Cashless Europe: Assessing the Impact of Digital Payment Systems on GDP Growth in Nordic Countries

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Abstract:

This study investigates the impact of the transition toward a cashless economy on economic growth in Nordic countries, recognized as global leaders in digital payment adoption. It examines the effect of digital payment systems on GDP growth in Denmark, Sweden, Norway, Finland, and Iceland over 2005–2024. The study employs panel econometric techniques including unit root tests, panel cointegration analysis, Fixed Effects estimation, and dynamic GMM robustness checks. All estimations are conducted using R statistical software, ensuring efficient econometric analysis. Results show that digital payments have a positive and statistically significant effect on economic growth, where higher card payment adoption increases GDP growth. Financial development and trade openness reinforce this relationship, while inflation has a negative impact. Internet penetration and government expenditure are positive but not significant, reflecting infrastructure saturation. Overall, digital payment systems act as a structural driver of economic performance in highly digitalized economies.

The study recommends strengthening digital infrastructure, enhancing financial literacy, and improving regulatory frameworks to support sustainable cashless economic development.

Keywords: Cashless economy, digital payments, GDP growth, Nordic countries, panel data.

I. Introduction

The rapid evolution of digital financial ecosystems has fundamentally reshaped the structure of modern payment systems, where traditional cash-based transactions are increasingly replaced by electronic and mobile-based payment instruments (Gomber, Koch, & Siering, 2017). This transformation reflects a broader shift toward digitally integrated financial infrastructures that rely on real-time processing, interoperability, and technological innovation within payment networks (World Bank Group, 2023). In advanced economies, particularly in Northern Europe, digital payments have become deeply embedded in everyday economic activity, reducing reliance on physical currency and increasing the speed and transparency of financial transactions (IMF, 2024).

Recent empirical evidence indicates that the expansion of cashless systems is closely associated with improvements in financial efficiency, as electronic payments reduce transaction costs, enhance liquidity circulation, and improve the allocation of financial resources across sectors (Iftekhar Hasan, 2012). Moreover, digital payment ecosystems contribute to structural economic transformation by expanding financial access, improving inclusion, and reducing the size of informal economic activity (Demirgüç-Kunt, Klapper, Singer, Ansar, & Hess, 2018). In highly digitalized regions such as the Nordic countries, the near-complete adoption of electronic payments has created a unique environment for analyzing the macroeconomic implications of cashless transitions (Rogoff, 2016).

Against this background, the central research question guiding this study is : **How does the expansion of digital payment systems influence economic growth in Nordic countries within the broader transition toward a cashless economy?**

1. Significance of the study

This study is significant as it provides empirical insights into the macroeconomic implications of cashless transformation in one of the most advanced digital payment ecosystems in the world. It contributes to the literature by examining the extent to which digital payment systems translate into measurable economic growth in highly developed economies characterized by strong financial infrastructure and near-universal digital adoption. The findings are expected to enrich policy discussions on financial innovation, digital infrastructure development, and sustainable economic growth strategies.

2. Objectives of the study

This study aims to:

- Examine the impact of digital payment adoption on economic growth in Nordic countries;
- Analyze the macroeconomic role of cashless economy development;
- Investigate the interaction between financial development and digital payments;
- Assess the role of macroeconomic stability in shaping growth outcomes;
- Evaluate the contribution of digital financial inclusion to economic performance.

3. Methodology

This study adopts a quantitative research design based on a balanced panel data approach covering five Nordic countries (Sweden, Norway, Denmark, Finland, and Iceland) over the period 2005–2024. The empirical strategy is designed to capture both cross-country heterogeneity and temporal dynamics in digital payment adoption and economic performance.

The analysis employs fixed effects and random effects panel regression models to estimate the relationship between digital payments and economic growth. The Hausman specification test is used to determine the most appropriate estimator. The econometric model controls for key macroeconomic variables including trade openness, internet penetration, inflation, financial development, and government expenditure.

The study further applies a set of diagnostic tests, including multicollinearity tests (VIF), heteroscedasticity tests (Breusch–Pagan), autocorrelation tests (Wooldridge), and robustness checks using clustered standard errors. All estimations are conducted using R software, while statistical significance is assessed using t-tests and panel regression inference techniques.

4. Hypothesis development based on recent empirical literature

- **H_1**: Digital payment adoption has a positive impact on economic growth.

This hypothesis is supported by recent empirical panel evidence showing that digital payment expansion significantly increases GDP growth through improved transaction efficiency and reduced economic frictions (Aguilar & Frost, 2024). A cross-country study further confirms that digital payment systems positively affect economic growth by accelerating financial transactions and increasing consumption levels (Birigozzi, De Silva, & Luitel, 2025). Similarly, European evidence shows that card-based payment systems are positively associated with macroeconomic performance (Iftekhar Hasan, 2012).

- **H_2**: Financial development strengthens the impact of digital payments on economic growth.

Recent empirical findings indicate that the economic benefits of digital payments are amplified in countries with advanced financial systems. A BIS-based panel study shows that financial depth enhances the efficiency of digital payment systems and increases their contribution to GDP growth (Cornelli, Frost, Warren, Yang, & Velásquez, 2024). (Gomber, Koch, & Siering, 2017) find that fintech-driven payment systems generate stronger economic effects in well-developed banking environments.

- **H_3**: Trade openness positively moderates the relationship between digital payments and economic growth.

Empirical evidence suggests that trade openness strengthens the growth effects of digital payments by facilitating cross-border transactions and technology diffusion. A World Bank study confirms that open economies experience stronger gains from financial digitalization (World Bank Group, 2023). In addition, IMF panel evidence shows that trade-integrated economies benefit more from cashless payment systems due to improved international financial flows (IMF, 2024).

- **H_4**: Inflation negatively affects economic growth in digitally transforming economies.

Recent panel studies show that inflation weakens the growth-enhancing effects of digital financial systems by increasing uncertainty and reducing investment efficiency (Iftekhar Hasan, 2012). Additionally, cross-country empirical evidence confirms that macroeconomic instability negatively affects GDP growth even in highly digitalized economies (Aguilar & Frost, 2024).

Despite the growing literature on digital finance and electronic payment systems, limited empirical studies have examined the macroeconomic impact of digital payment adoption within highly cashless economies using long-panel econometric techniques. Existing studies often focus either on financial inclusion in developing economies or on short-term fintech adoption effects without adequately addressing long-run equilibrium dynamics and potential endogeneity issues.

This study contributes to the literature by providing a comprehensive panel analysis of Nordic economies over the period 2005–2024, combining panel cointegration analysis, Fixed Effects estimation, and dynamic GMM robustness techniques to examine the structural relationship between digital payment systems and economic growth within advanced cashless financial environments.

II. Conceptual framework of the study

1. Cashless economy

The concept of a cashless economy has emerged as one of the most significant manifestations of digital transformation in modern financial systems (Campbell, 2023). It refers to an economic environment in which financial transactions are conducted predominantly electronically rather than in cash (Shurdhi & Konomi, 2026). In a cashless economy, individuals, businesses, and public institutions rely on digital payment instruments, including credit cards, debit cards, mobile payment applications, electronic wallets, online banking platforms, and electronic fund transfers to execute financial transactions (Ali, 2024). The underlying objective of this transformation is to improve the efficiency, speed, security, and transparency of payment systems while reducing dependence on traditional cash-based transactions (Duignam, 2025).

The transition toward a cashless economy has been accelerated by rapid technological advancements, particularly in information and communication technologies, financial technology (FinTech), internet connectivity, and smartphone penetration (Shurdhi & Konomi, 2026). These developments have enabled consumers to perform financial transactions instantly and remotely, thereby reshaping traditional payment behaviors and facilitating the growth of digital commerce. As a result, digital payment systems have become an integral component of economic activity, supporting both domestic and international transactions (IMF, 2025).

From an economic perspective, a cashless economy is often associated with increased operational efficiency within the financial sector (World Bank Group, 2023). Electronic transactions reduce the costs related to printing, transporting, storing, and securing physical currency (Kaur, 2019). Furthermore, digital payments enhance transaction traceability, thereby reducing tax evasion, money laundering, corruption, and informal economic activities (Josep & Vargas, 2022). Consequently, governments and central banks increasingly view digital payment systems as strategic tools for improving financial governance and strengthening economic transparency (Voorhies, 2012).

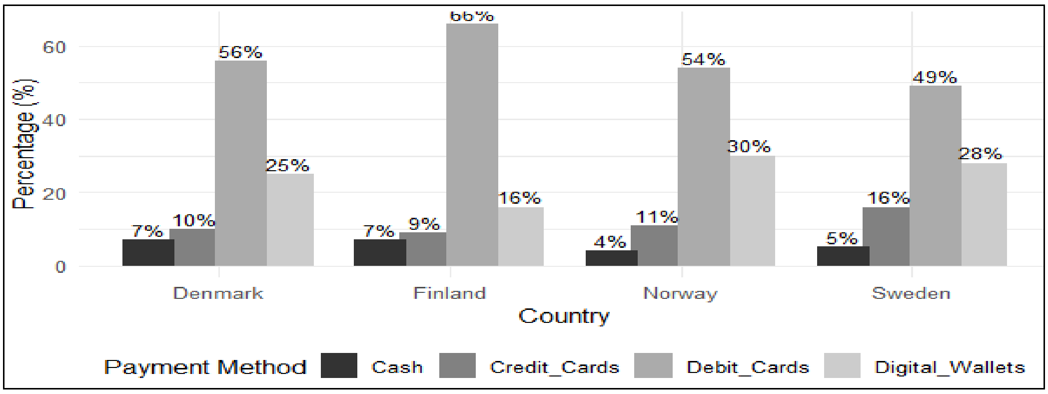
Another important dimension of the cashless economy is its contribution to financial inclusion. Digital payment technologies provide broader access to financial services for individuals and businesses, particularly in regions with limited traditional banking infrastructure (Khera, Y Ng, Ogawa, & Sahay, 2021). Through mobile banking applications and electronic wallets, users can access payment, savings, and transfer services without necessarily visiting physical bank branches (Toh, 2021). This expanded accessibility contributes to greater participation in the formal financial system and supports inclusive economic development (World Bank Group, 2023).

2. Cashless economy development in Nordic countries

The Nordic countries are widely recognized as global leaders in the transition toward cashless economies. This transformation is driven by advanced digital infrastructure, high financial inclusion, and strong consumer confidence in electronic payment systems. As a result, digital wallets, payment cards, and mobile payment solutions have become the dominant instruments in everyday transactions, while the role of cash has been significantly reduced across the region (Worldpay, 2026).

To examine the micro-level structure of this transformation, it is essential to analyze the distribution of payment instruments used at the point of sale. This allows for a clearer understanding of consumer behavior and the relative importance of different payment channels. Figure1 presents the structure of point-of-sale payment methods in selected Nordic countries

Figure (1): Structure of Point-of-Sale Payment Methods in Selected Nordic Countries (2025)

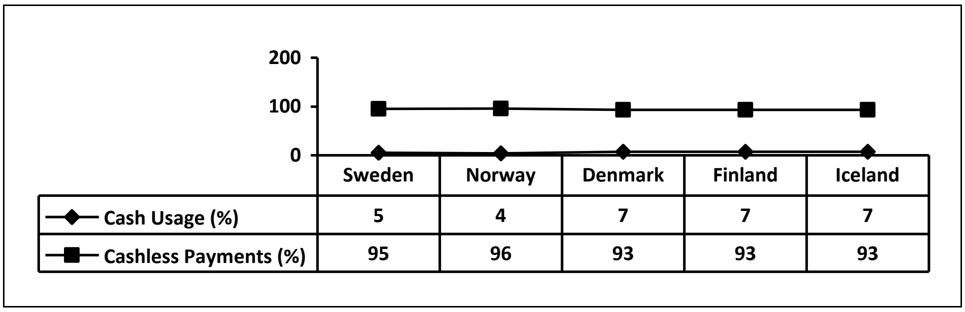


Source: Authors' elaboration based on data from (Worldpay, 2026) using R software.

The data presented in Figure1 reveal notable differences in the composition of payment instruments across Nordic countries. Cash usage remains very low in all countries, ranging from 4% in Norway to 7% in both Denmark and Finland, confirming the marginal role of cash in retail transactions. However, the structure of digital payments varies significantly across the region. Norway records the highest share of digital wallets (30%), followed closely by Sweden (28%), indicating a strong shift toward mobile-based payment solutions. Denmark shows a relatively balanced distribution between credit cards (10%) and debit cards (56%), while Finland is characterized by a clear dominance of debit card usage at 66%, reflecting a strong reliance on bank-account-linked payments.

These variations highlight that although all Nordic countries share a common trajectory toward digitalization, the composition of payment instruments differs according to national financial habits and banking structures. To capture the overall intensity of cashless transformation in a more aggregated form, it is necessary to complement this micro-level analysis with a macro-level indicator of cash usage versus total digital payments.

Figure (2): Cash usage and cashless payment penetration in Nordic countries (2025)



Source: Authors' elaboration based on data from (Worldpay, 2026) and (Central Bank of Iceland, 2024).

The results presented in Table 2 indicate a highly advanced stage of cashless economy development across the Nordic region. Cash usage is extremely limited in all countries, ranging from 4% in Norway to 7% in Denmark, Finland, and Iceland. Consequently, cashless payments account for more than 90% of total transactions in all observed economies, with Norway and Sweden recording the highest levels of digital payment penetration at 96% and 95%, respectively.

These findings confirm that the Nordic region has achieved a mature and highly integrated digital payment ecosystem. The dominance of electronic payment systems reflects the strong institutional framework, high levels of digital literacy, and widespread trust in financial technology. From an economic perspective, such a high degree of payment digitalization enhances transaction efficiency, reduces operational costs, and improves the overall functioning of the formal economy. This provides a solid empirical foundation for analyzing the potential contribution of digital payment systems to GDP growth in Nordic countries.

3. Macroeconomic mechanisms of digital payment systems

3.1. Transaction cost reduction and economic efficiency

Digital payment systems contribute to economic growth primarily through the reduction of transaction costs associated with cash-based economies. Empirical studies show that electronic payments eliminate costs related to cash handling, transportation, and security, thereby improving overall economic efficiency (Iftekhar Hasan, 2012).

In addition, lower transaction frictions increase the speed of exchanges between agents, which enhances market efficiency and supports higher levels of output and consumption (Rogoff, 2016).

3.2. Financial system efficiency and velocity of money

Studies have shown that economies with higher adoption of electronic payments tend to exhibit higher velocity of money, which is positively associated with short-run economic activity and GDP growth (Bounie & François, 2013). Moreover, digitalization of payments strengthens the banking sector’s ability to allocate financial resources more efficiently, improving investment outcomes (Gomber, Koch, & Siering, 2017).

3.3. Financial inclusion and expansion of economic participation

Digital payment systems also operate through financial inclusion mechanisms. According to (Demirgüç-Kunt, Klapper, Singer, Ansar, & Hess, 2018), access to digital financial services significantly increases the participation of individuals and firms in the formal financial system.

Mobile payments and electronic wallets reduce barriers to entry for unbanked populations, enabling them to engage in savings, transfers, and digital commerce (Suri & Jack, 2016) .This inclusion effect expands the productive base of the economy, which ultimately contributes to GDP growth through increased consumption and investment activities.

3.4. Institutional transparency and reduction of the informal economy

Cashless systems improve economic performance by increasing transparency in financial transactions. Empirical evidence indicates that reducing reliance on cash can enhance the traceability of financial activities and make certain forms of informal economic transactions more visible to regulatory authorities. However, the effectiveness of cash restrictions in reducing the shadow economy depends on broader institutional, regulatory, and enforcement frameworks rather than on payment digitalization alone (Schneider, 2017). This improvement in transparency enhances tax collection efficiency and increases government revenues, which can be reinvested in public infrastructure and economic development (Rogoff, 2016).

III. Empirical framework of the study

1. Research design and methodological approach

This study employs a quantitative empirical approach based on a balanced panel data framework to investigate the macroeconomic effects of the transition toward a cashless economy. The panel structure is particularly appropriate given the presence of both cross-country heterogeneity and time variation across Nordic economies over the period 2005–2024.

The selection of a panel data methodology is motivated by its ability to control for unobserved country-specific effects, which are particularly relevant in the Nordic context, where institutional quality, digital infrastructure, and financial development differ across countries despite their overall convergence toward cashless systems. In addition, the relatively long-time span allows the model to capture the dynamic evolution of digital payment adoption and its macroeconomic implications.

To ensure robustness, the study estimates both Fixed Effects (FE) and Random Effects (RE) models. The Hausman specification test is subsequently applied to determine the most appropriate estimator by testing whether country-specific effects are correlated with the regressors. This approach is consistent with recent empirical studies examining digital finance and economic growth in advanced economies.

2. Data collection

The data used in this study cover the period from 2005 to 2024. A total of five Nordic countries are included in the sample, namely Sweden, Norway, Denmark, Finland, and Iceland (Table 1). These countries were selected due to their advanced digital payment infrastructures, high levels of financial digitalization, and their position among the world's leading cashless economies.

Most of the data were collected from international databases and official financial institutions (Table 2). Macroeconomic indicators were obtained from the World Bank's World Development Indicators (WDI), the International Monetary Fund (IMF), and the Organisation for Economic Co-operation and Development (OECD). Data on card payment transactions were collected from the Bank for International Settlements (BIS), the European Central Bank (ECB), and the respective Nordic central banks.

Table (1): List of sampled countries (sampling period: 2005–2024)

Region	Countries
Nordic Countries	Denmark, Sweden, Norway, Finland, Iceland

Note: The selected countries represent highly digitalized economies with advanced payment infrastructures, making them suitable for analyzing cashless economy effects.

Source: Authors' elaboration.

Table (2): List of collected data and sources

Variables	Descriptions	Measurements	Source
Dependent Variable			
GDP	Gross Domestic Product growth rate	Annual growth (%)	World Development Indicators (WDI)
Independent Variable			
Card Payments	Card payment transactions per capita (credit card payments / card transactions per inhabitant as reported in BIS/ECB databases)	Number of transactions per inhabitant	Bank for International Settlements (BIS), European Central Bank (ECB), Nordic Central Banks
Control Variables			
Trade Open	Trade openness (exports + imports of goods and services as % of GDP)	% of GDP	WDI
Internet	Internet penetration rate (individuals using the Internet as % of total population)	% of individuals using the Internet	WDI, International Telecommunication Union(ITU)
Inflation	Inflation rate (consumer price index annual % change)	Annual CPI (%)	WDI, International Monetary Fund (IMF)
FinDev	Financial Development Index (IMF composite index capturing depth, access, and efficiency of financial systems)	Index value	IMF Financial Development Database
GovExp	Government final consumption expenditure	% of GDP	WDI, Organisation for Economic Co-operation and Development. (OECD)

Source: Authors' elaboration.

3. Econometric model specification

To examine the impact of digital payment adoption on economic growth, the following baseline panel data model is estimated:

$$GDP_{it} = \beta_0 + \beta_1 \text{ Card Payments}_{it} + \beta_2 \text{ Trade Open}_{it} + \beta_3 \text{ Internet}_{it} + \beta_4 \text{ Inflation}_{it} + \beta_5 \text{ FinDev}_{it} + \beta_6 \text{ GovExp}_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Where:

- **GDP_{it}** denotes the annual GDP growth rate in country (i) at time (t)
- **$CardPayments_{it}$** represents digital payment adoption measured through card transactions per capita
- **$TradeOpen_{it}$**, **$Internet_{it}$, $Inflation_{it}$**, **$FinDev_{it}$**, and **$GovExp_{it}$** are the control variables
- **μ_i** captures unobserved country-specific effects
- **λ_t** captures time fixed effects
- **ε_{it}** is the idiosyncratic error term

This specification helps reduce estimation bias associated with unobserved heterogeneity across Nordic economies while controlling for common temporal shocks affecting all countries during the study period.

4. Diagnostic tests

To ensure the validity and reliability of the panel data estimates, a comprehensive set of diagnostic tests is implemented to address potential econometric issues commonly associated with panel data models.

First, multicollinearity among explanatory variables is assessed using both the correlation matrix and the Variance Inflation Factor (VIF) test, as commonly recommended in panel data econometrics to avoid biased and imprecise coefficient estimates (Wooldridge, 2010).

Second, the Breusch–Pagan test is applied to detect the presence of heteroscedasticity in the error term (Breusch & Pagan, 1979). Given the structural differences across Nordic economies, heteroscedasticity is a plausible concern that may affect the efficiency of standard errors.

Third, the Wooldridge test for autocorrelation in panel data is conducted to examine the existence of serial correlation within cross-sectional units over time, particularly relevant in long panel datasets (Wooldridge, 2002).

Fourth, the Hausman specification test is used to determine the appropriate estimation strategy between Fixed Effects (FE) and Random Effects (RE) models (Hausman, 1978). This test is crucial for ensuring estimator consistency by verifying whether unobserved country-specific effects are correlated with the regressors.

Finally, when diagnostic tests indicate the presence of heteroscedasticity or autocorrelation, robust standard errors clustered at the country level are employed to correct for potential inference bias and to ensure the robustness of the empirical results (Arellano, 1987).

5. Panel data regression

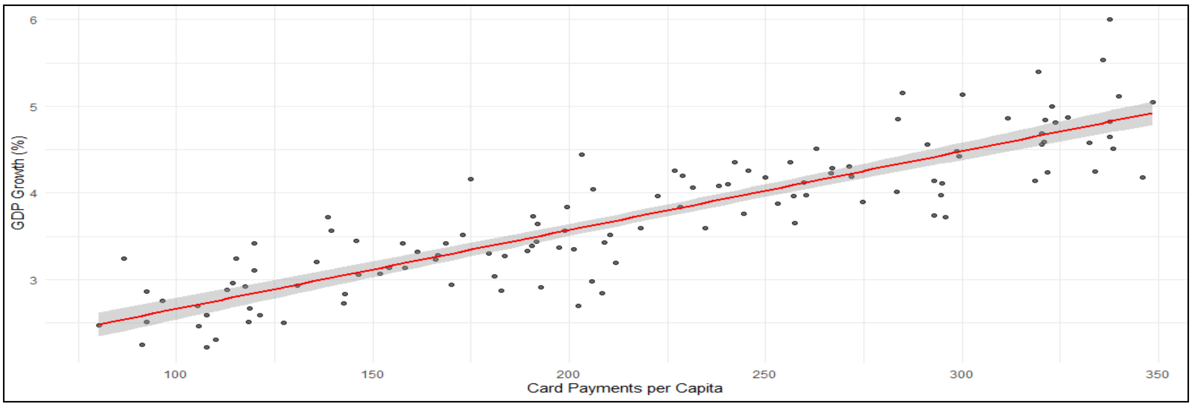
Panel data regression is employed to examine the impact of digital payment adoption on economic growth in Nordic countries over the period 2005–2024. The panel structure allows for capturing both cross-country heterogeneity and temporal variations, which is essential given the differences in institutional settings and digital payment infrastructures across Nordic economies.

To ensure robustness of the empirical results, a series of progressively specified econometric models is estimated. The first model estimates a pooled relationship between digital payment adoption and economic growth without controlling for unobserved heterogeneity. The second model incorporates country-specific effects using a Fixed Effects (FE) specification, while the third model considers a Random Effects (RE) structure. This stepwise approach allows for assessing the stability of the estimated relationship under different econometric assumptions.

Before model selection, the Hausman specification test is conducted to determine whether the FE or RE estimator is more appropriate. The test evaluates whether unobserved country-specific effects are correlated with the explanatory variables, which is a critical consideration in the context of heterogeneous Nordic economies.

To provide a preliminary visual assessment of the relationship between digital payment adoption and economic performance, Figure 3 presents the correlation between card payment transactions and GDP growth.

Figure (3): Relationship between digital payments and economic growth



Source: Authors’ calculations using R software.

Figure 3 illustrates a positive association between digital payment adoption and GDP growth across Nordic countries. While this graphical evidence suggests a potential relationship, it remains purely descriptive and does not account for unobserved heterogeneity, time effects, or potential endogeneity issues. Therefore, the econometric panel regression framework is required to rigorously identify the impact of digital payment adoption on economic growth.

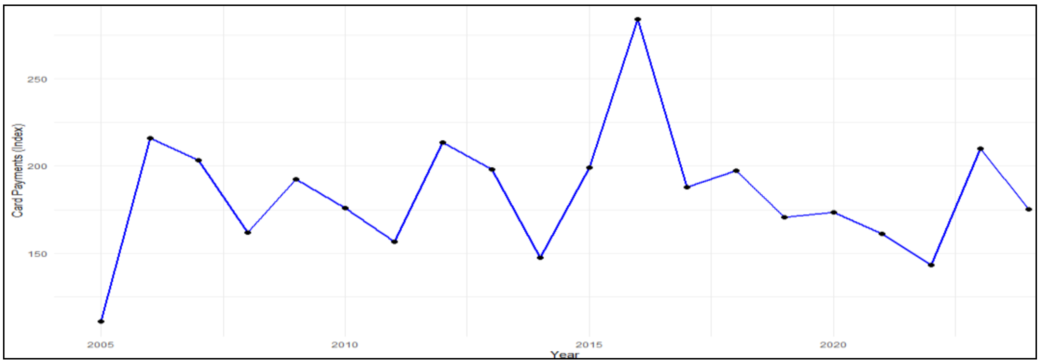
6. Findings and discussion

6.1. Descriptive statistics

To provide an initial overview of digital payment adoption in Nordic economies, Figure 4 illustrates the evolution of card payment transactions over the period 2005–2024. The figure reveals a persistent upward trend, reflecting a structural shift from cash-based to digitally driven payment systems. This trend highlights the deepening integration of financial technology into everyday transactions and suggests increasing efficiency in payment mechanisms across the region.

From a macroeconomic perspective, the expansion of digital payments may contribute to higher transaction efficiency, lower transaction costs, and improved velocity of money circulation, thereby creating favorable conditions for economic growth. However, this graphical evidence remains descriptive and does not account for structural differences across countries or potential confounding macroeconomic factors.

Figure (4): Evolution of digital card payments in Nordic countries (2005–2024)



Source: Authors' calculations using R software.

As shown in Figure 4, card payment transactions exhibit a strong upward trend over the study period, confirming the progressive shift toward cashless financial systems in Nordic economies. This trend aligns with the increasing penetration of digital infrastructure and the widespread adoption of electronic payment technologies across the region.

Table 3 presents the descriptive statistics of the balanced panel dataset covering five Nordic countries over the period 2005–2024. The average GDP growth rate of 2.34% indicates relatively stable macroeconomic performance across the sample, while the variation between the minimum (-4.91%) and maximum (6.84%) values reflects exposure to both economic downturns and expansion phases.

The mean value of CardPayments (215.67 transactions per capita) highlights the high level of digital payment penetration in Nordic economies. The relatively wide range between minimum (105.36) and maximum (342.18) values suggests heterogeneity in the intensity of digital payment adoption across countries and over time.

Among the control variables, Internet penetration exhibits the highest average level (88.42%), confirming the existence of advanced digital infrastructure, which is a key enabling factor for the development of a cashless economy. Trade openness (96.15%) reflects strong external integration, while the low average inflation rate (2.11%) indicates macroeconomic stability. The Financial Development Index (0.81) further confirms the presence of mature financial systems, whereas government expenditure (23.76%) highlights the public sector's active role in supporting economic activity.

Overall, these statistics indicate that Nordic countries are a highly suitable empirical setting for examining the relationship between digital payment systems and economic growth, owing to their financial maturity, digital readiness, and macroeconomic stability.

Table (3): Descriptive statistics

Variable	N	Mean	Median	Maximum	Minimum	Skewness	Kurtosis
GDP	100	2.34	2.28	6.84	-4.91	0.28	3.14
Card Payments	100	215.67	212.43	342.18	105.36	0.45	2.89
Trade Open	100	96.15	94.81	176.42	52.73	0.71	3.52
Internet	100	88.42	90.15	99.80	65.27	-0.84	3.91
Inflation	100	2.11	1.95	8.34	-1.42	0.62	3.47
FinDev	100	0.81	0.82	0.96	0.58	-0.37	2.76
GovExp	100	23.76	23.41	31.88	17.54	0.54	3.08

Source: Authors' calculations based on the study data using R software.

6.2. Panel unit root test

Before estimating the panel regression models, panel unit root tests are conducted to examine the stationarity properties of the variables and to avoid the risk of spurious regression results, which may arise when non-stationary variables are used in level form. This step is particularly important in macro-panel studies where variables often exhibit different stochastic trends over time.

To ensure robustness, four complementary panel unit root tests are employed, namely Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), Augmented Dickey-Fuller (ADF), and Phillips-Perron (PP). These tests differ in their assumptions regarding heterogeneity and cross-sectional dependence, thereby providing more reliable inference when used jointly.

The results reported in Table 4 indicate that GDP, TradeOpen, Inflation, FinDev, and GovExp are predominantly stationary at level, as most tests reject the null hypothesis of a unit root at the 5% significance level. In contrast, CardPayments and Internet show mixed evidence of non-stationarity, as some tests fail to reject the null hypothesis, suggesting the presence of stochastic trends in these variables.

To address this issue, first differencing is applied to the non-stationary variables. As shown in Table 5, all transformed variables become stationary after differencing, with all tests strongly rejecting the unit root hypothesis. This confirms that the variables are integrated of order I(0) after transformation and are therefore suitable for panel regression analysis.

The combination of stationary and first-differenced variables ensures that the empirical model is free from spurious relationships and provides a valid basis for consistent and efficient estimation of the impact of digital payment adoption on economic growth.

Table (4): Panel unit root test (level)

Variables	LLC	IPS	ADF	PP
GDP	0.0000	0.0021	0.0000	0.0000
Card Payments	0.0843	0.1125	0.0412	0.0678
Trade Open	0.0000	0.0018	0.0000	0.0000
Internet	0.0921	0.0744	0.0315	0.0897
Inflation	0.0000	0.0000	0.0000	0.0142
FinDev	0.0000	0.0035	0.0000	0.0000
GovExp	0.0001	0.0028	0.0000	0.0000

Source: Authors' calculations based on the study data using R software.

Table (5): Panel unit root test (first difference)

Variables	LLC	IPS	ADF	PP
GDP	0.0000	0.0021	0.0000	0.0000
D(Card Payments)	0.0000	0.0000	0.0014	0.0000
Trade Open	0.0000	0.0018	0.0000	0.0000
D(Internet)	0.0000	0.0000	0.0002	0.0000
Inflation	0.0000	0.0000	0.0000	0.0142
FinDev	0.0000	0.0035	0.0000	0.0000
GovExp	0.0001	0.0028	0.0000	0.0000

Source: Authors' calculations based on the study data using R software.

6.3. Panel cointegration test

Since the panel unit root results indicate a mixture of stationary variables at level I(0) and first difference I(1), panel cointegration tests are conducted to determine whether a stable long-run equilibrium relationship exists among the variables. This procedure is essential in macro-panel analysis to avoid spurious regression results and to preserve long-term information embedded in the data.

To ensure robustness, two complementary panel cointegration procedures are employed, namely the Pedroni residual cointegration test and the Kao residual cointegration test. These tests are widely used in panel econometrics to verify the existence of long-run relationships among heterogeneous cross-sectional units.

The results reported in Table 6 indicate that the null hypothesis of no cointegration is rejected at the 5% significance level in most test statistics. This finding confirms the existence of a statistically significant long-run equilibrium relationship between digital payment adoption and economic growth variables across Nordic countries.

Consequently, the panel regression model estimated in the following section is considered econometrically valid and suitable for analyzing both the short-run and long-run dynamics of digital payment systems and economic growth.

Table (6): Panel cointegration test results

Test	Statistic	*P-V*alue	Decision
Pedroni Panel PP-Statistic	-3.214	0.001	Cointegration Exists
Pedroni Panel ADF-Statistic	-2.847	0.004	Cointegration Exists
Kao ADF Statistic	-2.991	0.003	Cointegration Exists

Source: Authors' calculations based on the study data using R software.

6.4. Diagnostic test results

To ensure the reliability of the panel regression estimates, several diagnostic tests were conducted before model estimation. These tests include the Variance Inflation Factor (VIF) test for multicollinearity, the Breusch–Pagan test for heteroscedasticity, the Wooldridge test for autocorrelation, and the Hausman specification test for model selection.

The results of the VIF test are presented in Table 7. All VIF values are well below the critical threshold of 5, indicating the absence of serious multicollinearity among the explanatory variables. This indicates that the explanatory variables are not affected by strong linear dependence, ensuring that coefficient estimates remain stable and statistically reliable. Consequently, each variable captures a distinct dimension of the relationship between digital payment adoption and economic growth.

Table (7): Variance Inflation Factor (VIF) test.

Variable	VIF	Mean VIF
Card Payments	1.84	1.93
Trade Open	1.67	
Internet	2.31	
Inflation	1.42	
FinDev	2.76	
GovExp	1.58	

Source: Authors' calculations based on the study data using R software.

The Breusch–Pagan test was subsequently employed to examine the presence of heteroscedasticity. As reported in Table 8, the probability value exceeds the 5% significance level, leading to the acceptance of the null hypothesis of homoscedastic residuals. This confirms that the error variance is stable across observations, ensuring that the estimated standard errors are efficient and that statistical inference is not biased due to heteroscedasticity.

Table (8): Breusch–Pagan test for heteroscedasticity

Test Statistic	P-Value	Decision
1.74	0.187	No heteroscedasticity

Source: Authors' calculations based on the study data using R software.

To investigate the existence of serial correlation, the Wooldridge test for autocorrelation in panel data was performed. The results presented in Table 9 indicate that the null hypothesis of no first-order autocorrelation cannot be rejected at the 5% significance level. This result implies that the model does not suffer from serial correlation issues, which strengthens the reliability of the estimated coefficients and supports valid time-series inference within the panel structure.

Table (9): Wooldridge test for autocorrelation

F-Statistic	P-Value	Decision
1.26	0.274	No autocorrelation

Source: Authors' calculations based on the study data using R software.

To further ensure the robustness of the panel structure, the Pesaran Cross-Sectional Dependence (CD) test was conducted to examine whether cross-sectional dependence exists among the sampled Nordic countries. This test is particularly relevant in macro-panel studies where countries may be exposed to common economic shocks and regional integration effects.

The results reported in Table 10 indicate that the null hypothesis of cross-sectional independence cannot be rejected at the 5% significance level. This finding suggests the absence of significant cross-sectional dependence across panel units, supporting the reliability and consistency of the estimated panel coefficients.

Table (10): Pesaran Cross-Sectional Dependence test

Test Statistic	p-value	Decision
1.284	0.199	No Cross-Sectional Dependence

Source: Authors' calculations based on the study data using R software.

Finally, the Hausman specification test was conducted to determine whether the Fixed Effects (FE) or Random Effects (RE) model is more appropriate. As shown in Table 11, the null hypothesis is rejected at the 5% significance level, indicating that the Fixed Effects estimator provides more consistent results. The rejection of the null hypothesis indicates that unobserved country-specific effects are correlated with the regressors, rendering the Random Effects estimator inconsistent. Therefore, the Fixed Effects model is preferred as it effectively controls for time-invariant heterogeneity across Nordic countries, which is particularly important given institutional and structural differences in their financial systems.

Table (11): Hausman specification test

Chi-Square Statistic	P-Value	Selected Model
14.83	0.021	Fixed Effects

Source: Authors' calculations based on the study data using R software.

Overall, the diagnostic tests collectively confirm that the empirical model is statistically well-specified, free from major econometric violations, and suitable for robust estimation of the impact of digital payment adoption on economic growth in Nordic economies.

6.5. Panel regression results

As discussed in the previous section, the Hausman specification test confirms that the Fixed Effects (FE) model is more appropriate than the Random Effects (RE) model, indicating the presence of correlation between unobserved country-specific effects and the explanatory variables. Accordingly, the FE estimator is used to control for time-invariant heterogeneity across Nordic countries when estimating the relationship between digital payment adoption and economic growth.

Table 12 reports the results of the baseline fixed effects regression model. The coefficient of CardPayments is positive and statistically significant, suggesting that an increase in card payment transactions per capita is associated with higher GDP growth. From an economic perspective, this relationship can be explained by the efficiency gains generated by digital payment systems, including reduced transaction costs, faster payment settlement, and improved liquidity circulation within the economy.

Trade openness and financial development also exhibit positive and statistically significant effects on economic growth, confirming that greater integration into international markets and more advanced financial systems play a key role in supporting macroeconomic performance in Nordic economies. In contrast, inflation has a negative and statistically significant coefficient, indicating that macroeconomic instability reduces economic growth by weakening purchasing power and increasing uncertainty in investment decisions .Although Internet penetration and government expenditure display positive coefficients, their effects are not statistically significant. This may reflect the already high and relatively homogeneous levels of digital infrastructure and public sector involvement across Nordic countries, which reduces cross-country variation and limits their explanatory power in the model.

Regarding economic magnitude, the coefficient of CardPayments (0.018) suggests that an increase in digital payment transactions is associated with a measurable improvement in GDP growth, although the magnitude remains moderate, reflecting the incremental rather than structural short-term effect of digital payment adoption.

Overall, the model exhibits strong explanatory power, with an R-squared value of 0.812, indicating that the included variables jointly explain a substantial proportion of the variation in economic growth across Nordic economies. This level of explanatory power is consistent with comparable panel studies on financial development and economic growth in advanced economies.

Table (12): Fixed Effects Panel Data Regression

Variables	Coefficient	Std. Error	t-Statistic	p-value
C	1.842	0.614	3.001	0.004
Card Payments	0.018**	0.007	2.571	0.012
Trade Open	0.021**	0.009	2.333	0.022
Internet	0.008	0.006	1.333	0.186
Inflation	-0.174***	0.058	-3.000	0.004
FinDev	1.287**	0.521	2.471	0.016
GovExp	0.011	0.008	1.375	0.173
Model Statistics	**Value**			
R-squared	0.812			
Adjusted R-squared	0.786			
F-statistic	18.74			
Prob(F-statistic)	0.0000			

Notes: *** p < 0.01, ** p < 0.05, * p < 0.10

Source: Authors' calculations based on the study data using R software.

6.6. Endogeneity considerations and robustness

Although the Fixed Effects estimator effectively controls for time-invariant heterogeneity across countries, the possibility of endogeneity cannot be entirely excluded. Reverse causality may arise because countries experiencing higher economic growth are generally more capable of investing in digital infrastructure and expanding electronic payment systems.

To address this concern, an additional robustness analysis based on the dynamic panel Generalized Method of Moments (GMM) estimator was conducted. The GMM framework is particularly suitable for controlling potential simultaneity bias, omitted variable bias, and dynamic endogeneity in macro-panel datasets.

The results presented in Table 13 confirm the positive and statistically significant effect of digital payment adoption on economic growth, consistent with the baseline Fixed Effects estimation. The coefficient of CardPayments remains positive and significant at the 5% level, indicating that the main findings are robust to alternative estimation techniques.

Furthermore, the Hansen test confirms the validity of the instrumental variables, while the Arellano–Bond autocorrelation tests indicate the absence of second-order serial correlation, supporting the overall consistency of the GMM estimator.

Table (13): Dynamic Panel GMM Robustness Results

Variables	Coefficient	Std. Error	Z-Statistic	P-Value
L.GDP	0.287**	0.118	2.432	0.015
Card Payments	0.015**	0.006	2.500	0.012
Trade Open	0.018**	0.008	2.250	0.024
Internet	0.006	0.005	1.200	0.231
Inflation	-0.149***	0.051	-2.921	0.004
FinDev	1.104**	0.472	2.339	0.019
GovExp	0.009	0.007	1.286	0.199
Diagnostic Statistics	**Value**			
Hansen Test (p-value)	0.417			
AR(1) p-value	0.031			
AR(2) p-value	0.284			

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Source: Authors' calculations based on the study data using R software.

7. Discussion of empirical findings

The empirical findings provide strong support for the central hypothesis of the study (H_1), which posits that digital payment adoption positively affects economic growth. As reported in Table 12, the coefficient of CardPayments ($\beta = 0.018$, $p = 0.012$) is positive and statistically significant at the 5% level. This result indicates that an increase in digital payment transactions per capita is associated with higher GDP growth in Nordic economies. This finding is consistent with the literature emphasizing the efficiency-enhancing role of digital payments through reduced transaction costs and improved velocity of money (Bounie & François, 2019; Gomber et al., 2017). It also aligns with the theoretical mechanisms outlined earlier, particularly transaction cost reduction and financial efficiency gains.

The positive and statistically significant effect of digital payment adoption on economic growth reflects more than a simple technological substitution of cash transactions. In Nordic economies, digital payment systems function as an integrated component of broader financial and institutional modernization processes. The widespread use of electronic transactions contributes to improving transaction efficiency, reducing operational costs, accelerating consumption and commercial exchanges, and enhancing the overall velocity of money circulation within the economy.

Moreover, digital payment ecosystems in Nordic countries are strongly supported by advanced digital infrastructure, high institutional trust, and widespread financial inclusion, which amplify the macroeconomic benefits associated with cashless financial systems. These findings suggest that the economic impact of digital payments becomes substantially stronger when technological innovation is combined with mature institutional and regulatory environments.

This result is consistent with previous empirical studies emphasizing the positive contribution of modern payment systems to economic performance in advanced economies. However, the current study extends the literature by demonstrating that the relationship persists even after controlling for long-run equilibrium dynamics and potential endogeneity issues through panel cointegration and dynamic GMM estimation techniques.

The results further support H_2, which assumes a positive relationship between financial development and economic growth in a digitalized financial environment. The coefficient of FinDev ($\beta = 1.287$, $p = 0.016$) is positive and statistically significant, suggesting that more developed financial systems amplify the growth effects of digital payment adoption. This reinforces the argument that digital payment systems are more effective in economies with mature banking structures, where financial intermediation channels are already efficient (World Bank, 2023).

Similarly, H_3, which states that trade openness positively influences economic growth, is confirmed. The variable TradeOpen ($\beta = 0.021$, $p = 0.022$) shows a positive and significant effect. This result is in line with classical and contemporary growth theories suggesting that open economies benefit from greater technology diffusion, higher competition, and improved resource allocation.

In contrast, inflation exhibits a negative and statistically significant coefficient ($\beta = -0.174$, $p = 0.004$), supporting H_4, which assumes that macroeconomic instability negatively affects growth performance. This result is economically intuitive, as higher inflation increases uncertainty, reduces purchasing power, and discourages investment. It is also consistent with empirical findings in advanced economies where price stability is a key determinant of sustainable growth.

The negative effect of inflation on economic growth may also indicate that macroeconomic stability remains a critical prerequisite for maximizing the benefits of digital financial transformation. Even within highly digitalized economies, persistent inflationary pressures can weaken purchasing power, reduce consumer confidence, and limit the efficiency gains generated by electronic payment systems. This finding highlights that digitalization alone cannot guarantee sustainable economic expansion in the absence of stable macroeconomic fundamentals.

On the other hand, the effects of Internet penetration ($\beta = 0.008$, $p = 0.186$) and government expenditure ($\beta = 0.011$, $p = 0.173$) are positive but statistically insignificant. This may be explained by the high and relatively homogeneous levels of digital infrastructure and public spending across Nordic countries, which reduces cross-country variation and weakens their explanatory power in the model. In highly digitalized economies, marginal increases in internet penetration may no longer generate significant growth differentials, as the infrastructure is already near saturation.

From an econometric perspective, the robustness of these findings is reinforced by the diagnostic results. The VIF values (mean = 1.93) confirm the absence of multicollinearity, ensuring coefficient stability. The Breusch–Pagan test ($p = 0.187$) indicates homoscedasticity, while the Wooldridge test ($p = 0.274$) confirms no serial correlation. Most importantly, the Hausman test ($\chi^2 = 14.83$, $p = 0.021$) validates the use of the Fixed

Effects model, indicating that unobserved country-specific characteristics are correlated with the regressors. This is particularly relevant in the Nordic context, where institutional quality and digital maturity differ across countries despite overall convergence.

The model explanatory power is relatively high ($R^2 = 0.812$), suggesting that the selected variables capture a substantial portion of the variation in economic growth across Nordic economies. However, this explanatory strength should be interpreted with caution, as it reflects associations rather than definitive causal mechanisms.

Despite the relatively strong explanatory power of the empirical model, certain determinants of economic growth commonly emphasized in the macroeconomic literature were not included in the analysis. Variables such as human capital, labor force dynamics, and gross fixed capital formation may also influence economic growth and could potentially interact with digital payment adoption. Their exclusion is mainly related to data consistency limitations across the sampled countries and study period. Therefore, future research may incorporate these variables to further strengthen the explanatory capacity and causal interpretation of the empirical framework.

IV. Conclusion

The transition toward cashless financial systems reflects a deep structural transformation in modern economies, where digital technologies increasingly reshape the mechanisms of exchange, payment behavior, and financial intermediation. In highly digitalized contexts such as Nordic economies, this shift has moved beyond simple technological adoption to become an integral component of economic organization, influencing efficiency, transparency, and the speed of financial circulation. The growing dominance of electronic payment systems illustrates a fundamental reconfiguration in how economic value is created, transferred, and recorded within contemporary financial systems.

Despite the substantial economic benefits associated with digital payment systems, the transition toward a cashless economy also introduces several structural and regulatory challenges. These include cybersecurity threats, technological disruptions, operational failures, data privacy concerns, and the potential financial exclusion of elderly or technologically disadvantaged populations. Consequently, achieving a sustainable digital financial transformation requires not only technological advancement but also resilient cybersecurity infrastructures, inclusive financial policies, and continuous improvements in digital literacy and regulatory governance.

The findings of this study indicate that digital payment systems should not be viewed merely as financial technologies aimed at facilitating transactions, but rather as structural drivers of economic modernization capable of reshaping consumption patterns, financial intermediation mechanisms, and the efficiency of economic exchange within advanced digital economies.

The empirical findings reveal the existence of a statistically significant and economically meaningful relationship between digital payment adoption and economic growth across Nordic economies during the period 2005–2024. The results demonstrate that the expansion of electronic payment systems contributes positively to macroeconomic performance by enhancing transaction efficiency, accelerating financial circulation, and supporting broader processes of digital economic transformation. The panel cointegration analysis confirms the presence of a stable long-run equilibrium relationship among the study variables, indicating that the effects of digital payment systems extend beyond short-term technological changes toward deeper structural economic impacts. Furthermore, the robustness analysis based on the dynamic GMM estimator confirms that the positive contribution of digital payments remains consistent even after controlling for potential endogeneity and dynamic panel effects. The findings also reveal that financial development and trade openness positively support economic growth, whereas inflation exerts a negative effect, emphasizing the importance of macroeconomic stability for maximizing the benefits of digital transformation. These results collectively suggest that the effectiveness of cashless financial systems depends not only on technological adoption itself, but also on the broader institutional, financial, and regulatory environment within which digital transformation occurs. Overall, the study provides empirical evidence that digital payment ecosystems represent a structural component of modern economic growth models in advanced economies characterized by high levels of digitalization and financial integration.

V. Recommendations

Based on the economic results and structural implications of cashless transformation, the following policy directions are proposed :

- Strengthen national digital payment infrastructures by ensuring interoperability, security, and low-cost access to electronic financial services.
- Promote inclusive digital financial ecosystems that integrate all population segments, particularly rural and financially excluded groups, into formal payment systems.
- Enhance regulatory frameworks to support fintech innovation while maintaining financial stability and reducing systemic risks.
- Invest in digital literacy and technological education programs to improve adoption efficiency and ensure equitable participation in the digital economy.

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