative payment technologies, the retail payment system may grind to a halt. Prolonged technical failures could have negative economic consequences, fostering widespread fear and panic due to financial insecurity (Allen et al., 2021). Thus, the success of any digital payment method and the adoption of digital payment transactions heavily depend on the stability and technical reliability of the digital platform, as well as the broader internet infrastructure.

Trust issues are arguably the most significant barrier to the adoption of digital payment transactions, as many consumers hesitate to share financial information due to doubts about data security. The risk of data breaches or fraud heightens the perceived risk associated with digital payment mechanisms. A substantial body of literature has focused on the role of trust in digital payment adoption. For instance, research based on trust transfer theory and the valence framework, using Structural Equation Models (SEMs) to develop a trust model for consumer decision-making, reveals that trust directly and indirectly influences digital consumer behaviour and is a statistically significant determinant of digital payment adoption (Lu et al., 2011). Therefore, digital payment providers must establish trust in their mobile or online payment systems to overcome customer reluctance.

Complexity is another barrier that can hinder the adoption of digital payment transactions, particularly for less educated or older individuals who struggle with technology. Research has shown that ease of use and perceived usefulness are critical predictors of mobile payment adoption

(Kim et al., 2010). Hence, digital payment providers should simplify the user experience through improved design and user-friendly interfaces to address the complexity barrier and enhance adoption.

Finally, the literature identifies inadequate internet infrastructure and lack of access to digital payment methods as additional barriers to adoption. These challenges are particularly significant in rural areas with limited internet and smartphone access. Improving such infrastructure in rural regions could not only boost the adoption of digital payment transactions but also foster developmental resilience (Wu et al., 2023).

Based on this discussion, it is evident that barriers such as lack of point-of-sale infrastructure, technical failures, complexity of digital transactions, inadequate infrastructure, and trust issues significantly impede the adoption of digital payment transactions. Thus, this thesis hypothesises and empirically estimates whether these barriers have a statistically significant impact on the adoption of digital payment transactions in the USA and the EU, and whether these regions differ in the severity of such barriers.

4.2.4 Factors influencing digital payment transactions

Just as there are numerous barriers to the adoption of digital payment transactions, there are also many factors that positively influence and incentivise digital consumers to adopt digital payments as an alternative to traditional banking transactions. These factors include, but are not limited to, convenience, trust, security, discounts and promotions, ease of use, and perceived usefulness.

Convenience is frequently cited as a key factor influencing the adoption of digital payment transactions in the literature. Today, digital consumers value the ability to make payments quickly and easily using smartphones or other digital devices. The convenience offered by digital payment platforms integrates them into the daily activities of consumers, supporting peer-to-peer transfers, bill payments, and shopping. This convenience factor is particularly significant in promoting digital payment transactions in countries like the USA and the countries of the EU, where consumers have access to a wide range of digital payment providers for fast and efficient transactions. For example, research examining the relationship between perceived convenience and digital payment options, such as mobile banking and debit/credit cards, demonstrates a statistically significant link between customer convenience and digital payments (Boden, Maier, & Wilken, 2020).

Similarly, trust is a critical determinant of digital payment transaction adoption. Research indicates that digital consumers are more likely to use digital payment systems if they trust the service provider and believe their financial data is secure. Scholarly papers applying the Technology Acceptance Model (TAM), which emphasises perceived ease of use and usefulness, also identify trust as a significant factor in digital transactions and mobile payment adoption. Researchers suggest that users are more willing to trust a digital payment provider when they perceive it as legitimate and equipped with robust safety mechanisms to protect financial data (Gefen et al., 2003). Digital mobile payment service providers can thus build trust by implementing enhanced security measures, such as encryption and two-factor authentication. Other studies argue that secure mobile technology and credible digital payment providers can more easily establish trust in their services and products (Chandra et al., 2010). Consequently, trust can be cultivated by digital payment platforms themselves to promote adoption.

Likewise, perceived ease of use is an important determinant of digital payment adoption, as highlighted by the Technology Acceptance Model (TAM). Research suggests that perceived ease of use significantly shapes consumer decisions regarding mobile payment mechanisms and their adoption (Nurhasanah et al., 2023). Studies also show that providing customers with a digital payment system that is easy to navigate and understand can boost adoption, as simple user interfaces and clear instructions enable less tech-savvy individuals to use digital payment applications effectively.

The availability of incentives, discounts, and loyalty programmes can also positively influence the adoption of digital payment transactions. For instance, a study using logistic regression found that consumers seeking discounts are more likely to use online payment mechanisms. The researchers also noted that awareness of cashback offers can shift consumer preferences towards digital payment options, though they argue that discounts are a more effective promotional tool than cashback offers (Mishra et al., 2016). Thus, research demonstrates that digital consumers are more inclined to use digital payment platforms when appropriately incentivised and rewarded. Such incentives not only attract new customers but also help retain existing ones, thereby increasing the volume of digital payment transactions.

Lastly, demographic factors such as education, age, and income play a significant role in determining the adoption of digital payment transactions. Research indicates that this information can be used to segment and target different customer groups across markets, influencing their adoption of digital payment transactions. Such demographic data would also be valuable for governments and policymakers aiming to enhance digital payments and reduce the digital divide (Akhter, 2003). Similarly, studies show that young, highly educated consumers with higher incomes are more likely to adopt digital payment transactions.

Based on this discussion, it is clear that factors such as convenience, trust, security, discounts and promotions, ease of use, and perceived usefulness significantly enhance the adoption of digital payment transactions. Thus, this dissertation hypothesises and empirically estimates whether these factors have a statistically significant impact on the adoption of digital payment transactions in the USA and the EU, and whether these regions differ in the strength of such influences.

4.2.5 Survey design

This dissertation employs a survey methodology developed using established theoretical frameworks to assess the determinants of digital payment transaction adoption in the USA and the EU. The survey was designed following best practices in survey research to ensure the collection of valid, accurate, and representative data for the target population. This section details the survey design process and the rationale behind key methodological choices, including the survey structure, questionnaire, target population, and mode of administration. These elements are critical to establishing a robust framework for the survey. The complete survey questionnaire used to gather data for this research is available in the Appendix.

Target population and sampling

The target population for the survey comprises individuals aged 18 or above with prior experience in using digital payment systems, residing in the USA or the EU. Respondents with some experience in digital payment systems were selected to provide insights into their behaviour and preferences when using digital payment platforms, as well as any barriers they encounter. Clearly defining the target population is a vital step in survey research, as it facilitates the generalisation of findings in empirical studies. This thesis adopts a non-probability sampling method, specifically convenience sampling, as the target population was accessed through digital platforms. Whilst non-probability sampling may introduce some bias, it is widely used in exploratory research with logistical constraints due to its cost-efficiency (Bryman, 2016).

Sample representativeness is a concern, particularly when conducting a survey across two regions with cultural and infrastructural differences, such as the USA and the EU, using a cross-sectional research method. To mitigate potential bias, the survey was tailored to the sociocultural context of each country, and culturally neutral language was employed to ensure accessibility to a broad range of demographics in both regions. This approach renders the survey a culturally neutral instrument for international research (Fowler, 2013).

Survey structure

The survey questionnaire was structured into different sections, i.e., demographics, adoption, and usage of digital payment preferences, along with the reasons and barriers to digital adoption. These different sections in the survey were incorporated to signify the role of attitudes, behaviour, and subjective norms in adopting new technologies, as also advocated by the Technology Acceptance Model and the Theory of Planned Behaviour (Ajzen, 1991).

Demographics

The first section captures demographic information such as income, age, gender, and education, as research indicates these factors significantly influence technology adoption, particularly digital payments and transactions (Akhter, 2003).

Digital payment usage and preferences

This section explores the digital payment methods frequently used by respondents in the USA and the EU, including options such as debit/credit cards, Google/Apple Pay, PayPal, and cryptocurrencies. A Likert scale was employed to measure respondents' attitudes and perceptions in these preference-based and behavioural questions. Likert scales are valuable in behavioural studies and are considered reliable for assessing attitudes and perceptions (Boone & Boone, 2012). They provide subjective measures of behaviour, preferences, and attitudes towards digital payment adoption, ensuring comparability across respondents. Additionally, data were collected on reasons for using digital payments, such as convenience, offers and discounts, trust, and ease of use, which are thoroughly discussed in the literature review of this dissertation.

Barriers to digital payment adoption

The final section examines barriers to adopting digital payment transactions in the USA and the EU, including lack of point-of-sale infrastructure, technical failures, complexity of digital transactions, and trust issues. The Diffusion of Innovations theory also recognises barriers such as risk and complexity as significant determinants of technology and digital payment adoption (Rogers, 2010). The survey questionnaire used only closed-ended questions to collect quantifiable data suitable for empirical testing.

Mode of survey administration

The survey was conducted online. Online surveys have become increasingly prevalent in research due to their scalability and efficiency. They significantly reduce the cost and time required to collect responses, particularly when participants are geographically dispersed (Evans & Mathur, 2018). However, online surveys may introduce sampling bias, as they are accessible only to individuals with internet access and sufficient digital literacy. To mitigate this, the survey questionnaire was distributed via emails and various social media platforms to reach a diverse audience, leveraging the connectivity of these digital channels and modern data collection techniques to enhance response rates and obtain high-quality feedback. The survey adhered to the Total Design Method (TDM), incorporating strategies such as personalised invitations, reminders, and confidentiality assurances to maximise participation (Dillman et al., 2014). Additionally, a redundancy question was included to automatically exclude bots or respondents not paying attention, ensuring data quality.

***Ethical* considerations**

The survey methodology rigorously adhered to ethical best practices throughout the process. Informed consent forms were provided to all respondents, who were also granted the right to withdraw from the study at any time. Furthermore, respondents were assured that their responses would remain confidential, and that the data would be used solely for academic research, in line with best research practices (Fink, 2015).

Data collection period

The survey was conducted over two weeks in August 2024 over the platform of Centiment.co, which is a reputable platform used by global enterprises such as Walmart, BMW, Lyft, McKinsey, and reputable universities such as Harvard and Stanford. This allowed participants sufficient time to respond without feeling rushed and minimising survey fatigue. During this period, follow-up reminders were sent to participants who had not yet responded, maximising the response rate. Further responses were also collected in May-August 2024 from the University of Sopron and the University of Burgenland forming the EU dataset.

As a result of this survey methodology, the study successfully gathered reliable, noise-free data. The specifics of the collected data will be discussed in later sections of this thesis, alongside the results of descriptive and empirical analyses using Stata.

Empirical methodology

This section outlines the empirical methodological approach used to assess the determinants of digital payments and transactions in the USA and the EU. The dissertation employs statistical tests and econometric models well-established in the literature for cross-sectional datasets to ensure the validity of its findings. This section covers data collection, data cleaning and pre-processing, model specification, and diagnostic and robustness checks. All data modelling and empirical estimations were performed using Stata, a widely recognised statistical software in academic research.

Data collection

The dataset for the empirical estimations is a primary cross-sectional dataset collected through the structured survey design and questionnaire described earlier. Details of the target population and survey specifics have already been provided in the previous section.

Data cleaning and preprocessing

Data cleaning is critical in econometric analysis to ensure error-free and unbiased results. The raw survey dataset was thoroughly cleaned before statistical analysis. It contained minimal missing values with no systematic patterns; these were addressed using listwise deletion. Outliers were carefully identified and removed, as they can disproportionately skew regression results (Wooldridge, 2016).

Descriptive statistics, including the number of observations, mean, median, maximum, and minimum values,were computed for each variable to enhance data understanding. Measures such as skewness and kurtosis were also calculated for variables used in regression models to assess their distribution, as a normal distribution is essential to satisfy the normality assumption of OLS regression (Doane & Seward, 2011). Additionally, visualisations such as pie charts and bar graphs were created for initial data exploration.

Statistical tests and econometric models

Given the cross-sectional dataset, Ordinary Least Squares (OLS) multilinear regression models were used to estimate the determinants of digital payment transactions in the USA and the EU. OLS regression models are widely applied to estimate linear relationships among variables in cross-sectional data and are theoretically simple yet robust under the Gauss-Markov assumptions of homoscedasticity and no perfect multicollinearity (Greene, 2012).

Many scholarly papers on digital payment adoption also employ OLS regression models. For instance, Liébana-Cabanillas et al. (2014) used OLS regression to quantify the effects of risk, trust, and ease of use on digital payment adoption and online transactions. Similarly, OLS multilinear regression models have been used to explore mobile banking adoption (Aboelmaged & Gebba, 2013). These studies provide a theoretical basis for using OLS regressions in this thesis, which investigates the determinants of digital payment transactions and their adoption in the USA and the EU.

Model specification and assumptions

The dependent variable for all OLS regression models is the volume of digital payment transactions in the USA and the EU. The study estimates four distinct OLS model specifications, each with key independent variables derived from the literature to test the four hypotheses. These include various digital payment methods (e.g., debit/credit cards, Google/Apple Pay, PayPal, cryptocurrencies), factors promoting adoption (e.g., trust, ease of use, convenience, offers and discounts), and factors hindering adoption (e.g., lack of point-of-sale infrastructure, risk, complexity, technical failures). Established theories, such as the Technology Acceptance Model (TAM), endorse the use of these variables to explore digital payment adoption determinants.

The mathematical equations for each of the four OLS model specifications will be presented in later sections discussing empirical results. As a final check before running the regression models, a correlation matrix was calculated, providing pairwise correlation coefficients for all variables to detect potential multicollinearity. Variance Inflation Factors (VIFs) were also estimated for each OLS model to confirm the absence of perfect multicollinearity (Marquardt, 1970). Fortunately, the models exhibited low VIFs, indicating that perfect multicollinearity is not a concern.

Diagnostic testing and robustness checks

Post-regression diagnostic tests were conducted to validate the OLS regression estimates. The Breusch-Pagan/Cook-Weisberg test for heteroscedasticity was used to determine whether the residuals are homoscedastic, with the null hypothesis positing heteroscedasticity and the alternative suggesting homoscedasticity (Breusch & Pagan, 1979). The Durbin-Watson statistic was also applied to check for serial autocorrelation in the OLS models (Durbin & Watson, 1950). As a precaution, robust standard errors were used in the OLS regression models to address any potential heteroscedasticity or serial autocorrelation issues.

Finally, the coefficient of determination (R-squared and adjusted R-squared) was used to compare the four OLS multilinear regression models. The results of this empirical methodology will be elaborated in subsequent sections.

Limitations

Although the research and empirical methodology appear robust and offer valuable insights into the determinants of digital payment transactions in the USA and the EU, this thesis, like all studies, has limitations that must be acknowledged.

Firstly, the study uses a medium sample size of 530 respondents, which limits the generalisability of the empirical findings; a larger sample would enhance robustness. Secondly, the data do not fully account for regulatory, infrastructural, and economic differences between and within the USA and the EU, such as variations in banking infrastructure, government policies, and internet penetration, potentially restricting generalisability. Thirdly, sample selection bias may affect the findings, as the sample primarily includes respondents with internet access and experience using digital applications, potentially excluding older, less educated individuals in remote rural areas of the USA and EU. Consequently, the results may not reflect the digital adoption behaviours of groups facing educational or infrastructural barriers. Lastly, while the dissertation models key variables like trust, convenience, and barriers, it omits other factors such as cultural attitudes towards technology, regulatory frameworks, or marketing efforts beyond discounts, raising concerns about omitted variable bias.

Future researchers are encouraged to address these limitations by using larger, more diverse datasets with a comprehensive set of variables. Expanding the geographical scope to include countries beyond the USA and the EU could also uncover additional determinants of digital payment transaction adoption in the internet age.

4.2.6 Descriptive statistics

This section explains descriptive statistics of the survey data. This part comprises multiple parts, including demographics (education, employment, gender, income, and residence), preferences, reasons, usage, and hindrances. Each part is explained as follows.

Demographics

The sample used in the study is gathered through a survey experiment given to a sample from two regions (Figure 15) the USA and Europe (EU). There are 483 respondents from the US and 47 from the EU, totaling 530 respondents.

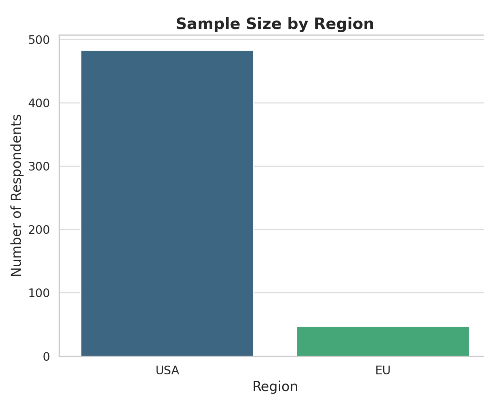

Figure 15 Sample size by region (Source: Author's own research)

Residence

Regarding residence, 53.6% of US respondents live in city areas, while 33.1% live in towns, making up 91.54% living in non-rural areas (Figure 16). Only 8.5% live in villages, and 4.8% live in metropolises. Similarly, 48.9% of EU respondents live in cities, and 21.3% live in towns, totaling 76.6% residing in non-rural areas. Conversely, only 23.4% of the respondents live in villages. Therefore, it can be concluded that most of the US and EU survey respondents reside in non-rural areas.

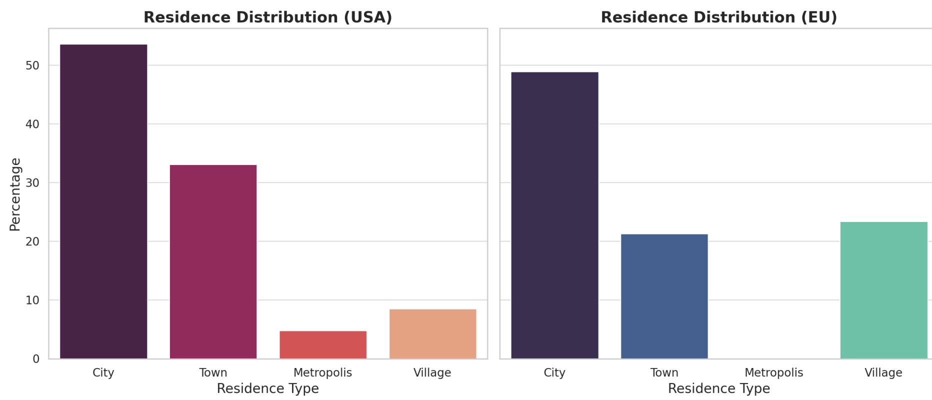

Figure 16 Residence distribution (Source: Author's own research)

Gender

In the United States, 51% of respondents identify as female, while 49% identify as male, indicating a nearly equal balance between genders (Figure 17). Conversely, 57% of European respondents are female, 40% are male, and 2% identify as other genders. These findings from both surveys demonstrate a relatively equitable gender distribution between males and females.

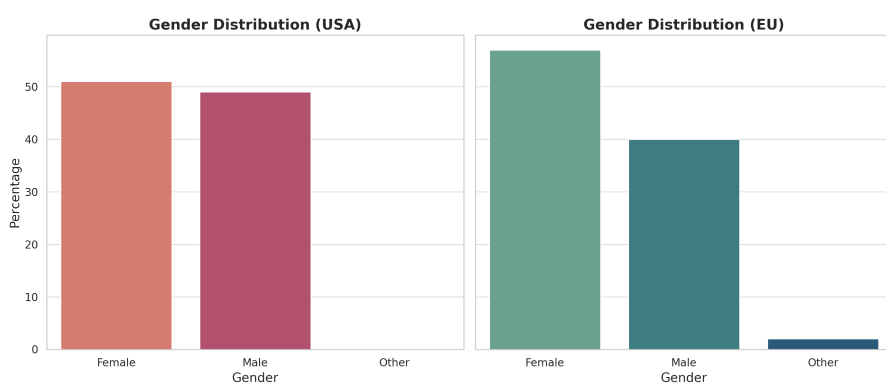

Figure 17 Gender distribution (Source: Author's own research)

Education

In the United States, the majority of respondents had completed high school (55%), followed by a bachelor’s degree (22%), a master's degree (11%), and a doctorate (3%). In the EU, a bachelor's degree was the most common (43%), followed by high school (28%), a master's degree (17%), and a doctorate (13%) (Figure 18). However, both regions share similarities in that high school and bachelor's degree graduates are the primary respondents in the survey.

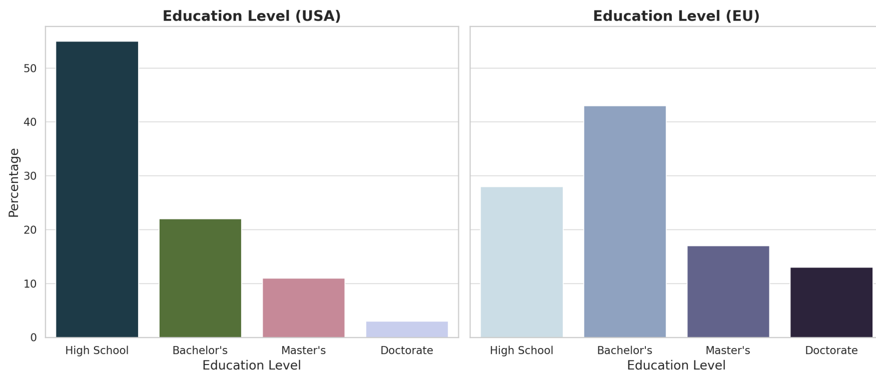

Figure 18 Education level (Source: Author’s own research)

Employment

The survey shows that in the USA 36% of respondents are employed in the public and business sectors, 24% are unemployed, and 22% fall into the "others" category (Figure 19). In contrast, European respondents are primarily students (62%), followed by those employed in public and business (32%).

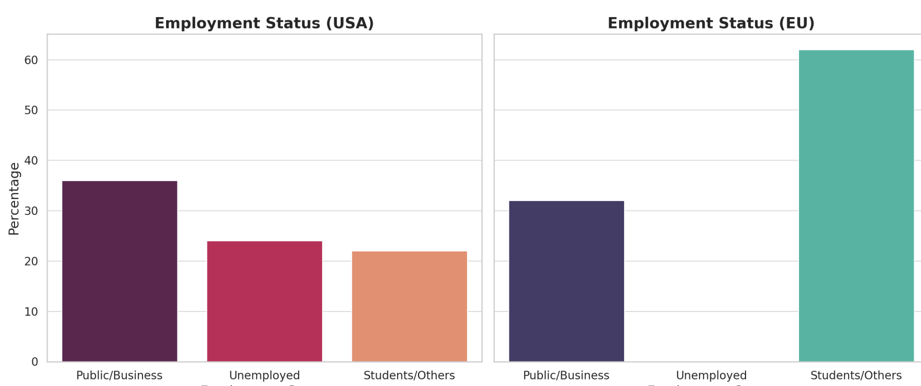

Figure 19 Employment status (Source: Author’s own research)

Income

The survey data from the US shows that most respondents (43%) have an annual income exceeding 35,000 USD, followed by 36% earning between 12,000 and 35,000 USD, and the remaining 21% earning less than 12,000 USD annually (Figure 20). On the other hand, in Europe, 64% of respondents earn less than 12,000 EUR per year, followed by 190% earning between 12,000 and 35,000 EUR, and 17% earning over 35,000 EUR annually. This disparity in income distribution between the two regions could impact their perspectives on digital payment services.

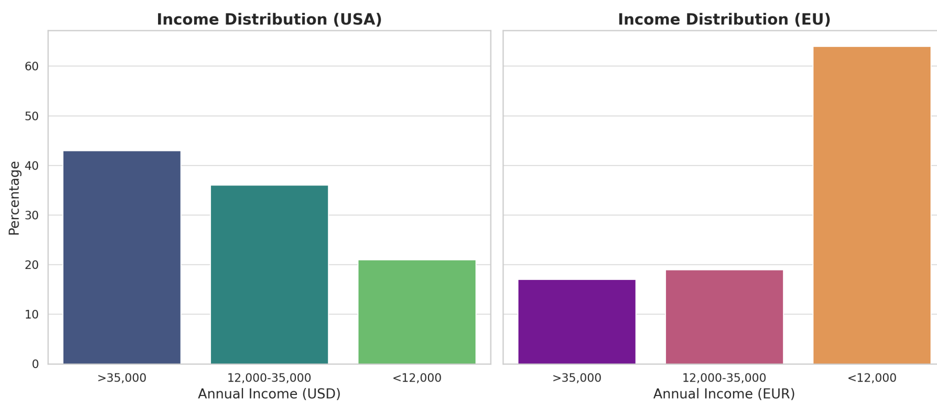

Figure 20 Income distribution (Source: Author's own research)

4.2.7 Preferences

General payment preference

This study assessed the respondents' preferences regarding card payment, cash payment, and digital payment. The opinions were measured on a scale of 1 to 5, with 1 representing the lowest preference ("I do not like it at all") and 5 representing the highest preference ("I love it"). A strong preference was considered when participants rated 4 or 5, while a rating of 1 or 2 indicated a weak preference. A rating of 3 was considered indifferent. The results from the US sample indicate that card and cash payments are almost equally preferred, with cash being favored by 56% of the respondents and card by 55%. Digital payment, however, was less popular than card and cash, receiving votes from only 44% of the respondents.

In the EU sample, card payment was identified as the most preferred payment method, receiving 72% of the votes from respondents (45% voted scale 5 and 27% voted scale 4). However, unlike the US sample, digital payments emerged as the second preferred method in the EU, with 52% of the sample favoring it (30% voted scale 5 and 22% voted scale 4). Finally, cash was ranked as the least preferred payment method compared to the other two. Cash payment received 47% of the votes from the EU sample (35% voted scale 5 and 12% voted scale 4).

Digital preference

This study assessed respondents' preferences for digital payment methods, including credit cards, debit cards, Google/Apple Pay, mobile banking, and PayPal. Responses were measured on a 1 to 5 scale, with 1 indicating the lowest preference ("I do not like it at all") and 5 representing the highest preference ("I love it"). Strong preferences were defined as the sum of votes for scales 4 and 5, weak preferences for scales 1 and 2, and indifference for scale 3. For the US sample, the results indicate that the most preferred digital payment method is the debit card, with 47% of respondents expressing a strong preference (32% for scale 5 and 15% for scale 4). This is followed by mobile banking (40%), PayPal (39%), credit cards (38%), and Google/Apple Pay (26%). Conversely, for the EU sample, the survey reveals that mobile banking is the most preferred digital payment method, with 63% of respondents showing a strong preference (41% for scale 5 and 22% for scale 4). Following closely is the debit card, preferred by 59% of respondents, along with Google/Apple Pay (50%), credit cards (39%), and PayPal (26%).

Reason

When it comes to the factors influencing the adoption of digital payments, the survey conducted in the US indicates that convenience is the primary reason, cited by 74% of the respondents, followed by ease of use, which is mentioned by 58% of the participants. A smaller proportion of respondents mentioned availing discounts (24%) and trustworthiness (25%) as reasons for using digital payments. Similarly, the survey conducted in the EU also highlights convenience as the most significant factor, identified by 70% of the participants. The following closely follows ease of use, which is mentioned by 66% of the respondents. The remaining reasons cited were discount offers (26%) and trustworthiness (15%). A comparison of these two surveys reveals that the preference order for reasons among the US and EU samples is identical.

Digital usage

According to the survey, the majority of respondents in the US use digital payments primarily for groceries (63%), followed by payment of bills (60.5%), shopping (51%), online shops (47%) money transfers (41%), food ordering apps (40%). In contrast, the survey conducted in the EU indicates that ticket booking and travels 87%, then online shopping is the most common use of digital payments (72%), followed by money transfers (70%), food ordering (66%), mobile TV recharges (64%), groceries (57%), general shopping (55%), hotel, fuel, and taxi payments (53%), and bill payments (51%).

Hindrance

According to the survey, technical failure is the most significant obstacle preventing respondents from using digital payment applications. In the US sample, 41% of respondents identified this as a major hindrance. Additionally, trust and risk (34%), unfamiliarity or discomfort (28%), lack of access to the app (25%), and complexity of digital (19%) were also cited as important barriers. In the EU sample, the survey reveals that technical failure is the primary obstacle, with 45% of respondents considering it the most significant. Trust issues are the second most significant hindrance, cited by 36% of respondents, followed by the complexity of digital (26%), unfamiliarity or discomfort (21%), and the lack of digital apps (23%).

Top of mind

The survey assesses the top-of-mind awareness of various digital payment methods using a scale ranging from 1 to 6, where 1 represents the highest awareness and 6 is the lowest. The digital payment methods evaluated include PayPal, mobile banking, Google or Apple Pay, debit cards, credit cards, and cryptocurrency. Analysis reveals that debit cards hold top-of-mind awareness across all methods and are ranked as the most prominent payment method, with 43.95% of US respondents selecting them. The second most recognized payment method is credit cards (23.75%), followed by mobile banking (13.12%), PayPal (11.69%), Google/Apple Pay (4.59%), and cryptocurrency (2.92%).

4.2.8 Modelling the hypotheses

In this section, we model four hypotheses. All hypotheses are modeled using fixed-effect regression models and estimated using R. The dependent variable across all models is digital payment transactions, presented in percentage value. Cross-sectional analysis may suffer from heteroskedasticity issues. Hence, all models in the study are estimated using OLS regression with robust standard error to adjust for heteroskedasticity. Even if the original model does not suffer from heteroskedasticity, the robust estimation already handles the issue. Furthermore, the total number of samples is high (Kwak, 2017; Islam, 2018), so the central limit theorem satisfies the normality assumption. All independent variables are well retained across all models, confirming no multicollinearity exists since the model only incorporates one independent variable. There are also no outliers in the dependent and independent variables because both dependent and independent variables used in the model are constrained within a specific range. For example, digital payments are constrained between 0 – 100, the number of payments is constrained between 1 – 6, and reasons and hindrances are coded as dummy variables. The estimation of each hypothesis is presented in the sequent sections.

Hypothesis 1

The first hypothesis aims to determine if increasing digital payment options significantly impacts digital payment transactions. The null hypothesis states that it cannot be concluded if the rise in digital payment options substantially affects the volume of digital payment transactions. Conversely, the alternative hypothesis suggests that the growing number of digital payment methods significantly impacts digital payment transactions. A model is constructed to investigate this with the percentage of digital payment transactions as the dependent variable. This data is collected from an open question in the survey regarding the percentage of digital payments compared to cash payments.

The primary independent variable in the model will be the number of digital payment methods, which is determined based on respondents' preferences for six digital payment methods. The number of payment methods is calculated by summing the preferred methods rated on a scale of 4 and 5. In this analysis, it is assumed that an individual rarely uses a payment method rated below 4. Demographic variables, such as country (US/EU), gender, age, residence, education, and employment, are also included as fixed effects in the model. Based on this assumption, the estimated model is as follows:

$$Digital\ transaction_i = \beta_0 + \beta_1 Number\ of\ digital\ payment_i + \boldsymbol{A}'\boldsymbol{X} + \varepsilon_i$$

Where β_0 denotes intercept and β_1 is the estimated impact of the number of digital payment methods on the amount of digital payment transactions. Furthermore, $\boldsymbol{X}$ is the vector of control variables {gender, age, residence, education, and employment}, $\boldsymbol{A}$ is the vector of estimated coefficients of control variables, and ε_i is the error term. The estimated model is provided in Table 9.

Table 9 *Regression Model for Hypothesis 1(Source: Author's own research)*

Digital percent	Coef.	Std.Err.	t	P>t	[95%Conf.	Interval]
Number of digital payment	2.387	0.791	3.015	0.0027	0.831	3.942
_cons	46.602	1.927	24.180	0.000	42.816	50.388

(MWFE estimator converged in 8 iterations)

HDFE Linear regression	Number of obs.	=1Absorbing 6 HDFE groups
	F(1,503)	= 9.27
	Prob > F	= 0.0025
	R-squared	= 0.1037
	Adj R-squared	= 0.0622
	Within R-sq.	= 0.0181
	Root MSE	=26. 876

The model presented in Table 9 reveals the following insights. Firstly, the estimated coefficient is positively significant at 2.387 with a p-value of 0.0027. This suggests that increasing the number of digital payments adopted by one method significantly boosts digital payment transactions by 2.39%, all else being constant. The low p-value of 0.003, below the 5% significance level, provides substantial evidence to reject the null hypothesis and supports the alternative, indicating that the influence of the number of payment methods on digital payment transactions is significant. This finding confirms our hypothesis that more digital payment methods encourage individuals to engage in digital payment transactions.

Secondly, the model indicates a probability of F-statistics of 0.0025, also below the 5% significance level. This implies that the joint impact of the explanatory variables, including the independent and fixed effect variables (or control variables), is collectively significant in influencing digital payment transactions. However, thirdly, the model demonstrates a relatively low R-squared value of 0.0622, indicating that the explanatory variables can only account for 6.22% of the variance in the share of digital payment transactions. This low R-squared value suggests the potential influence of other independent variables on the share of digital payment transactions.

Table 10 *Detailed Model for Hypothesis 1*

Digital percent	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Number of digital payment	2.388	.743	3.21	.001	.928	3.848	***
Country: base Europe							
USA	-21.92	4.328	-5.06	0	-30.423	-13.416	***
Gender: base Female							
Male	-2.238	2.556	-0.88	.382	-7.259	2.783	
Other (key in)	-31.871	8.635	-3.69	0	-48.836	-14.906	***
Age: base 18-24							
25-34	-8.128	4.019	-2.02	.044	-16.025	-.231	**
35-44	-1.636	4.32	-0.38	.705	-10.124	6.852	
45-54	.403	4.531	0.09	.929	-8.499	9.305	
55-64	3.338	4.495	0.74	.458	-5.494	12.169	
65 and above	-2.3	5.1	-0.45	.652	-12.32	7.72	
Residence: base City							
Metropolis	3.881	6.142	0.63	.528	-8.187	15.949	
Town	-1.986	2.641	-0.75	.452	-7.174	3.203	
Village	-7.601	4.196	-1.81	.071	-15.845	.643	*
Education: base Bachelor							
Doctorate	-1.098	7.129	-0.15	.878	-15.105	12.909	
High School	-4.095	3.191	-1.28	.2	-10.365	2.174	
Master's Degree	1.87	4.478	0.42	.676	-6.928	10.668	
Other (key in)	4.568	4.963	0.92	.358	-5.183	14.319	
Employment: business							
Housewife	4.096	4.689	0.87	.383	-5.117	13.309	
Other (key in)	2.219	4.265	0.52	.603	-6.16	10.599	
Self-employed	2.441	3.876	0.63	.529	-5.175	10.057	
Student	21.617	7.405	2.92	.004	7.068	36.166	***
Unemployed	3.646	3.318	1.10	.272	-2.873	10.165	
Constant	69.889	5.766	12.12	0	58.561	81.217	***
Mean dependent var		51.265	SD dependent var			27.792	
R-squared		0.107	Number of obs			525	
F-test		4.071	Prob > F			0.000	
Akaike crit. (AIC)		4964.347	Bayesian crit. (BIC)			5058.142	

**** p<.01, ** p<.05, * p<.1*

The detailed estimations of control variables are outlined in Table 10. According to this table, digital transactions in the US sample are significantly lower than those in the EU, holding the number of digital payment options constant. Additionally, there is no notable difference in digital transactions between male and female respondents when the number of digital payment options remains unchanged. Among the sample, it is observed that only respondents aged 25–34 years exhibit significantly lower levels of digital transactions compared to other age groups. Furthermore, the model indicates that respondents residing in villages tend to have lower digital transaction levels than those living in cities. Lastly, students are associated with higher digital spending compared to individuals working in the public or private sectors; no other occupations show a significant impact on digital spending.

In conclusion, a strong positive correlation exists between the number of digital payment methods used and the volume of digital payment transactions. Introducing an additional digital payment method is significantly associated with a 2.38% increase in digital spending, all other variables held constant. This result suggests that offering more digital payment options encourages greater engagement in digital payment transactions. This finding also creates opportunities for new market players to enter, innovate, and introduce novel payment methods. For example, if an individual previously used only two digital payment methods—mobile banking and Apple Pay—and then added PayPal, the model projects a 2.38% increase in digital spending. Moreover, the projected increase in spending could be even more substantial for a European female, aged 18–24, who is a student.

Hypothesis 2

The second hypothesis explores whether specific digital payment methods substantially impact increasing digital payment transactions. The null hypothesis posits that it can be concluded if no specific digital payment method substantially affects the volume of digital payment transactions. Conversely, the alternative hypothesis suggests that at least one digital payment method significantly affects digital payment transactions. In investigating this hypothesis, a structure model is as follows:

$$Digital\ transaction_i = \beta_0 + \boldsymbol{B'Y} + \boldsymbol{A'X} + \varepsilon_i$$

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The model's dependent variable is the percentage of digital payment transactions relative to total spending. The vector of independent variables, denoted as Y, includes mobile banking, debit cards, credit cards, PayPal, Google/Apple Pay, and cryptocurrencies, all represented as binary variables. Specifically, these independent variables are coded as either 0 or 1: an independent variable (e.g., debit card) is coded as 1 if a respondent rates the method (i.e., debit card) with a rank of 4 or 5; otherwise, it is coded as 0 if the respondent assigns a rank less than 4. The vector of estimated coefficients for the independent variables is denoted as B. Additionally, X represents the vector of control variables, including country, gender, age, residence, education, and employment, with A as the vector of estimated coefficients for these control variables. The error term is denoted as ε_i. The estimated model is presented in Table 6 as follows:

Table 11 *Regression Model for Hypothesis 2 (Source: Author's own research)*

Digital percent	Coef.	Std.Err.	t	P>t	[95% Conf	Interval]
Mobile banking	5.564	3.999	1.390	0.165	-2.293	13.421
Debit card	-1.343	4.254	-0.320	0.752	-9.701	7.014
Credit card	2.185	3.916	0.560	0.577	-5.509	9.880
PayPal	6.307	4.128	1.530	0.127	-1.803	14.418
Google/Apple pay	1.189	4.266	0.280	0.781	-7.193	9.570
Cryptocurrency	-0.261	5.746	-0.050	0.964	-11.550	11.028
Constant	44.066	9.717	4.530	0.000	24.974	63.158

(MWFE estimator converged in 8 iterations)

HDFE Linear regression	Number of obs.	=525
Absorbing 6 HDFE groups	F(6,498)	= 1.01
	Prob > F	= 0.4199
	R-squared	= 0.1016
	Adj R-squared	= 0.0547
	Within R-sq.	= 0.0120
	Root MSE	=27.0208

According to table above (Table 11), it is evident that none of the payment methods have a statistically significant impact on digital payment transactions, even after controlling for country, age, gender, residence, education, and employment. Specifically, the p-values of the estimated coefficients for mobile banking, debit cards, credit cards, PayPal, Google/Apple Pay, and cryptocurrencies all exceed the 5% significance level. This suggests there is insufficient evidence to reject the null hypothesis and support the alternative hypothesis that a limited number of digital payment methods significantly affect digital payment transactions. Furthermore, this finding indicates that, despite descriptive statistics suggesting a preference for specific digital payment methods in the US or EU samples, individuals do not significantly rely on any particular method for their transactions. Additionally, this points to the possibility that individuals may not strongly favour a specific digital method as long as it is a digital payment option.

The model specification under Hypothesis 2 also performed less well compared to the previous model in Hypothesis 1. The coefficient of determination for the model is 0.1016, indicating that the independent variables account for only 10.16% of the variance in the dependent variable. Moreover, the F-statistic value is relatively low, and its associated p-value exceeds the 5% significance level, suggesting that the linear combination of the independent variables is not statistically significant in influencing the dependent variable.

The detailed impact of control variables is presented in Table 12. According to this table, the digital transaction volume in the US sample is significantly lower than that in the EU, while holding the number of digital payment options constant. Additionally, there is no significant difference in digital transactions between male and female respondents when the number of digital payment options remains constant. The data also reveal that only respondents aged 25–34 exhibit significantly lower digital transactions compared to other age groups.

In conclusion, the second hypothesis suggests that people do not excessively rely on a particular digital payment method when conducting transactions. This finding indicates that the digital payment methods market remains competitive, with no single method dominating individual preferences. This paints an optimistic picture for digital payment providers, as it signals potential opportunities for new businesses and ongoing innovation. No top-of-mind brand dominates individuals' preferences, allowing companies to innovate and become leading players. In other words, existing digital payment methods still have potential for further expansion and capturing a larger market share. Under these circumstances, firms may also consider mergers and acquisitions between payment providers as a potential strategy to expand their captive market

***Table 12** Detailed Model for Hypothesis 2 (Source: Author's own research)*

Digital percent		Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Mobile banking		5.564	4.6	1.21	.227	-3.473	14.601	
Debit card		-1.343	4.902	-0.27	.784	-10.975	8.288	
Credit card		2.185	4.444	0.49	.623	-6.546	10.917	
PayPal		6.307	4.777	1.32	.187	-3.078	15.693	
Google/Apple pay		1.189	4.798	0.25	.804	-8.238	10.615	
Cryptocurrency		-.261	5.684	-0.05	.963	-11.428	10.906	
Country: base Europe								
	USA	-26.474	7.653	-3.46	.001	-41.509	-11.438	***
Gender: base Female								
	Male	-2.126	2.6	-0.82	.414	-7.235	2.982	
	Other (key in)	-31.007	9.876	-3.14	.002	-50.41	-11.604	***
Age: base 18-24								
	25-34	-7.858	4.411	-1.78	.075	-16.526	.809	**
	35-44	-2.147	4.5	-0.48	.633	-10.989	6.694	
	45-54	.371	4.83	0.08	.939	-9.12	9.861	
	55-64	1.933	4.794	0.40	.687	-7.487	11.352	
	65 and above	-3.83	5.275	-0.73	.468	-14.194	6.534	
Residence: base City								
	Metropolis	2.01	6.17	0.33	.745	-10.112	14.132	
	()Town	-1.942	2.655	-0.73	.465	-7.158	3.275	
	Village	-7.569	4.271	-1.77	.077	-15.961	.823	*
Education: base Bachelor								
	Doctorate	-.655	7.389	-0.09	.929	-15.173	13.863	
	High School	-4.945	3.193	-1.55	.122	-11.217	1.328	
	Master's Degree	1.216	4.468	0.27	.786	-7.564	9.995	
	Other (key in)	4.462	4.986	0.89	.371	-5.335	14.259	
Employment: base public								
	Housewife	3.524	4.812	0.73	.464	-5.931	12.98	
	Other (key in)	1.106	4.262	0.26	.795	-7.268	9.48	
	Self-employed	1.306	3.998	0.33	.744	-6.55	9.162	
	Student	22.767	7.934	2.87	.004	7.178	38.355	***
	Unemployed	2.027	3.408	0.59	.552	-4.668	8.722	
Constant		73.454	8.756	8.39	0	56.251	90.656	***

Mean dependent var	51.265	SD dependent var	27.792
R-squared	0.102	Number of obs	525
F-test	3.152	Prob > F	0.000
Akaike crit. (AIC)	4977.603	Bayesian crit. (BIC)	5092.714

Statistical Hypothesis 1

The first statistical hypothesis aims to explore whether any obstacle significantly hinders an individual from conducting digital payment transactions. The null hypothesis states that the estimated coefficient of it can be concluded if no hindrance substantially affects the volume of digital payment transactions. Conversely, the alternative hypothesis suggests that at least one hindrance significantly affects digital payment transactions. A model constructed under this hypothesis has a structure as follows:

$$Digital\ transaction_i = \beta_0 + \boldsymbol{B'H} + \boldsymbol{A'X} + \varepsilon_i$$

The dependent variable in the model represents the percentage of digital payment transactions relative to total spending. The vector H comprises hindrance factors, including lack of point-of-sale infrastructure, technical failures, complexity of digital methods, discomfort, trust issues, and unavailability, expressed as binary variables. The vector B represents the estimated coefficients of these independent variables. In contrast, the vector X includes control variables such as country, gender, age, residence, education, and employment, with the vector A containing the estimated coefficients of these control variables. The error term is denoted as ε_i. The estimated model is presented in the table below.

Table 13 *Regression Model for Statistical Hypothesis 1 (Source: Author's own research)*

Variables	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]
Lack of point sales	2.687	3.020	0.890	0.374	[-3.247, 8.620]
Technical failures	0.186	2.554	0.070	0.942	[-4.831, 5.204]
Complexity	0.133	3.197	0.040	0.967	[-6.148, 6.415]
Uncomfortableness	-1.082	2.808	-0.390	0.700	[-6.599, 4.435]
Trust issue	-7.651	2.685	-2.850	0.005	[-12.926, -2.375]
Unavailability	-6.724	3.024	-2.220	0.027	[-12.665, -0.784]
Constant	55.076	2.337	23.570	0.000	[50.485, 59.668]

(MWFE estimator converged in 7 iterations)

HDFE Linear regression	Number of obs	=525
Absorbing 5 HDFE groups	F(6, 499)	= 2.30
	Prob > F	= 0.0334
	R-squared	= 0.0848
	Adj R-squared	= 0.0390
	Within R-sq.	= 0.0269
	Root MSE	=27.2452

Table 13 shows two hindrances with statistically significant impacts based on their p-values. The first hindrance is trust issues, reflecting individuals' skepticism about the security and safety of a digital payment app. The second hindrance is unavailability, indicating a situation where the app does not exist. Trust issues are a major hindrance that prevents individuals from adopting a digital app with a p-value of 0.005, which is less than the 5% significance level. Therefore, we have ample evidence to reject the null hypothesis and accept the alternative hypothesis that trust issues significantly affect individuals' decisions to adopt a digital payment method. Specifically, the estimation reveals that the estimated coefficient is negative, indicating that a feeling of distrust towards a digital payment significantly reduces digital payment spending by 7.65% of the total spending, all else being equal. This finding underscores the importance of developers or payment providers addressing security issues to boost individuals' confidence in adopting a digital payment method.

Additionally, more availability must be available to influence individuals' decisions to embrace digital payment methods. The estimated coefficient for this obstacle has a p-value of 0.027, which is below the 5% significance level. This provides sufficient evidence to reject the null hypothesis and conclude that unavailability has a significant impact on digital payment transactions. Specifically, the estimated coefficient is negative, indicating that the unavailability of a digital payment method reduces digital payment spending by 6.72% of the total spending, all else being equal. This finding suggests that developers and payment providers should continue innovating various digital payment methods to attract more potential customers. Under hypothesis 3, the model specification shows a coefficient of determination of 0.0848, indicating that the independent variables can only explain 8.48% of the variance in the dependent variable. Additionally, the F-statistic value is 2.30 with a p-value less than the 5% significance level, implying that the combined hindrance variables significantly influence the dependent variable.

The specific effects of control variables are detailed in Table 14 below. According to the table, the US sample's digital transaction volume is significantly lower than that of the EU while keeping the number of digital payment options constant. Additionally, there is no significant difference in digital transactions between males and females when the number of digital payment options is constant. In the overall sample, it is also observed that respondents aged between 25- and 34 years old exhibit significantly lower digital transaction volumes compared to other age groups.

Table 14 Detailed Model for Statistical Hypothesis 1 (Source: Author's own research)

Digital percent	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
Lack of point sales	3.332	3.006	1.11	0.268	-2.574	9.237	
Technical failures	0.501	2.542	0.20	0.844	-4.494	5.496	
Complexity	0.258	3.059	0.08	0.933	-5.752	6.267	
Uncomfortableness	-1.302	2.721	-0.48	0.633	-6.648	4.044	
Trust issue	-7.455	2.676	-2.79	0.006	-12.713	-2.198	***
Unavailability	-6.387	3.231	-1.98	0.049	-12.734	-0.040	**
Country: base Europe							
USA	-22.194	4.412	-5.03	0.000	-30.862	-13.526	***
Gender: base Female							
Male	-2.429	2.603	-0.93	0.351	-7.544	2.686	
Other (key in)	-27.664	8.153	-3.39	0.001	-43.682	-11.645	***
Age: base 18-24							
25-34	-8.488	4.024	-2.11	0.035	-16.394	-0.582	**
35-44	-3.710	4.239	-0.88	0.382	-12.038	4.619	
45-54	-1.149	4.474	-0.26	0.797	-9.939	7.641	
55-64	2.688	4.378	0.61	0.539	-5.913	11.289	
65 and above	-3.347	4.997	-0.67	0.503	-13.164	6.470	
Residence: base City							
Metropolis	2.789	5.905	0.47	0.637	-8.813	14.391	
Town	-1.496	2.695	-0.56	0.579	-6.791	3.800	
Village	-7.616	4.390	-1.74	0.083	-16.240	1.008	*
Education: base Bachelor							
Doctorate	-1.071	6.869	-0.16	0.876	-14.567	12.425	
High School	-3.748	3.227	-1.16	0.246	-10.089	2.593	
Master's Degree	2.637	4.510	0.58	0.559	-6.225	11.499	
Other (key in)	5.340	4.928	1.08	0.279	-4.342	15.023	
Employment: base public							
Housewife	2.990	4.794	0.62	0.533	-6.429	12.408	
Other (key in)	1.630	4.205	0.39	0.698	-6.631	9.891	
Self-employed	1.620	3.993	0.41	0.685	-6.226	9.466	
Student	21.554	6.576	3.28	0.001	8.633	34.475	***
Unemployed	3.817	3.322	1.15	0.251	-2.711	10.345	
Constant	79.167	5.610	14.11	0.000	68.146	90.189	***

Mean dependent var	51.265	SD dependent var	27.792
R-squared	0.116	Number of obs	525.000
F-test	3.878	Prob > F	0.000
Akaike crit. (AIC)	4969.135	Bayesian crit. (BIC)	5084.247

**** p<0.01, ** p<0.05, * p<0.1*

Statistical Hypothesis 2

This statistical hypothesis explores reasons that significantly influence an individual's decision to engage in digital payment transactions. The null hypothesis states that the estimated coefficients representing these factors are not substantially different from zero. Conversely, the alternative hypothesis suggests that the estimated impact of these factors on digital payment transactions is significantly different from zero. The model structure under this hypothesis is as follows:

$$Digital\ transaction_i = \beta_0 + \boldsymbol{B'R} + \boldsymbol{A'X} + \varepsilon_i$$

The model's dependent variable is the percentage of digital payment transactions in relation to total spending. Additionally, $\boldsymbol{R}$ represents the vector of reasons, including convenience, discount offers, trustworthiness, ease of use, and others. On the other hand, $\boldsymbol{B}$ denotes the vector of estimated coefficients for the independent variables. Furthermore, $\boldsymbol{X}$ encompasses the vector of control variables, such as country, gender, age, residence, education, employment, and income, while the vector $\boldsymbol{A}$ contains the estimated coefficients of control variables. Finally, ε_i represents the error term. The estimated model is given in Table 15 using the above equation.

Table 15 *Regression Model for Statistical Hypothesis 2 (Source: Author's own research)*

Digital percent	Coef.	Std.Err.	t	P>t	[95%Conf	Interval]
Convenience	1.277	2.929	0.440	0.663	-4.478	7.032
Discount offers	-2.711	2.944	-0.920	0.358	-8.495	3.073
Trusted	-2.732	2.990	-0.910	0.361	-8.606	3.141
Ease of use	6.260	2.545	2.460	0.014	1.260	11.261
Others	3.062	5.684	0.540	0.590	-8.106	14.230
Constant	47.778	3.105	15.390	0.000	41.677	53.879

(MWFE estimator converged in 8 iterations)

HDFE Linear regression	Number of obs.	=525
Absorbing 6 HDFE groups	F(5,499)	= 1.56
	Prob > F	= 0.1688
	R-squared	= 0.1048
	Adj R-squared	= 0.0599
	Within R-sq.	= 0.0154
	Root MSE	=26.9467

As indicated in Table 15, ease of use is the only significant factor impacting an individual's digital spending. The p-value of the estimated coefficient is 0.014, which is below the 5%

significance level, providing sufficient evidence to reject the null hypothesis and support the alternative, indicating that the estimated coefficient is significantly different from zero. Specifically, the model shows that the perception of user-friendliness is substantially linked to a 6.26% increase in digital spending, all else being constant. This finding highlights the importance of developers and payment providers prioritising the ease-of-use aspect of digital applications.

In the model specification under Hypothesis 3, the coefficient of determination is 0.1048, indicating that the independent variables account for 10.48% of the variance in the dependent variable. However, the F-statistic value is 1.56, with a p-value of 0.1688, which exceeds the 5% significance level. This suggests that the combined effect of the hindrance variables is not statistically significant in influencing the dependent variable. Additionally, the impact of control variables is detailed in Table 16 below. The analysis demonstrates that, with the number of digital payment options held constant, the volume of digital transactions in the US sample is significantly lower than that in the EU.

Moreover, when the number of digital payment options is held constant, there is no significant difference in digital transactions between male and female respondents. Furthermore, it was revealed that only respondents aged 25–34 exhibited a significantly lower level of digital transactions compared to other age groups. Additionally, the model suggests that respondents living in villages tend to have lower digital transaction volumes than those residing in cities.

In summary, the model presented in Hypothesis 4 emphasises the significant role of user-friendliness in encouraging individuals to engage in digital transactions. The study findings reveal that ease of use stands out as the primary motivating factor for digital transactions. This underscores the importance for developers to prioritise and invest in creating user-friendly applications. When users perceive an application as more intuitive and easier to use, it leads to increased digital transactions. However, this can also create a competitive environment among

***Table 16** Detailed Model for Statistical hypothesis 2 (Source: Author's own research)*

Digital percent	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
Convenience	1.277	2.734	0.47	0.641	-4.095	6.649	
Discount offers	-2.711	2.723	-1.00	0.320	-8.060	2.638	
Trusted	-2.732	2.895	-0.94	0.346	-8.420	2.955	
Ease of use	6.260	2.437	2.57	0.011	1.472	11.049	**
Others	3.062	7.463	0.41	0.682	-11.601	17.726	
Country: base Europe							
USA	-22.194	4.412	-5.03	0.000	-30.862	-13.526	***
Gender: base Female							
Male	-2.429	2.603	-0.93	0.351	-7.544	2.686	
Other (key in)	-27.664	8.153	-3.39	0.001	-43.682	-11.645	***
Age: base 18-24							
25-34	-8.488	4.024	-2.11	0.035	-16.394	-0.582	**
35-44	-3.710	4.239	-0.88	0.382	-12.038	4.619	
45-54	-1.149	4.474	-0.26	0.797	-9.939	7.641	
55-64	2.688	4.378	0.61	0.539	-5.913	11.289	
65 and above	-3.347	4.997	-0.67	0.503	-13.164	6.470	
Residence: base City							
Metropolis	2.789	5.905	0.47	0.637	-8.813	14.391	
Town	-1.496	2.695	-0.56	0.579	-6.791	3.800	
Village	-7.616	4.390	-1.74	0.083	-16.240	1.008	*
Education: base Bachelor							
Doctorate	-1.071	6.869	-0.16	0.876	-14.567	12.425	
High School	-3.748	3.227	-1.16	0.246	-10.089	2.593	
Master's Degree	2.637	4.510	0.58	0.559	-6.225	11.499	
Other (key in)	5.340	4.928	1.08	0.279	-4.342	15.023	
Employment: base public							
Housewife	2.990	4.794	0.62	0.533	-6.429	12.408	
Other (key in)	1.630	4.205	0.39	0.698	-6.631	9.891	
Self-employed	1.620	3.993	0.41	0.685	-6.226	9.466	
Student	21.554	6.576	3.28	0.001	8.633	34.475	***
Unemployed	3.817	3.322	1.15	0.251	-2.711	10.345	
Constant	79.167	5.610	14.11	0.000	68.146	90.189	***
Mean dependent var		51.265	SD dependent var			27.792	
R-squared		0.105	Number of obs			525.000	
F-test		3.826	Prob > F			0.000	
Akaike crit. (AIC)		4973.773	Bayesian crit. (BIC)			5084.621	

**** p<0.01, ** p<0.05, * p<0.1*

developers, ultimately fostering innovation within the industry. This finding also suggests that digital payment providers need to measure the degree of an application's user-friendliness more accurately and comprehensively. Therefore, market research is strongly recommended to address this issue. Furthermore, through thorough market research, digital payment providers must ensure that an application's user-friendliness is universally accepted and encompasses as broad a range of market segments as possible.

4.3 Summary of findings

The observed positive correlation between the availability of cashless payment options and the frequency of digital transactions aligns with findings from previous research. For instance, Borzekowski et al. (2008) analysed consumer payment choices and found that the introduction of new payment methods, such as contactless cards, led to a decrease in cash usage, indicating that consumers are inclined to adopt more convenient digital payment options when available. Similarly, Ramayanti (2024) examined the impact of digital payment infrastructure on transaction behaviours in emerging markets. The study concluded that enhancing the availability and accessibility of cashless payment systems significantly boosts the adoption of digital transactions, even in regions with previously low digital engagement. This underscores the importance of infrastructure development in promoting digital financial behaviours across diverse economic landscapes.

The findings regarding Hypothesis 2 that a limited number of payment systems account for the majority of cashless transactions appear to be data dependent. While some research points to a significant concentration around specific systems, other studies reveal a broader distribution across various payment methods, indicating that the dominance of particular systems can vary widely depending on regional and contextual factors. This data-dependent nature aligns with findings in this study as well meaning that while transaction concentration in a few dominant systems is common, it is influenced by local infrastructure, economic context, and the dataset in use, underscoring the importance of considering these factors when evaluating transaction trends.

The last hypothesis that a shift from cash to cashless transactions has a measurable impact on GDP is consistent with existing academic research. Hasan et al. (2013), in their analysis of 27 European countries over the period from 1995 to 2009, found that the adoption of electronic payment systems significantly contributed to economic growth, with notable positive effects on consumption and trade. Their study highlighted that among various cashless payment instruments, card payments had the most pronounced effect on GDP growth, followed by credit transfers and direct debits. These findings suggest that reducing dependency on cash can enhance transaction efficiency, promote financial inclusion, and support broader economic activity. Zandi et al. (2013) concluded that electronic payment usage increased economic growth across multiple global markets, estimating that a 1% increase in electronic payments led to a measurable rise in GDP. The research in this dissertation indicates similar results, demonstrating a measurable positive impact of cashless transactions on GDP. This alignment with other researchers reinforces the hypothesis that cashless payment systems serve not only as a modernization of financial infrastructure but also as a driver of economic growth which can be observed in the GDP figure.

CHAPTER 5: CONCLUSION

5. 1 Conclusion

In conclusion, this thesis has provided a comprehensive analysis of the impact of payment system diversity on financial transactions and consumer behaviour, offering critical insights into the evolving landscape of global economics. The findings stem from a robust research framework that integrates an extensive literature review, quantitative analysis of macroeconomic data, and primary data collected through consumer surveys. The quantitative analysis utilises the World Bank's G20 Financial Inclusion Data (2011–2015), accessed via the WDI package in R, focusing on indicators such as POS terminals per 100,000 adults, debit cards per 1,000 adults, and retail cashless transactions per 1,000 adults, complemented by GDP per capita metrics. This dataset was cleaned and analysed using pooled and two-way fixed-effects regression models to establish causal relationships whilst controlling for country- and year-specific effects.

Further, more recent data from G7 countries (2018–2023) were collected and analysed using the same methods as the 2011–2015 data. However, Breusch-Pagan tests revealed statistically significant heteroscedasticity in the models for Hypotheses 1 and 3 ($BP = 27.772$ and $BP = 30.894$, respectively; $p < 0.01$), indicating that the variance of errors is not constant across observations. This violation of the homoscedasticity assumption suggests that the regression coefficients from this recent data may be biased, leading to potentially inaccurate statistical inferences. Consequently, this analysis was not pursued further, as it became evident that external factors during these years, such as the COVID-19 pandemic, significantly influenced consumer behaviour, payment options, and payment possibilities.

Additionally, a survey of 530 respondents from the USA (483) and the EU (47) was conducted, employing a structured questionnaire to capture demographic profiles, payment preferences, usage patterns, and barriers to digital adoption. These mixed methods, combining secondary macroeconomic data with primary survey data, provide a solid empirical foundation for the conclusions drawn.

The research highlights a clear and positive correlation between the number of cashless payment options available and the frequency of digital transactions, a trend significant across both developed and less-developed nations. This indicates that as the availability of cashless options increases, so does engagement in digital financial behaviours. Notably, the survey-based regression analysis reveals that for every additional cashless payment method introduced, there is a statistically significant 2.38% increase in digital spending ($p < 0.01$, Table 10), underscoring the substantial role that payment diversity plays in consumer decision-making.

The study emphasises the importance of ease of use and convenience as critical drivers of consumer preference for digital payment methods. This factor emerged as the most influential in the consumer survey, with 74% of US and 70% of EU respondents citing convenience as a primary reason for adoption, and regression results showing a 6.26% increase in digital spending linked to perceived user-friendliness ($p = 0.014$, Table 15). These findings are particularly relevant for application developers and payment service providers, highlighting the necessity of prioritising intuitive design and streamlined functionality in digital payment applications. To capitalise on the growing demand for cashless transactions, developers must invest in solutions that are not only secure but also accessible and easy to navigate. This focus on user experience enhances consumer satisfaction, fosters loyalty, and encourages repeat usage.

Moreover, the thesis illuminates the competitive dynamics of the digital payment landscape. Contrary to the notion that a single dominant payment method may emerge, the findings—supported by the Global Payments Report data and survey preferences, suggest that consumers do not exhibit excessive reliance on any particular digital payment solution. For instance, digital wallets and credit cards dominate, accounting for 70% of e-commerce transactions globally (Hypothesis 2), yet diverse preferences persist, with debit cards and mobile banking also ranking highly (e.g., 47% and 40% strong preference in the US, Table 12). This competitive environment presents significant opportunities for innovation and market entry, as there remains substantial room for other solutions to capture market share.

Additionally, the analysis of the fixed-effects models demonstrates that whilst the number of debit cards per 1,000 people has an insignificant impact on cashless transaction intensity when accounting for the number of POS terminals, the latter remains a critical factor. The elasticity of cashless transactions with respect to the number of POS terminals, though diminished when controlling for other variables—still supports the hypothesis that infrastructure plays a vital role in enabling cashless transactions. This finding emphasises the importance of investment in POS terminal availability to drive cashless adoption, especially in regions where digital infrastructure is still developing.

The relationship between cashless transactions and economic growth, as indicated by per capita GDP, also underscores the significance of payment system diversity. The thesis found a positive elasticity of 0.026 between cashless retail transaction rates and GDP, suggesting that an increase in digital transactions contributes positively to economic performance. This correlation indicates that enhancing the availability and accessibility of cashless payment systems not only fosters individual consumer spending but also stimulates broader economic growth. As nations strive to improve their economic conditions, the promotion of cashless payment options can serve as a catalyst for increasing per capita GDP, demonstrating a clear pathway for developing countries to elevate their economic status through digital financial inclusion.

Furthermore, the demographic insights gained from the consumer survey reveal significant variations in digital transaction behaviours across different age groups and geographic locations. Younger consumers, particularly those aged 18–24, displayed higher engagement with digital payments, whilst rural residents showed lower transaction volumes compared to urban dwellers. These insights suggest that targeted marketing and education strategies may be necessary to enhance adoption rates among demographics that are currently lagging.

As the digital economy continues to evolve, the recommendations derived from this research are pivotal for stakeholders across the payment ecosystem. Policymakers and financial institutions must prioritise the development of inclusive, secure, and user-friendly payment solutions to support the transition towards a cashless society. By fostering an environment that encourages the proliferation of diverse payment options and focuses on the user experience, stakeholders can drive economic growth and improve financial inclusion globally.

In summary, the findings of this thesis not only illuminate the intricate relationship between payment system diversity and consumer behaviour but also advocate for a strategic approach to developing digital payment infrastructures. By understanding and responding to consumer needs and preferences, businesses can harness the potential of cashless transactions, ultimately contributing to a more efficient and inclusive global economy. The ongoing innovation in this space presents a promising outlook for both established players and new entrants, who can capitalise on the dynamic landscape of digital payments to meet the evolving demands of consumers.

5.2 Future Research Directions

While this study provides a robust foundation for understanding payment system diversity and its implications, several avenues for future research emerge. First, expanding the temporal scope beyond the 2011–2015 World Bank data and the current survey period could capture more recent trends, such as the rapid rise of contactless payments and cryptocurrencies post-2020. Incorporating data from not only the G7 countries or emerging economies with updated financial inclusion metrics (e.g., Global Findex 2025) could enhance generalisability and relevance. Second, extending the methodology to include longitudinal consumer surveys or experimental designs could track behavioural changes over time and test causal interventions, such as the impact of introducing new payment methods in controlled settings. Third, exploring the role of emerging technologies—such as blockchain-based payment systems or central bank digital currencies (CBDCs)—could assess their potential to further diversify payment options and influence economic outcomes. Finally, a deeper investigation into region-specific barriers (e.g., cultural attitudes or regulatory frameworks) and their interaction with infrastructure development could refine strategies for targeting underserved populations, enhancing the inclusivity of the cashless transition globally.

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APPENDIX I: Descriptive Statistics of the USA Respondents' Demographic

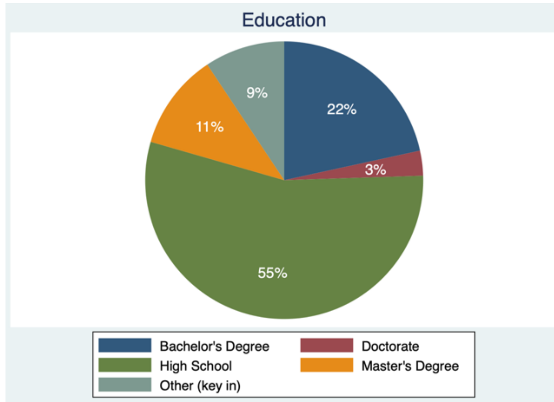

Figure 1 *Respondents Education - USA*

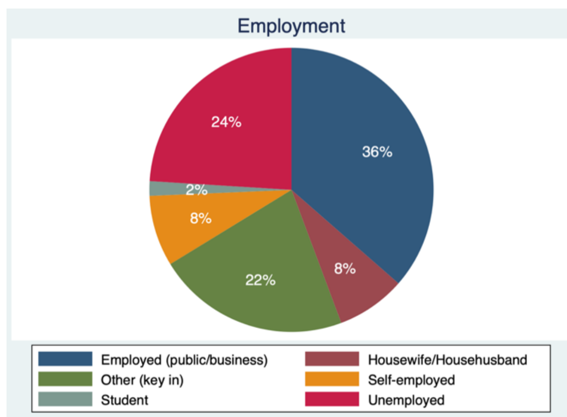

Figure 2 *Respondents Employment - USA*

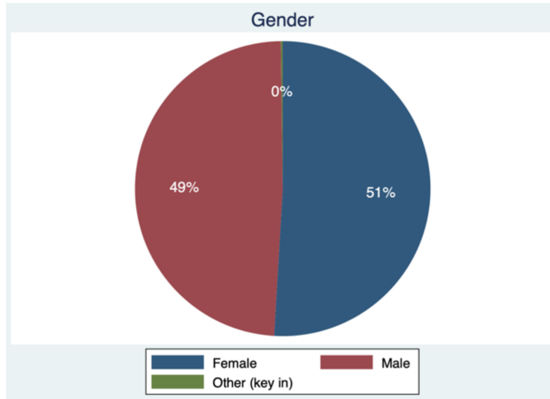

***Figure 3** Respondents Gender - USA*

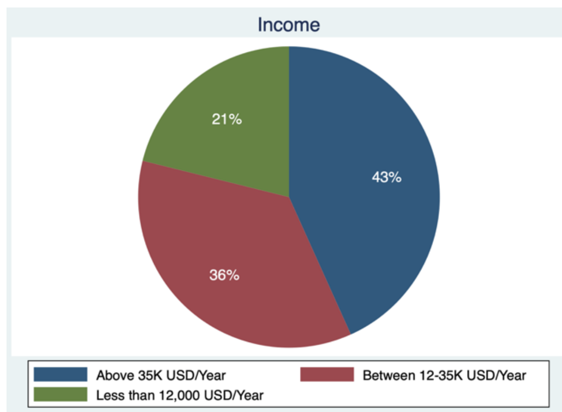

***Figure 4** Respondents Income - USA*

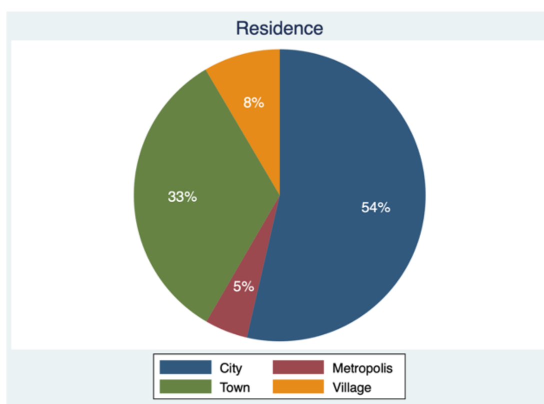

***Figure 5** Respondents Residence - USA*

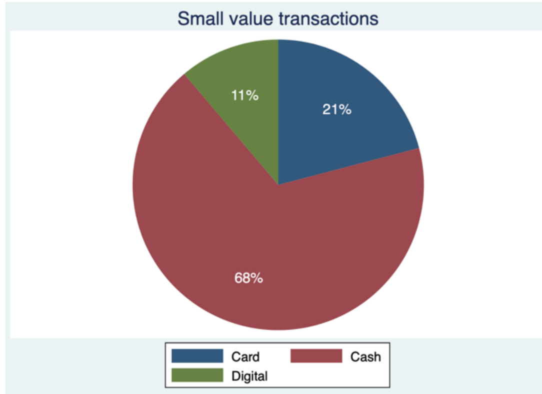

Figure 6 *Respondents Preference for small value transactions - USA*

General Payment Preference

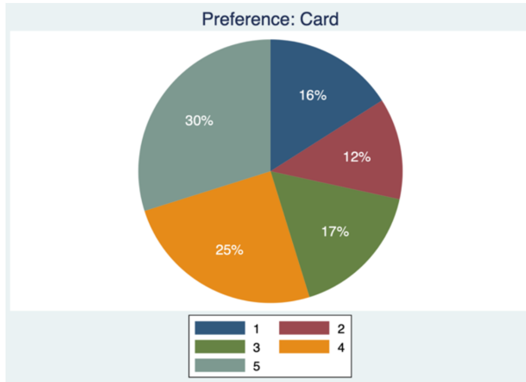

Figure 7 *Respondents Preference: Card - USA*

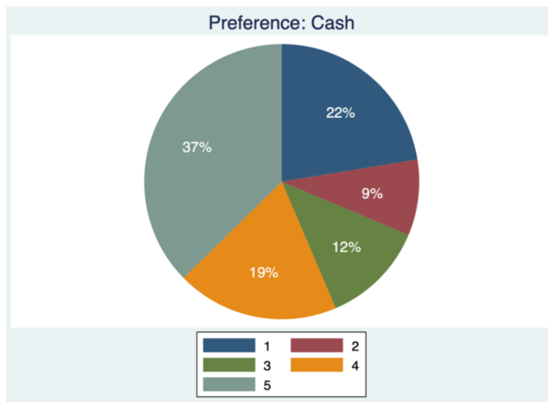

Figure 8 *Respondents Preference: Cash – USA*

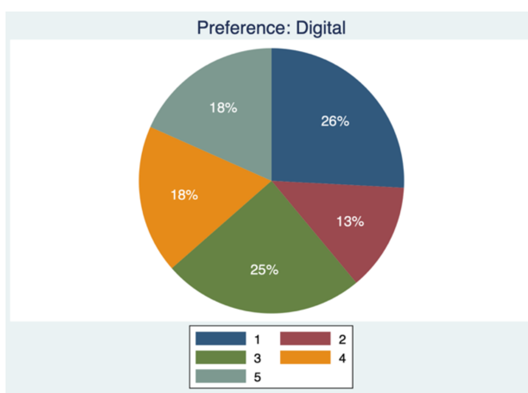

Figure 9 *Respondents Preference: Digital - USA*

Digital Payment Preference

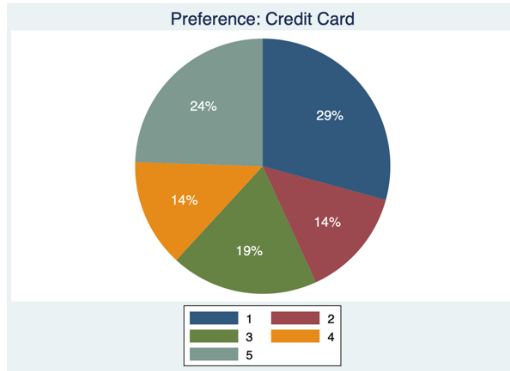

Figure 10 *Respondents Preference: Credit Card - USA*

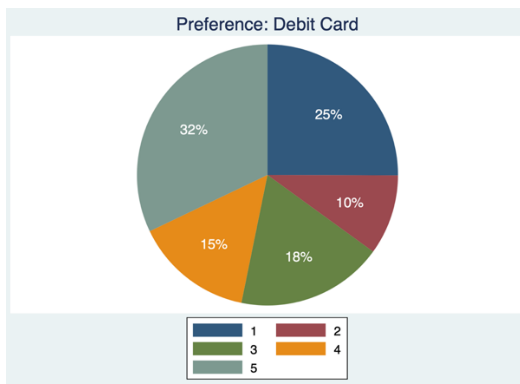

Figure 11 *Respondents Preference: Debit Card - USA*

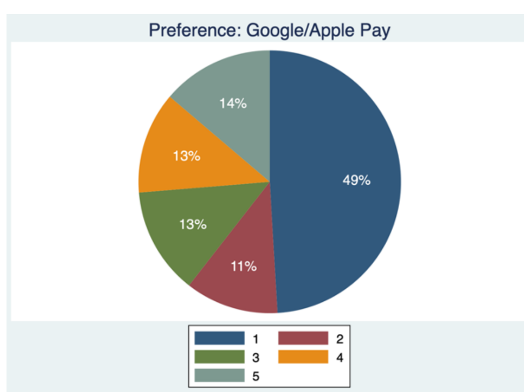

Figure 12 *Respondents Preference: Google/Apple Pay – USA*

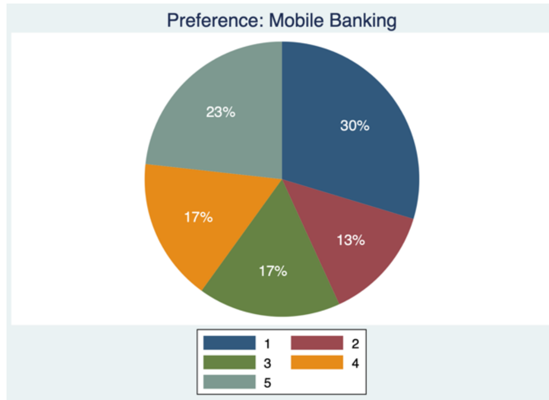

Figure 13 *Respondents Preference: Mobile Banking - USA*

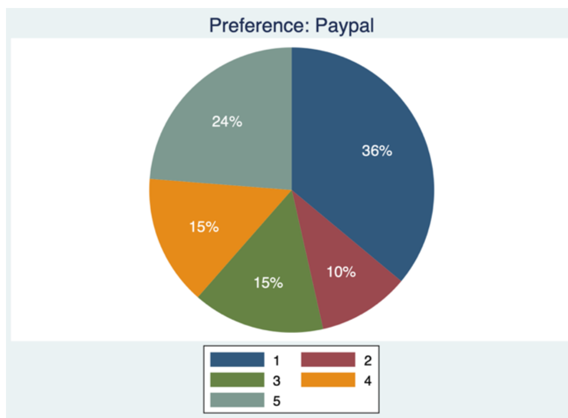

Figure 14 *Respondents Preference: PayPal - USA*

Reason

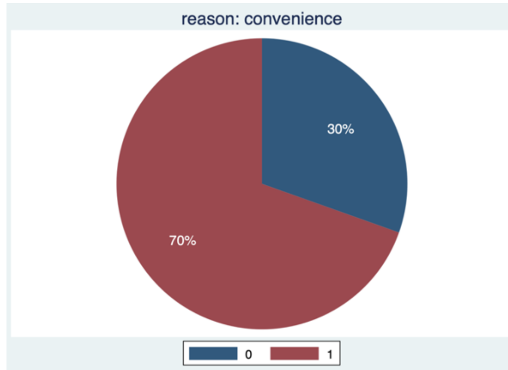

Figure 15 *Respondents Reason: Convenience - USA*

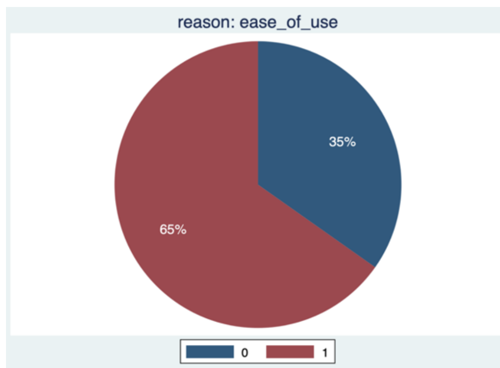

Figure 16 *Respondents Reason: Ease of Use - USA*

Figure 17 *Respondents Reason: Offers Discount - USA*

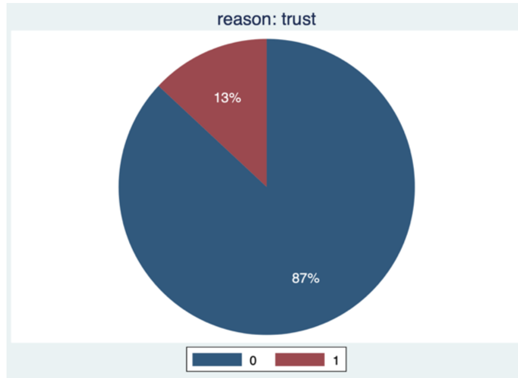

Figure 18 *Respondents Reason: Trust - USA*

Usage

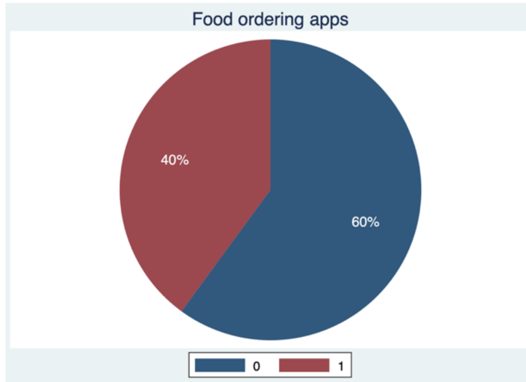

Figure 19 *Respondents Usage: Food ordering Apps - USA*

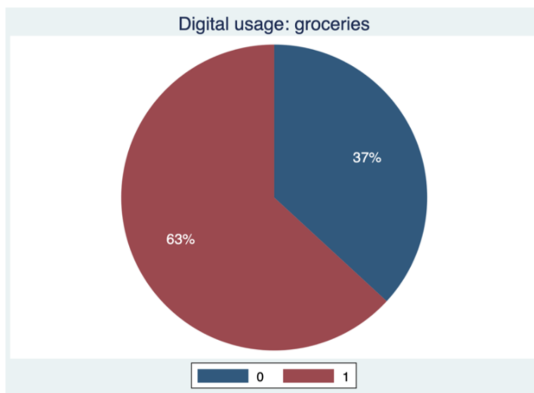

Figure 20 *Respondents Usage: Groceries - USA*

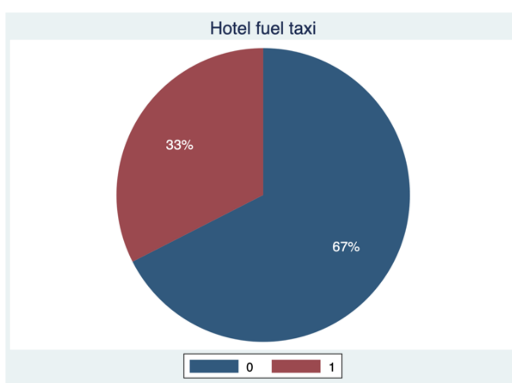

Figure 21 *Respondents Usage: Hotel Fuel Taxi - USA*

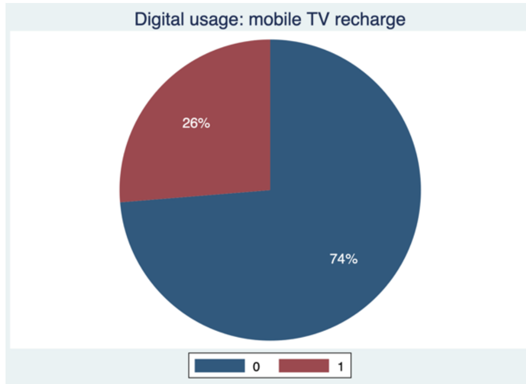

Figure 22 *Respondents Digital Usage: Mobile TV charge – USA*

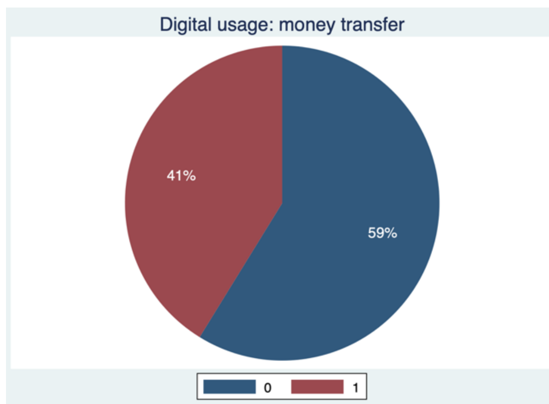

Figure 23 *Respondents Digital Usage: Money Transfer - USA*

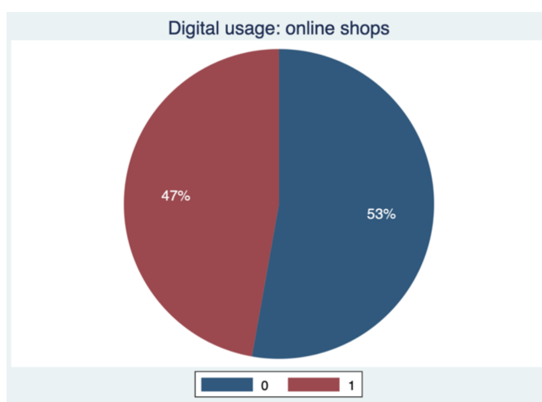

Figure 24 *Respondents Digital Usage: Online Shops - USA*

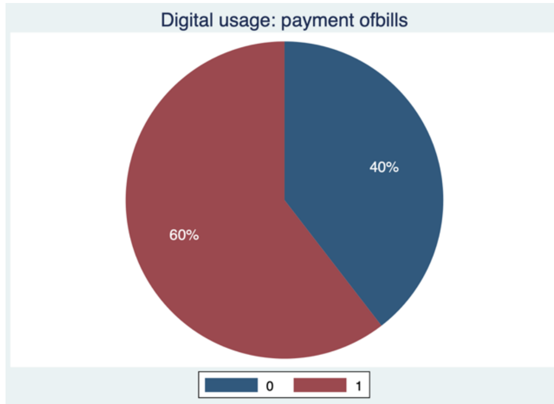

Figure 25 *Respondents Digital Usage: Payment of Bills - USA*

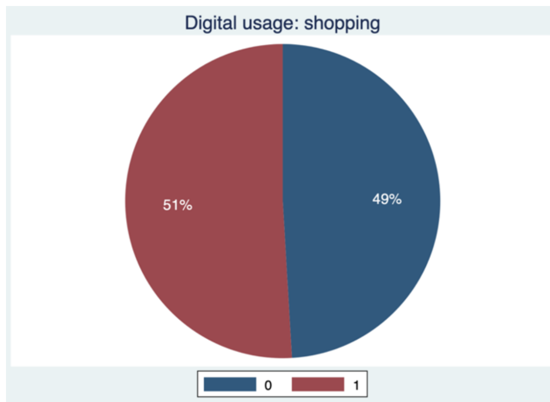

Figure 26 *Respondents Digital Usage: Shopping - USA*

Hindrance

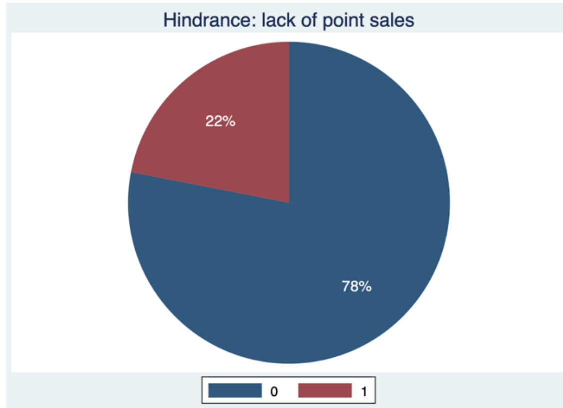

Figure 27 *Respondents Hindrance: Lack of Point Sales - USA*

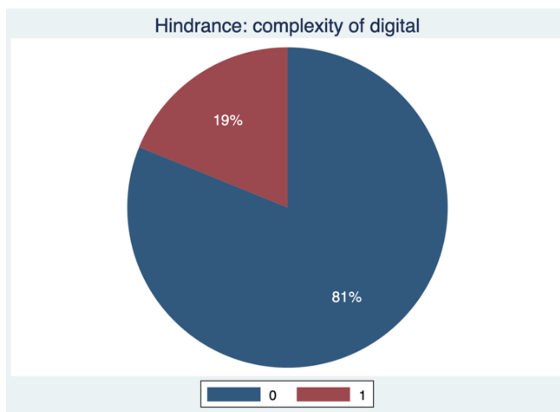

Figure 28 *Respondents Hindrance: Complexity of Digital - USA*

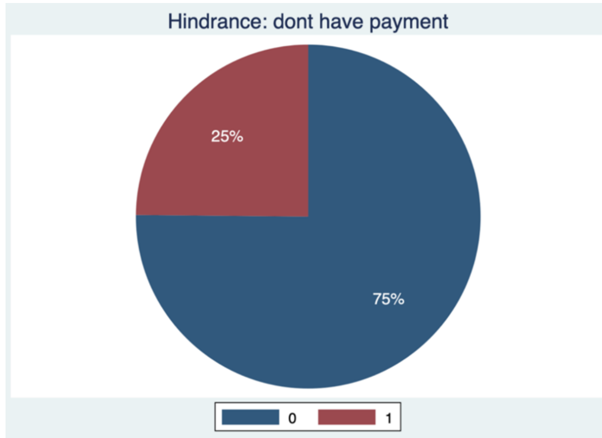

Figure 29 *Respondents Hindrance: Don't have payment – USA*

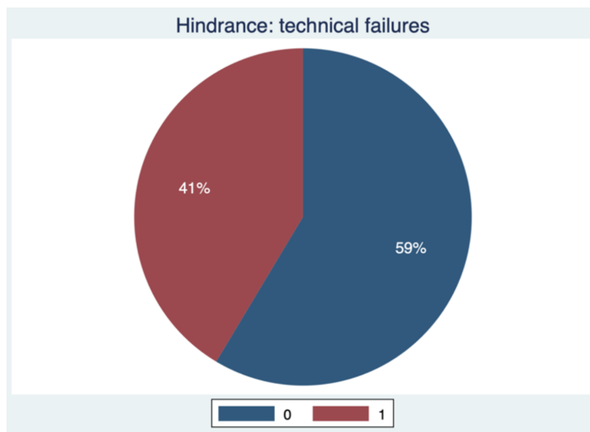

Figure 30 *Respondents Hindrance: Technical Failures - USA*

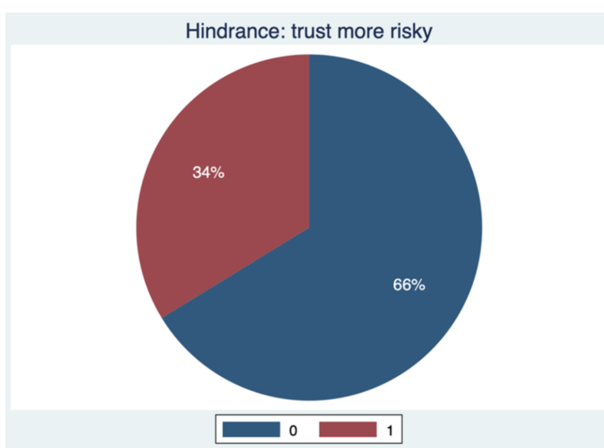

Figure 31 *Respondents Hindrance: Trust More Risky - USA*

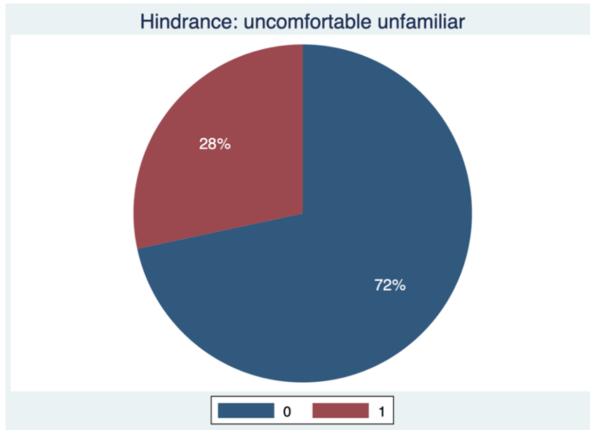

Figure 32 *Respondents Hindrance: Uncomfortable - USA*

Ranking

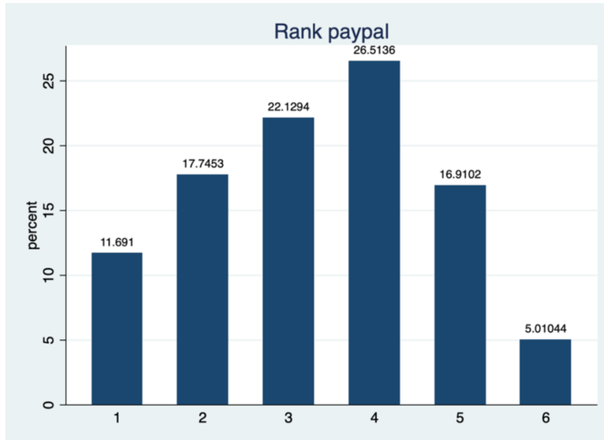

Figure 33 *Respondents Ranking: PayPal - USA*

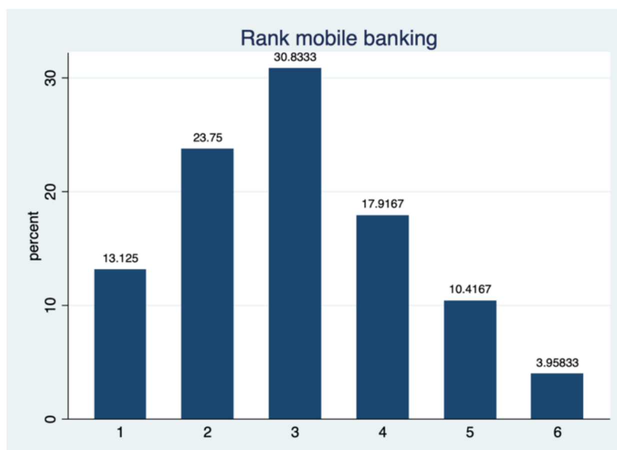

Figure 34 *Respondents Ranking: Mobile Banking - USA*

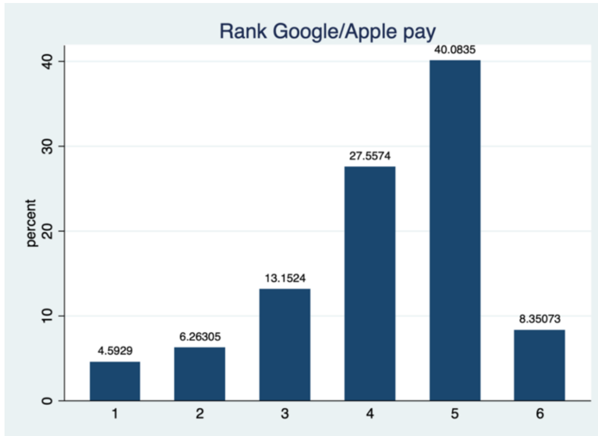

Figure 35 *Respondents Ranking: Google/Apple Pay - USA*

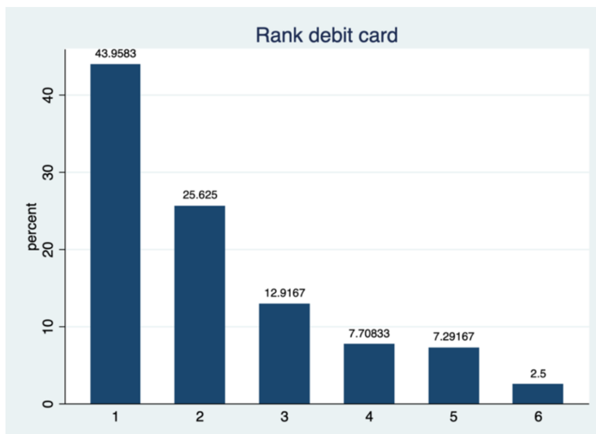

Figure 36 *Respondents Ranking: Debit Card - USA*

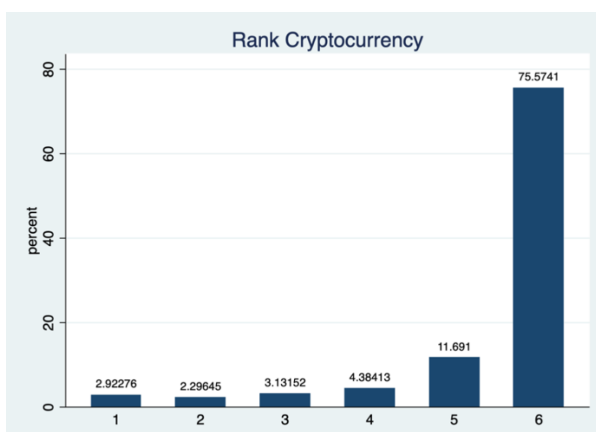

Figure 37 *Respondents Ranking: Cryptocurrency - USA*

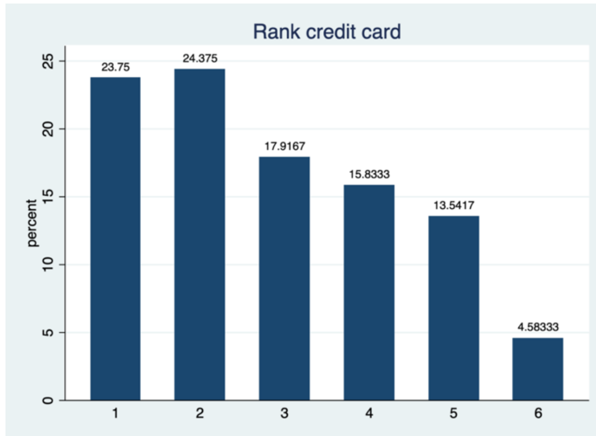

Figure 38 *Respondents Ranking: Credit Card - USA*

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APPENDIX II: Descriptive Statistics of the EU Respondents

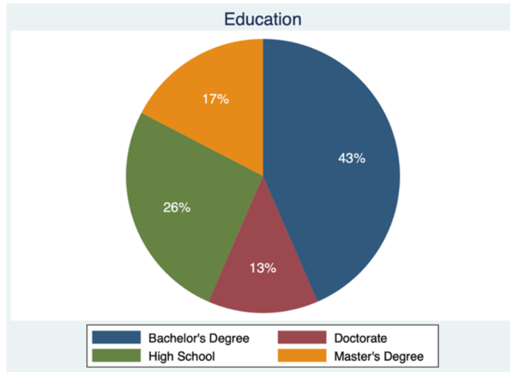

Figure 39 *Respondents Education - EU*

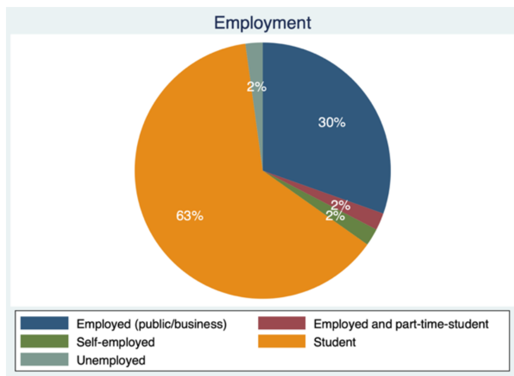

Figure 40 *Respondents Employment - EU*

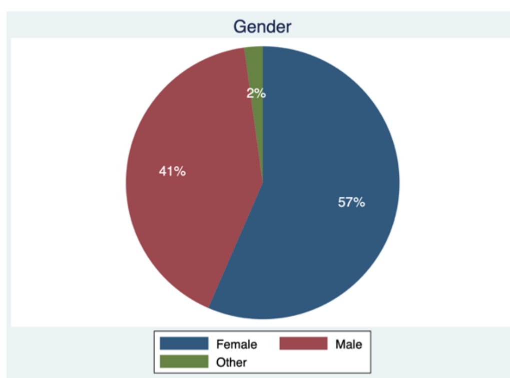

Figure 41 *Respondents Gender - EU*

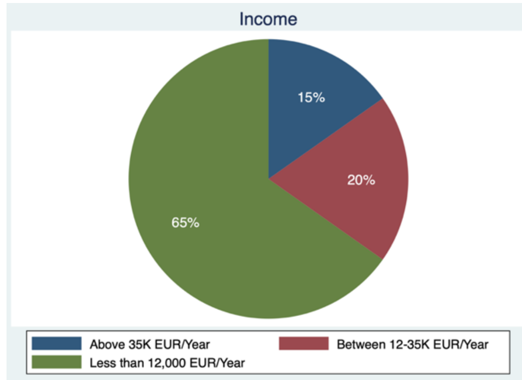

Figure 42 *Respondents Income - EU*

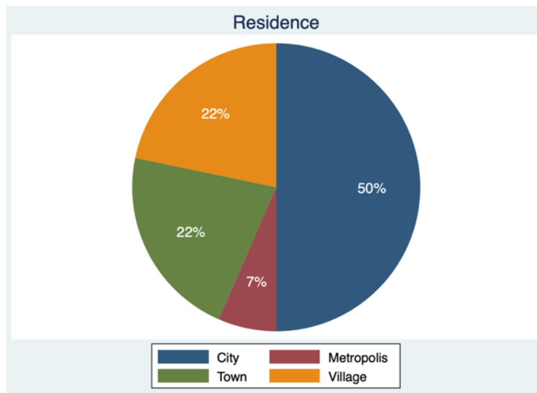

Figure 43 *Respondents Residence - EU*

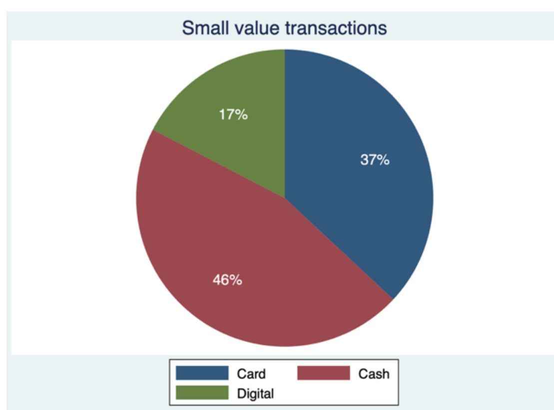

Figure 44 *Respondents Preference for small value transactions - EU*

General Payment Preference

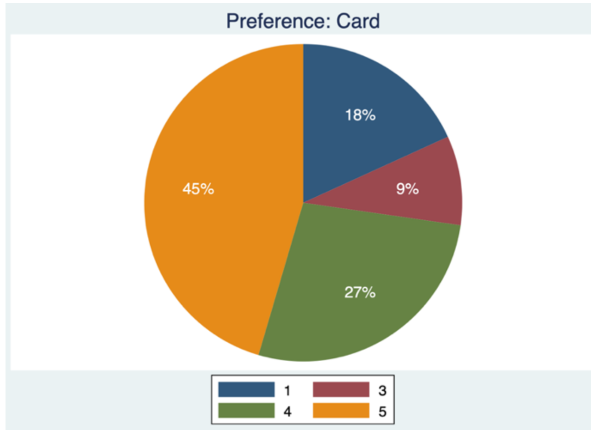

Figure 45 *Respondents Preference: Card - EU*

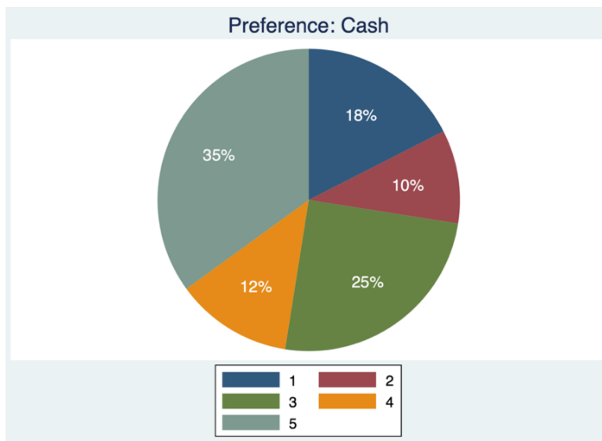

Figure 46 *Respondents Preference: Cash - EU*

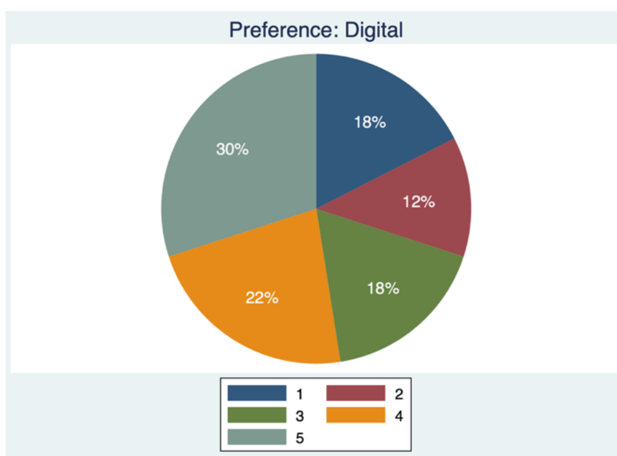

Figure 47 *Respondents Preference: Digital – EU*

Digital Payment Preference

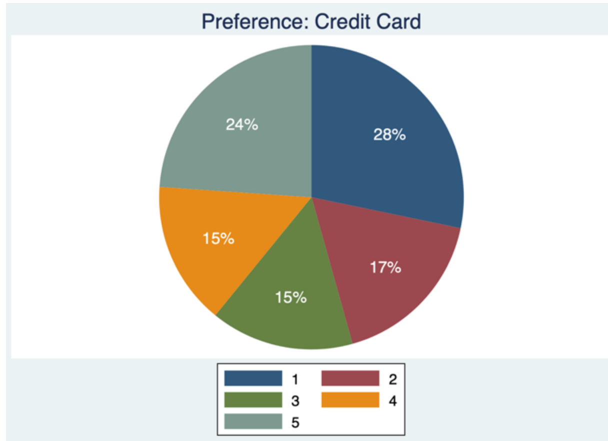

Figure 48 *Respondents Preference: Credit Card - EU*

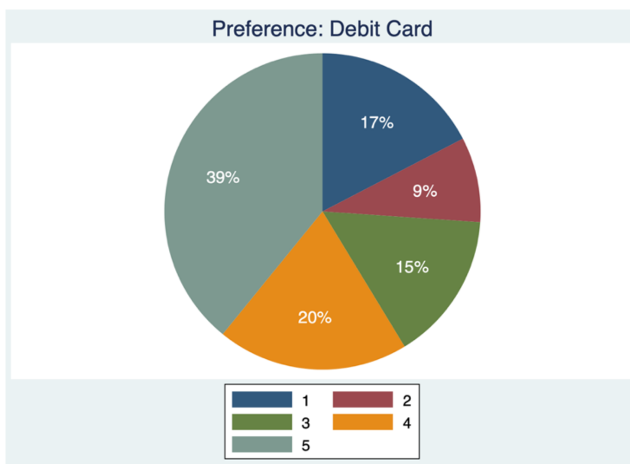

Figure 49 *Respondents Preference: Debit Card - EU*

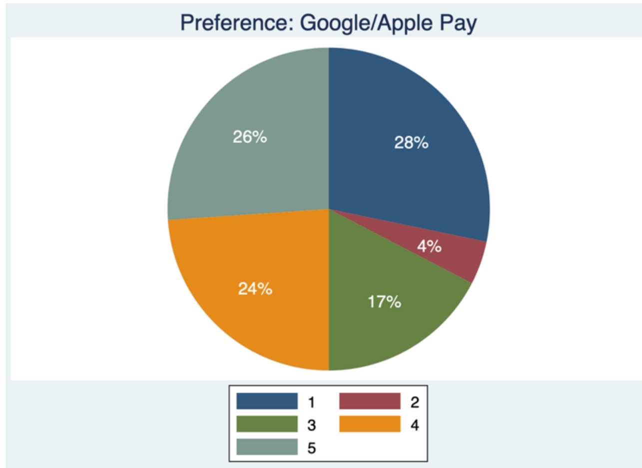

Figure 50 *Respondents Preference: Google/Apple Pay – EU*

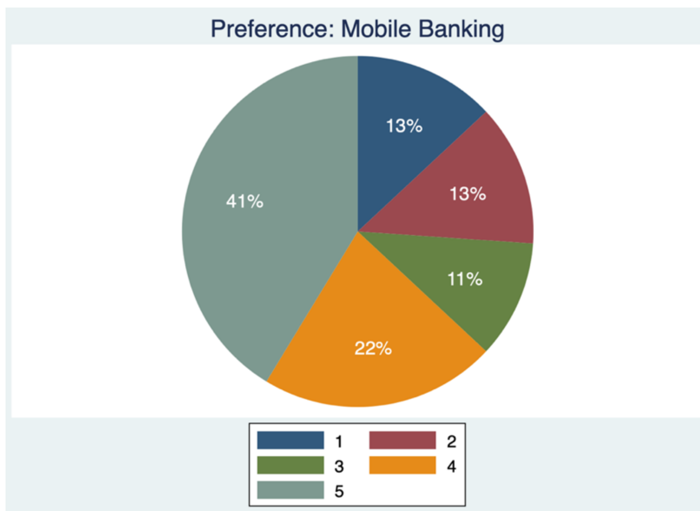

Figure 51 *Respondents Preference: Mobile Banking - EU*

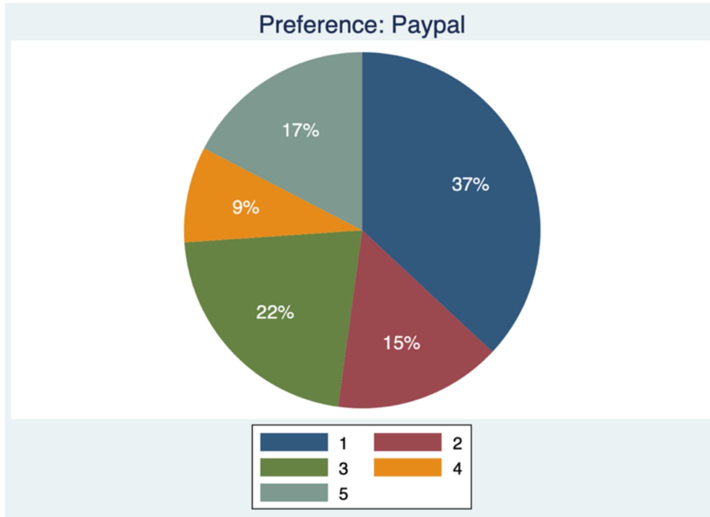

Figure 52 *Respondents Preference: PayPal - EU*

Reason

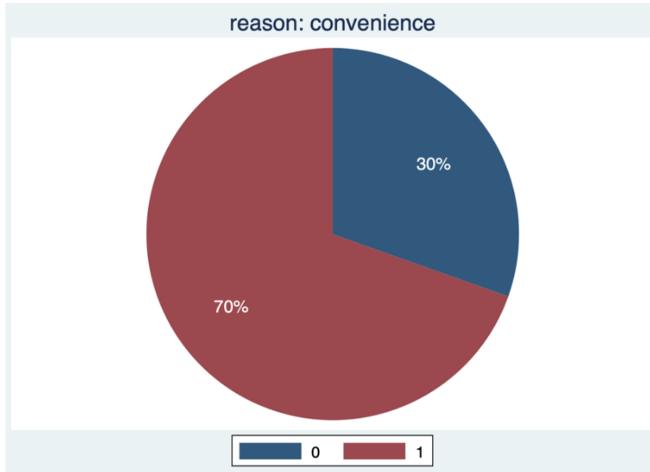

Figure 53 *Respondents Reason: Convenience - EU*

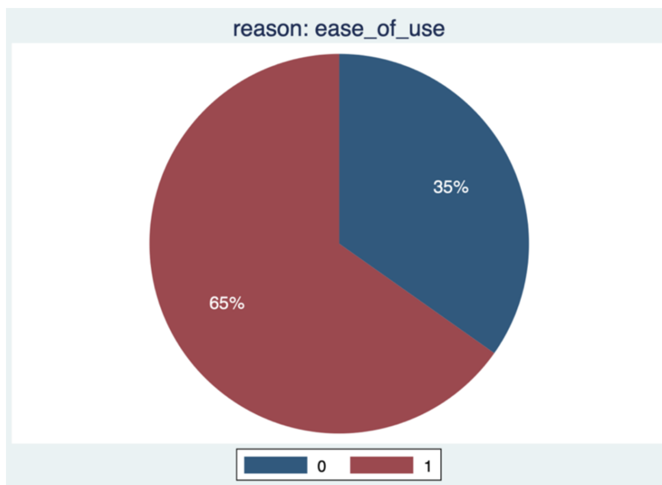

Figure 54 *Respondents Reason: Ease of Use - EU*

Figure 55 *Respondents Reason: Offers Discount - EU*

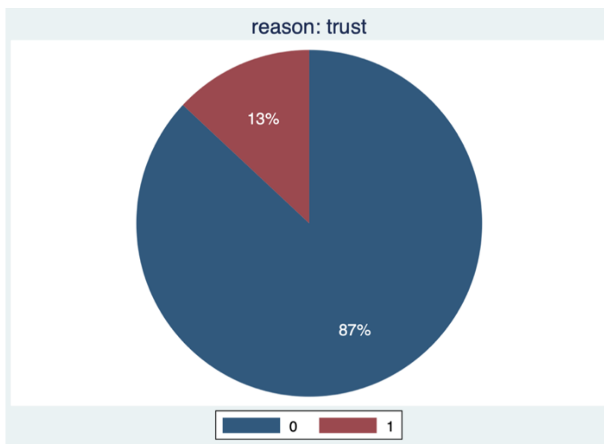

Figure 56 *Respondents Reason: Trust - EU*

Usage

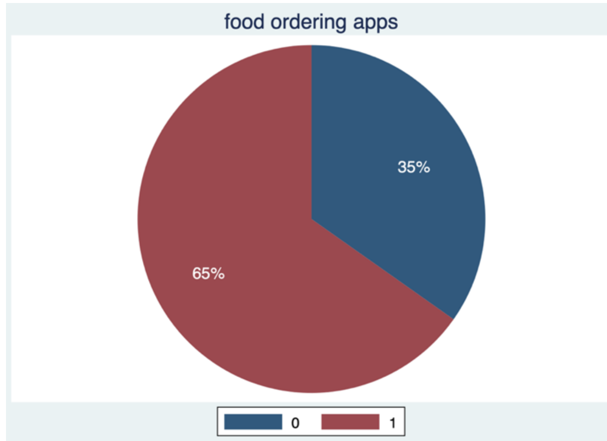

Figure 57 *Respondents Usage: Food ordering Apps - EU*

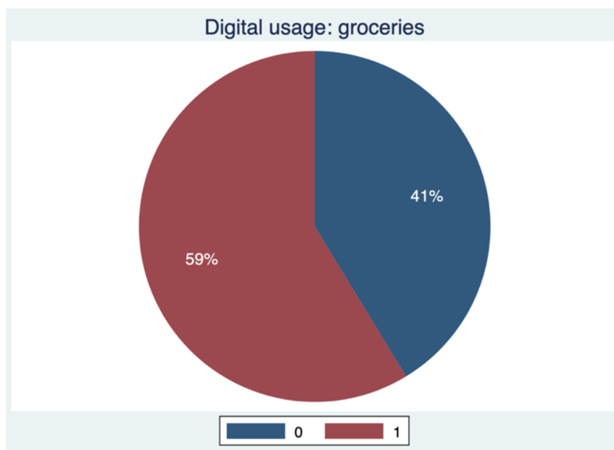

Figure 58 *Respondents Usage: Groceries - EU*

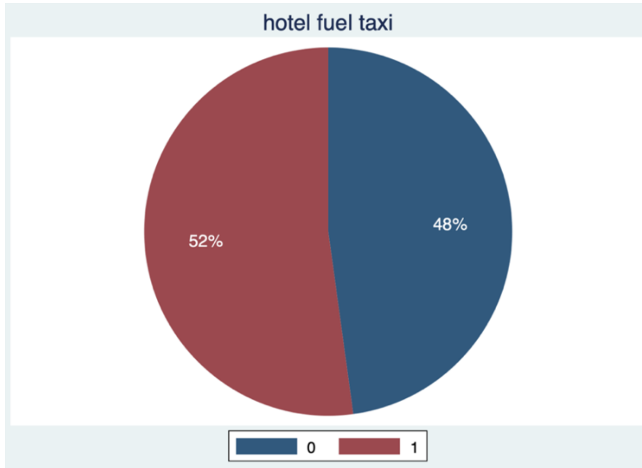

Figure 59 *Respondents Usage: Hotel Fuel Taxi - EU*

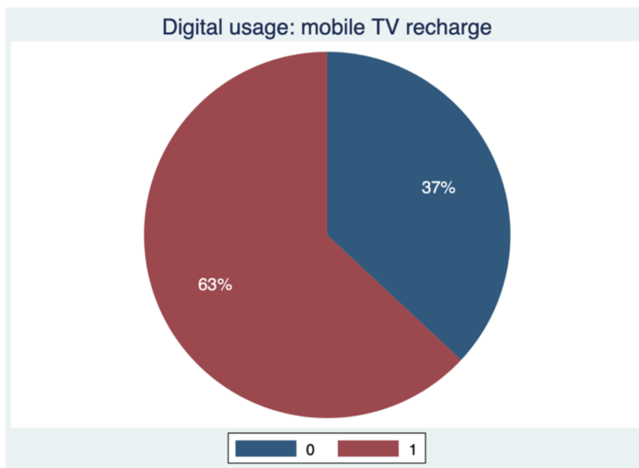

Figure 60 *Respondents Digital Usage: Mobile TV charge – EU*

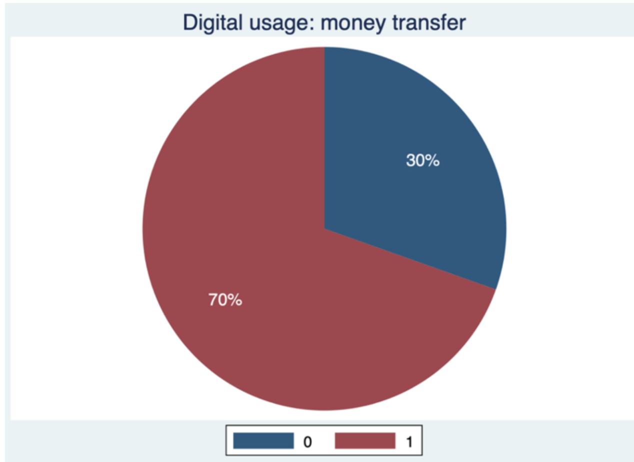

Figure 61 *Respondents Digital Usage: Money Transfer - EU*

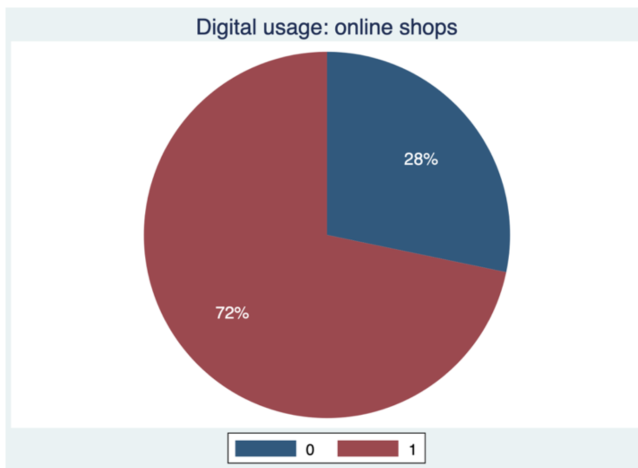

Figure 62 *Respondents Digital Usage: Online Shops - EU*

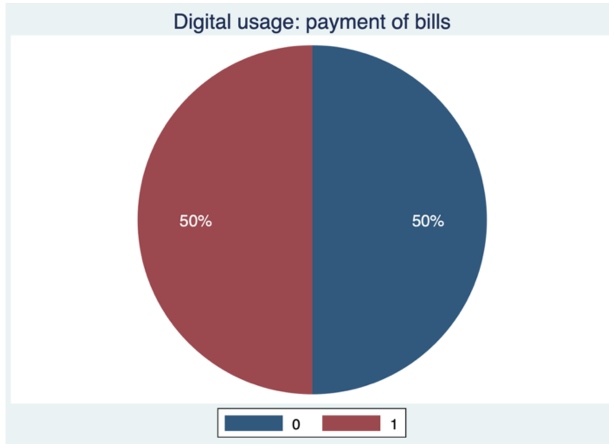

Figure 63 *Respondents Digital Usage: Payment of Bills - EU*

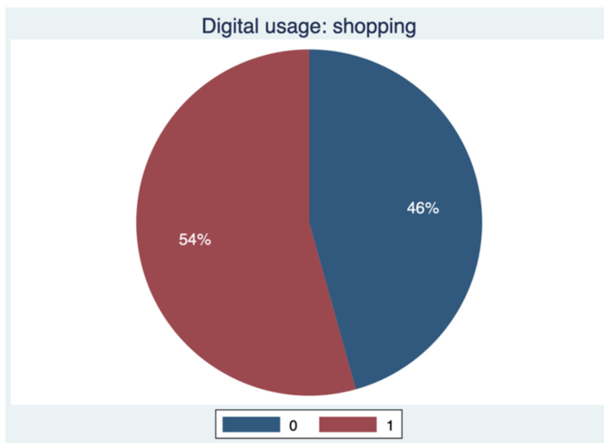

Figure 64 *Respondents Digital Usage: Shopping - EU*

Hindrance

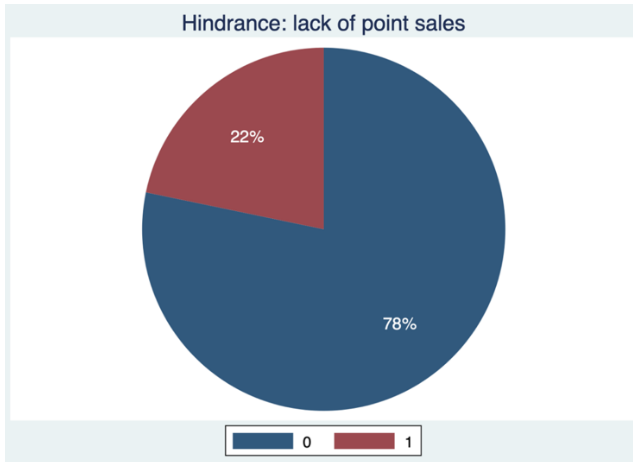

Figure 65 *Respondents Hindrance: Lack of Point Sales - EU*

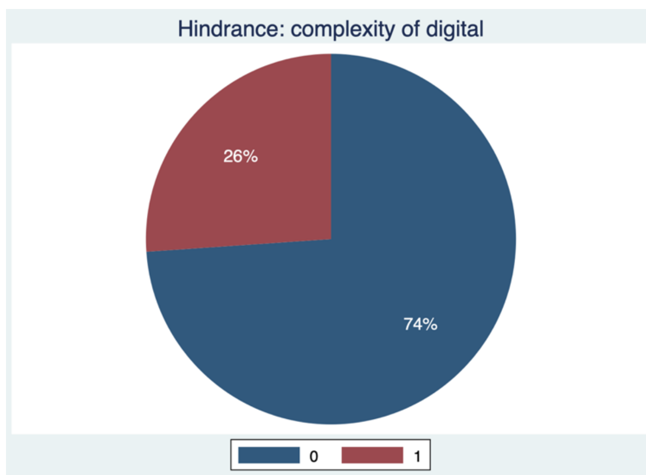

Figure 66 *Respondents Hindrance: Complexity of Digital - EU*

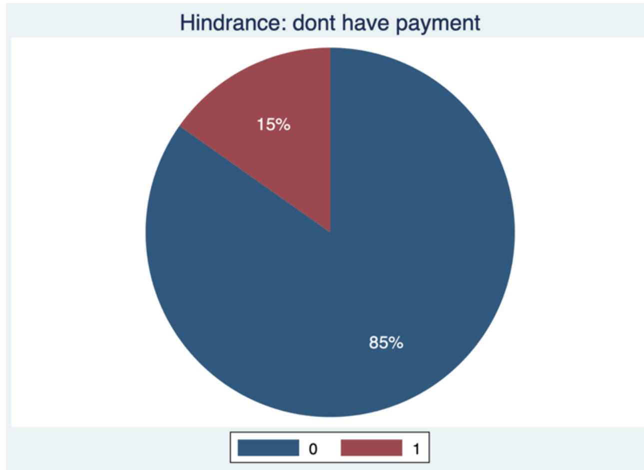

Figure 67 *Respondents Hindrance: Don't have payment – EU*

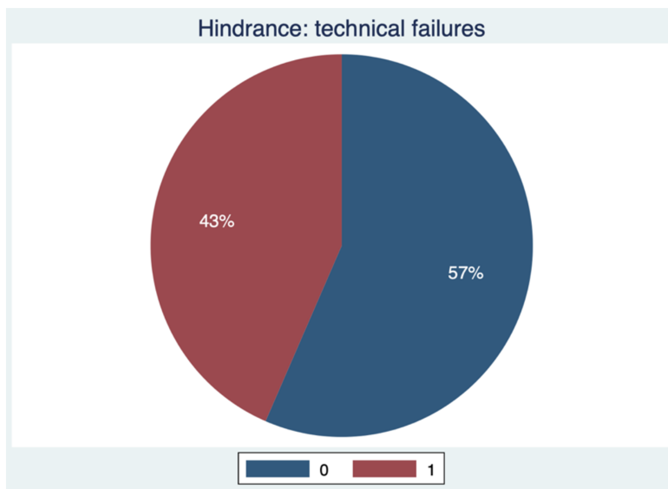

Figure 68 *Respondents Hindrance: Technical Failures - EU*

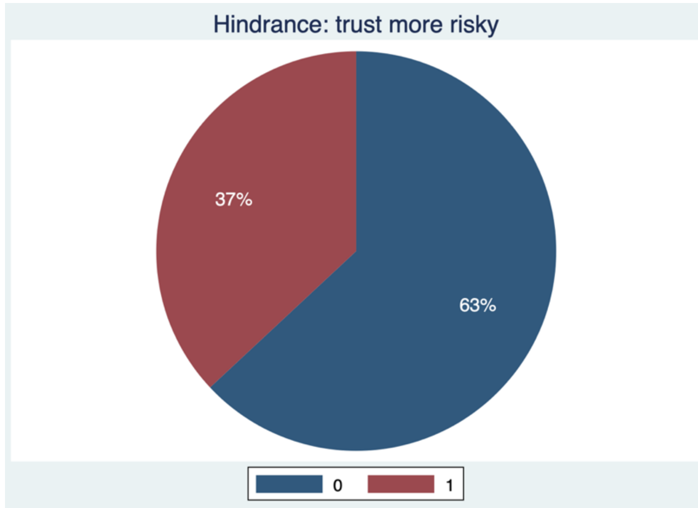

Figure 69 *Respondents Hindrance: Trust More Risky - EU*

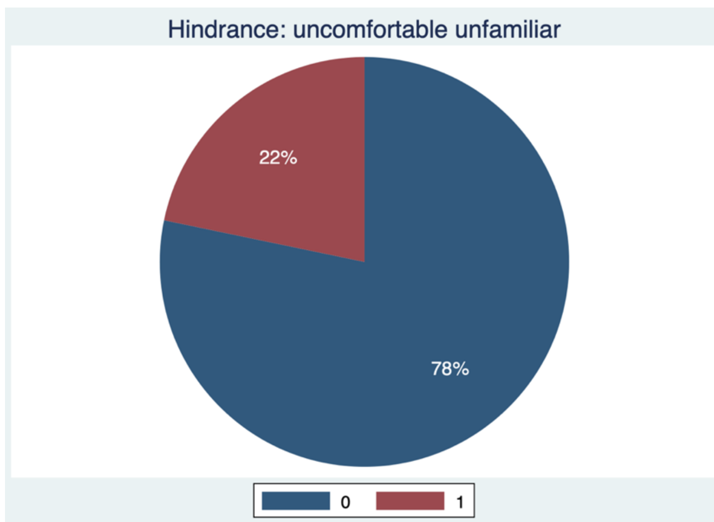

Figure 70 *Respondents Hindrance: Uncomfortable - EU*

APPENDIX III: Survey Questionnaire

Thank you for participating in this comprehensive survey. Your responses will contribute to valuable insights into digital payment usage. Please answer the following questions honestly.

Section 1: Demographics

1. Gender:

- Male
- Female
- Other (please specify)

2. Age:

- Under 18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and above

3. Type of Residence:

- Village
- Town
- City
- Metropolis

Section 2: Education

4. Highest Level of Education:

- High School
- Bachelor’s Degree
- Master’s Degree
- Doctorate
- Other (please specify)

Section 3: Geographical Information

5. Country of residence:

Section 4: Occupation

6. Employment Status:

- Employed (public/business)
- Student
- Housewife/Househusband
- Unemployed
- Self-employed
- Other (please specify)

Section 5: Income

7. Income Category:

- Less than 12,000 USD/Year
- Between 12,000-35,000 USD/Year
- Above 35,000 USD/Year

Section 6: Payment Preferences

Please rate your payment methods on a scale from 1 to 5, where 1 means "I do not like at all" and 5 means "I love it".

8. Debit Card:

- 1
- 2
- 3
- 4
- 5

9. Credit Card:

- 1
- 2
- 3
- 4
- 5

10. Mobile Banking:

- 1
- 2
- 3
- 4
- 5

11. Google Pay/Apple Pay:

- 1
- 2
- 3
- 4

- 5

12. PayPal:

- 1
- 2
- 3
- 4
- 5

13. Please rank the following payment methods in order of preference (1 being the most preferred and 5 being the least preferred):

- Debit Card
- Credit Card
- Mobile Banking
- Google Pay/Apple Pay
- PayPal
- Cash

Section 7: Small Value Transactions

Please rate how much you prefer each payment method for small value transactions on a scale from 1 to 5, where 1 means "I do not prefer at all" and 5 means "I strongly prefer."

14. Cash:

- 1
- 2
- 3
- 4
- 5

15. Card:

- 1
- 2
- 3
- 4
- 5

16. Digital Options:

- 1
- 2
- 3
- 4
- 5

17. What is the split between cash and digital payments per month with a budget of 1,000 USD? (Please provide the percentage split, e.g., 50% cash/50% digital.)

Section 8: Digital Payment Usage

18. Reasons for using digital payments (select all that apply):

- Convenience
- Offers & Discounts
- Trust
- Ease of Use
- Other (please specify)

19. Please rank the following modes of digital payments (1 being the most preferred and 6 being the least preferred):

- Mobile Banking
- Debit Card
- Credit Card

- PayPal
- Apple/Google Pay
- Cryptocurrency

20. Preferred mode for small value transactions (less than 5 USD):

- Cash
- Digital
- Card

21. When do you usually use digital transactions? (Select all that apply):

- Groceries
- Food Ordering Apps
- Hotel/Fuel/Taxi
- Ticket Booking/Travels
- Mobile/TV Recharge
- Payment of Bills
- Money Transfer
- Shopping
- Online Shops

22. Hindrance when using digital payments (select all that apply):

- Lack of Point of Sales
- Technical Failures
- Complexity of Digital Transactions
- Uncomfortable/Unfamiliar
- Less Trust/More Risky
- Don't have payment products like cards/wallets

Thank you for your participation!

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DECLARATION ON IDENTITY

I, the undersigned Dmitry Ganzha, declare that **the printed and electronic versions** of the doctoral dissertation and thesis booklet **are identical in all respects**.

Sopron, 19.03.2025

D.Ganzha

signature of PhD candidate

10.13147/SOE.2025.11

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