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The Nonlinear Impact of Payment System Innovation on Financial System Stability in the ASEAN-4 Countries

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Abstract

The increasing growth of financial system encourages payment system innovation that can affect financial system stability, particularly in ASEAN countries. This study explored a variety of payment system innovation, i.e. debit cards, credit cards, electronic money, and RTGS. The financial system stability index is measured by calculating the composite indexes of non-performing loans, Z-score from ROA and CAR, share price volatility, and yield bonds. The components of the indexes are structured to reflect risks from the banking, stock, and bond markets. The resulting index value indicates the level of risk in the financial system. A higher index specifies a higher risk and a more vulnerable financial system. Furthermore, it is noted that the effects of the independent variable can change according to economic conditions. The panel threshold model was applied to calculate the effects of various regimes, namely innovation, GDP, credit ratio, and stability index. The panel data were obtained from the ASEAN-4 countries (Indonesia, Malaysia, Thailand, and the Philippines) from 2012 to 2020. The panel threshold analysis shows an increase in the value of debit card, credit card, and RTGS transactions. Specifically, innovation and GDPR negatively affect the stability index. Increasing the value of payment system innovation will decrease the risk to financial system stability in ASEAN countries. The monetary authorities of each country can implement these findings by considering the rapid development of payment system innovation and the danger it may pose to financial system stability.

Keywords: threshold panel, payment system innovation, financial system stability

JEL classifications: C24; E44; E58

1. Introduction

Financial transactions have shown a critical development in the recent years. A financial system has a primary function to facilitate the movement of funds from the surplus to the surplus section of the deficit. Through the intermediary role of financial institutions, a stable financial system can boost the performance of the real sector to improve economic growth and assist the government in controlling inflation. Asare, Ding, & Prince (2021) and Chen & Du (2016) classify financial innovation into two categories: from the product side and from the process or method side. Innovation from the product side includes derivative products. Meanwhile, innovation from the process side covers credit scoring, financial reporting, and new payment techniques or systems. Payment system innovation is currently a rapidly growing innovation (the modernization of financial services).

As part of financial innovation, payment system innovation also initiates controversy regarding its implications for financial system stability. According to Al-Gasaymeh (2020), the impact of payment system innovation on financial system stability appears to be ambiguous. The current digital-based payment systems will increase efficiency in improving the smoothness of the payment system, thus ultimately have a positive impact on financial system stability. On the other hand, cashless payment systems allow the movement of a large amount of funds in a short

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time, which causes the need for liquidity and increases liquidity risk in the payment system (Frame & White 2015; Li et al. 2021). In addition, digital-based payment systems can pose new potential risks, namely cyber risk, which can also hamper the smooth operation of the payment systems. Andini & Falianty (2022) adds electronic-based payment instruments, namely electronic money and Real-Time Gross Settlement (RTGS), and concludes that payment system innovation has a negative relationship with the demand for money in Indonesia.

Several studies, such as Carbó-Valverde & Rodríguez-Fernández (2014), Jurgilas & Martin (2013), Kim, Koo & Park (2013), and Parves (2019), reveal various interesting developments regarding payment system innovation in influencing financial system stability. Obviously, a low level of innovation in financial stability will have a different impact than a high level of innovation. A high level of innovation allows swift and responsive economic activities (Niankara 2023). A low level of innovation, on the contrary, does not support economic activities with rapid financial transmission. However, at a high level of innovation, changes in transactions will be remarkably fast that they will affect the financial stability of a country. The effect of innovation on financial stability is asymmetric (Mishkin 2016).

This study aims to contribute to the literature on the impact of payment system innovation on finance system stability at a particular threshold. This study employed four instruments of payment system innovation, namely debit cards, credit cards, electronic money, and RTGS. These instruments are further categorized into low value payment systems (debit cards, credit cards, and electronic money) and high value payment systems (RTGS). The financial system stability index is measured by calculating the composite indexes of non-performing loans, Z-score (Return on Assets [ROA] and Capital Adequacy Ratio [CAR]), share price volatility, and yield bonds. The components of the indexes are structured to reflect risks from the banking, stock, and bond markets. The panel data of 2012 to 2020 were obtained from four ASEAN countries, namely Indonesia, Malaysia, Thailand, and the Philippines, to ensure a more homogeneous sample in terms of financial depth (Li et al. 2021; Zhang 2003). Singapore is not included since, based on the share of the financial sector to Gross Domestic Product (GDP), it is not a peer group of Indonesia, Malaysia, Thailand, and the Philippines. The panel threshold analysis displays an increase in the value of debit card, credit card, and RTGS transactions. The monetary authorities of each country can implement the findings of the study by taking into account the rapid development of payment system innovation as it will threaten the financial system stability.

2. Literature Review

Bank Negara Malaysia Statistic (2020) states that financial system stability describes a condition under which the intermediation process can run smoothly and trust in the operational activities of financial institutions exists (Botev, Égert, & Jawadi 2019). Bank of Thailand (2021) also adds that the financial system is deemed stable supposing public trust in it is maintained. Elfakir & Tkiouat (2019) and Mishkin (2016) argue that the main obstacle causing a non-functioning financial system is asymmetric information. Asymmetric information is a condition in which one of the parties has better information than other parties. Different information will generate two problems in the financial system: adverse selection and moral hazard. Adverse selection is the impact of asymmetric information prior to the implementation of financial transactions. Moral hazard is caused by different interests between institutions/markets and debtors/investors. Interest rates can go awry and influence changes in the behavior or decision of debtors to use the loaned funds. Higher interest rates cause debtors to allocate loan funds to risky projects, thus increasing the possibility of losses suffered by the bank. Chaudhuri et al. (2013) propose the factors affecting financial system stability. As stated by Batuo, Mlambo, & Asongu (2018), financial system stability/instability are caused by endogenous and exogenous factors. Endogenous

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factors in this regard originate from the financial system itself, namely financial institutions, financial markets, and the payment systems (Ramlall 2018).

Meanwhile, exogenous factors are sourced from outside the financial system, namely financial conditions, economic fundamentals, and event risks (global shocks). Economic fundamentals can lead to financial system instability, such as high inflation rate and unemployment. Global economic conditions also affect the stability of the domestic financial system, specifically for a country with an open economy. Referring to the approach introduced by Ramlall (2018), financial system stability depends on institutional conditions, markets, payment systems, macroeconomics, and global conditions.

Measuring financial system stability in quantitative measures is not an easy matter. Batuo, Mlambo, & Asongu (2018) and Chen & Siklos (2022) suggest a way to measure financial system stability. Their findings explain that binary variables are not suitable measures as they are unable to provide information on the severity of the crisis.

Several years ago, research in macroeconomics and monetary economics developed a method for measuring financial system stability. The growing number of financial institutions provide a great amount of data, indicating risks to the financial system (Financial Soundness Indicators). Various central banks also provide reports on financial system stability to evaluate their financial conditions based on indicators. Choudhury (2015) develops a stability index for Romania. The index is composed of 20 indicators divided into four groups, namely financial development index (FDI), financial vulnerability index (FVI), world economy climate index (WECI), and financial soundness index (FSI). Each is normalized using empirical normalization or the min-max method, then aggregated using the same weight to form a stability index for Romania named the Aggregate Financial Stability Index (AFSI) (Gustiana & Nasrudin 2021).

In the context of ASEAN, the stability index is developed by Andini & Falianty (2022). They consider risks in three financial components of institutions: banking, stock, and bond markets. Referring to Nasreen & Anwar (2020), these three components generally influence financial system stability in developing countries.

As specified by Beck et al. (2016), financial innovation is a breakthrough that can reduce costs and risks to increase the convenience and satisfaction of the members of the financial system. Schumpeter (1912) in Bernier & Plouffe (2019) state that financial innovation is a driver of economic growth by theory. The existence of technology in the financial sector derives from the emergence of more innovative products to increase efficiency, which in turn can increase productivity (De Portu 2022).

The measures of financial innovation are the primary issue explored in Ekananda & Suryanto (2021). Based on the empirical literature, at least two approaches are applied to measure financial innovation: input and output based. The input of financial innovation is all forms of resources used in the innovation process, including R&D expenditure, human capital, and IT capital in the financial sector. In this regard, Arnaboldi & Rossignoli (2015) as well as Beck et al. (2016) explain the drawbacks in measuring financial innovation based on R&D expenditure data. Financial institutions are not the only developers of financial innovation. Up to the present time, the breakdown of R&D expenditure data by sector only covers OECD countries. Thus, non-OECD countries usually use the second approach, which is based on output. The output of financial innovation is the resulting products. The selection of financial products used as a proxy for innovation is adjusted to the objectives of the study.

A secure and healthy payment system is a prerequisite for creating a stable financial system. However, achieving a secure payment system with a low level of risk frequently requires high costs. Al-Gasaymeh (2020) argues that the presence of technology can become the trade-off between risks and costs in the payment system. Studies on the impact of payment system innovation have been widely conducted. Several studies (Arnaboldi & Rossignoli

2015; Barbosa, de Paula Rocha, & Salazar 2015; Carbó-Valverde & Rodríguez-Fernández 2014; Nagayasu 2012) employ Automated Teller Machine (ATM) or debit card transactions as proxies for payment system innovation. Meanwhile, Shiva & Durai (2017) apply credit card transactions as a proxy for payment system innovation.

3. Method

This study employed a panel data structure obtained from the ASEAN-4 countries (Indonesia, Malaysia, Thailand, and the Philippines) in the 2012–2020 period. The need for digital technology-based payment systems in ASEAN will also be higher with the presence of the ASEAN Economic Community.

Nguyen, Brown & Skully (2019), corroborated by El Khoury, Harb & Nasrallah (2022), explain that the impact of financial developments on the economy of Singapore has a different direction from that of Indonesia, Malaysia, Thailand, and the Philippines. This study focuses on these four countries to ensure a more homogeneous sample regarding financial depth (Li et al. 2021; Zhang 2003). Singapore is not included because it is not a peer group of Indonesia, Malaysia, Thailand, and the Philippines in terms of the share of the financial sector to GDP.

The variable of cashless payment system innovation (TrInnov) includes card-based and electronic-based payments (Arnaboldi & Rossignoli 2015; Beck et al. 2016). Low value payment instruments consist of debit cards, credit cards, and electronic money. Meanwhile, the high value payment system is RTGS (Jurgilas & Martin 2013). The Consumer Price Index (PriceIndx) is presented in the form of a natural logarithm, thus the value of parameter estimation can be interpreted as PriceIndx growth or inflation. GDP per capita growth (GDPR) is the ratio of nominal GDP to the total population. GDPR is a measure of the welfare of a country. The value used is a natural logarithm, thus the parameter estimation results show the impact of GDPR on Unique Transaction Identifier (UTI). Trade openness (Openness) is a measure of the participation of several countries in international trade (Ma, Jiang & Yao 2022). Trade openness is calculated from the ratio of exports and imports to GDP.

$$\text{Openness} = \frac{\text{Export} + \text{Import}}{\text{GDP}} \tag{1}$$

Park & Mercado (2014) discover a significant relationship between the stability of developed and developing countries. This study applied the financial system stability index for the United States (USSI) to measure financial system stability in developed countries. Financial system stability index (ISSK) represents a risk in the financial system. A larger index indicates a more significant risk in the financial system, rendering it unstable. On the contrary, a smaller index shows a more stable financial system. The components of financial system stability in different countries may vary—influenced by the characteristics of each country. Identifying the components used to compile the index depends on the definition of financial system stability under consideration. The instability in the financial system in developing countries is generally determined by considering three risks: banking, stock, and bond market (Denis & Ioana-Alina 2018; Ekananda 2017; Próchniak & Wasiak 2016). This study did not consider the money market because the money market in ASEAN-4 has a small proportion of below 10% compared to the other two markets (Bank Indonesia, Bank Negara Malaysia, Bank of Thailand, bangko Sentral ng Pilipinas).

The first measure is the ratio of non-performing loans to total loans. Higher ratio of non-performing loans to the credit extended by banks means higher risk of banking failure (Ghassan & Guendouz 2019).

$$\text{NonPL} = \frac{\text{NonPerformingLoans}}{\text{TotalLoans}} \tag{2}$$

The second measure is the Z-score (Zsco), referring to Holpus, Alqatan & Arslan (2021). Zsco is commonly adopted as a proxy for bank health. Zsco is an index formed from the components of ROA and

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Table 1. Data and Source

Variable	Label	Unit	Source
Payment System Innovation (Transaction Scores) - Debit cards - Credit cards - Electronic money - Real Time Gross Statement	TrInnov DebitC CreditC Em RTGS	Million US Dollars	Bank Indonesia, Bank Negara Malaysia, Bank of Thailand, bangko Sentral ng Pilipinas
Consumer Price Index	PriceIndx	Index	bangko Sentral ng Pilipinas 2021; Bank Negara Malaysia 2020; Bank Indonesia 2022; Bank of Thailand 2021
Trade Openness - Total export - Total import	 Export t Import t	Percentage	bangko Sentral ng Pilipinas 2021; Bank Negara Malaysia 2020; Bank Indonesia 2022; Bank of Thailand 2021
US Financial System Stability Index	USSI	Index	Office of Financial Research
Financial System Stability Index - Non-Performing Loans - Z-Score (ROA & CAR) - Share Price Volatility - Yield Bonds	ISSK NonPL ZSco Volat YldObl	Index	bangko Sentral ng Pilipinas 2021; Bank Negara Malaysia 2020; Bank Indonesia 2022; Bank of Thailand 2021

CAR. Supposing the data is normally distributed, then the inverse of banking risk can be defined as the value of Zsco, namely:

$$\mathrm{ZSco} = \frac{\mathrm{ROA} + \mathrm{CAR}}{\sigma_{\mathrm{ROA}}} \tag{3}$$

with σ_{ROA} denotes the Standard Deviation of ROA. Different from the nonPL variable, larger Zsco represents the risk of bank failure, while smaller Zsco implies a healthier bank. Concerning the uniform direction, we transform Zsco into $=\frac{1}{\mathrm{Z_{Sco}}}$. A larger value of = $\frac{1}{\mathrm{Z_{Sco}}}$ indicates a more extensive risk.

Market risk is the third measure. This risk is measured by calculating the volatility of stock returns (Park & Mercado 2014). Stock return volatility is the tendency of stock return values to change. This change suggests the presence of uncertainty. High uncertainty reflects high level of risk ($\mathrm{ret_{it}}$) for investment (Ekananda & Suryanto 2021). Volatility is formulated as the following simple standard deviation:

$$\mathrm{Volat_i} = \sqrt{\frac{\sum_{t=1}^{n}(\mathrm{ret_{it}} - \mu_i)^2}{n-1}} \tag{4}$$

The fourth measure is bond market risk. Park & Mercado (2014) explain that yields are the rate of returns on bonds that reflects the level of bond risk. Another explanation is obtained from Chaudhuri et al. (2013) that the measurement of a single indicator requires a normalization process. The index is called the min-max method.

$$\mathrm{Idx_t^N} = \frac{\mathrm{I_t} - \mathrm{Min(Idx_t}}{\mathrm{Max(Idx_t)} - \mathrm{Min(Idx_t)}} \tag{5}$$

$\mathrm{Min(Idx_t)}$ is the minimum score of each indicator at a specific time. $\mathrm{Max(Idx_t)}$, on the other hand, is the maximum score of each indicator at a specific time. The next stage is to determine the weight for the index value. This study employed similar methods as Park & Mercado (2014), namely variance-equal weight and PCA methods, because they produce a similar pattern of stability index. This study also performed Principal Component Analysis (PCA) to form a single measure as a proxy for financial innovation from the first principal component. The resulting index value indicates the level of risk in the financial system. A higher index suggests a higher risk and a more vulnerable financial system. Conversely, a lower index signifies a lower risk and a more stable financial system.

3.1. Empirical Model

This study referred to Ramlall (2018) that endogenous and exogenous factors shape the financial system stability of a country. Endogenous factors include financial institutions, financial markets, and payment systems. Meanwhile, exogenous factors are variables outside the financial system, both domestic and global. In determining the variables as proxies for these determinants, this study also referred to Batuo, Mlambo, & Asongu (2018) and Ramlall (2018). Referring to these empirical studies, financial system stability is also influenced by economic fundamentals and openness. Thus, inflation and GDP per capita growth are used to represent economic conditions as well as trade openness to represent economic openness. This study also covered financial system stability in developed countries in accordance with Park & Mercado (2014). Financial system stability in developed countries displays a positive relationship with financial system stability in developing countries.

This study applied a panel threshold estimation technique (Model I). A panel data analysis can be employed for dynamic models, reflected in using the lagged dependent variable as the independent variable. It is due to the behavior of the dependent variable, which is closely influenced by the previous period (Albarran & Arellano 2019; Yu 2013). The estimator for the dynamic panel data analysis is Generalized Method of Moments (GMM).

Different levels of innovation cause an asymmetric impact on the payment system stability of a country. The countries observed in this study are Indonesia, Malaysia, Thailand and the Philippines. This study focuses on the types of innovation in the payment systems. A dynamic linear model and a dynamic non-linear model are implemented and compared to obtain the best model. The non-linear model applies panel threshold regression to capture any changes in impact at the level of certain variables. Variables that cause changes are analyzed to obtain the best model. In addition, this study focuses on the types of card-based and electronic-based payment system innovation (Niankara 2023). Therefore, the types of payment instruments referred to as payment system innovation are debit cards, credit cards, electronic money, and RTGS.

The econometric model using time period and ISSK causes an endogeneity problem, namely the correlation between the lagged dependent variable and the residual. The estimation method using Feasible Generalized least square will produce a biased estimator. Therefore, Albarran & Arellano (2019) and Lu, Gan & Shi (2022) develop the GMM estimator to solve the biased estimator in the first-difference model. It removes the fixed-effects components.

Albarran & Arellano (2019) argue that an endogeneity problem can be overcome by the GMM method. Hwang (2021) and Omri et al. (2015) state that GMM is the most common estimation method to observe multiple directional relationships between variables in models that use panel data. Verbeek (2018) suggests that the application of the GMM method in a panel data analysis can reduce bias in implementing OLS techniques, and the resulting standard error is more efficient compared to using two-stage least square (2SLS) estimates. Bias reduction is defined as overcoming the correlation between the residual and the independent variable. The OLS estimator guarantees no correlation between the residual and the independent variable. Meanwhile, GMM as an estimator minimizes the correlation between the residual and the independent variable and produces a better estimate. Smaller standard error as a parameter deviation is more efficient and an efficient standard error will produce more robust parameters. The estimator in this regard is a method for obtaining parameters, which includes least squares and GMM. First, GMM serves as a standard estimator and provides a more helpful framework for comparison and assessment. Second, GMM provides a simple alternative to other estimators, particularly the maximum likelihood.

Boldea, Hall, & Han (2012) and Liang & Reichert (2012) explain the need to conduct two specific tests, i.e. the endogeneity test and the overidentifying restrictions test, for the simultaneous equation model. However, this study assumed that all independent variables are strongly exogenous, thus the threshold regression estimator is used in the estimation instead of the instrument variables (Wang 2015). The general model for the panel threshold

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regression (Model 1) in this study is:

$$\begin{aligned}\mathrm{ISSK_{it}} &= \beta_i + \beta_2\mathrm{LnTrInnov_{it}} + \beta_3\mathrm{Credit} \\ &+\beta_4\mathrm{GDPR_{it}} + \beta_5\mathrm{gPriceIndx_{it}} \\ &+\beta_6\mathrm{Openness_{it}} + \beta_7\mathrm{USSI_t} + e_t \quad (6)\end{aligned}$$

with $\mathrm{ISSK_{it}}$ denotes the financial system stability index for a country, $\mathrm{LnTrInnov_{it}}$ represents the proxy for payment system innovation (in a natural logarithm), $\mathrm{GDPR_{it}}$, $\mathrm{Credit_{it}}$ symbolizes credit to GDP ratio, $\mathrm{PriceIndx_{it}}$ signifies price index, $\mathrm{Openness_{it}}$ indicates trade openness, and $\mathrm{USSI_t}$ means the financial system stability index for the United States.

The advantage of a threshold model is the capacity to implement different regimes for the same data and model. The threshold regression can demonstrate the significance of causality relationships under different threshold regimes, which cannot be demonstrated supposing we use interactions between variables. Furthermore, a dynamic panel threshold estimation method employs panel data in which dynamic processes and heterogeneity of economic variables occur (Wang 2015). The standard regression estimation model with panel data thresholds with individual-specific effects is provided with the following equations, for a single threshold model:

$$\begin{aligned}y_{it} &= \mu + X_{it}(q_{it} < \gamma)\beta_1 + X_{it}(q_{it} \geq \gamma)\beta_2 + u_i \\ &+\varepsilon_{it}, \quad (7)\end{aligned}$$

For a multiple threshold model:

$$\begin{aligned}y_{it} &= \mu + X_{it}(q_{it} < \gamma_1)\beta_1 + X_{it}(\gamma_1 \leq q_{it} < \gamma_2)\beta_2 \\ &+X_{it}(q_{it} \geq \gamma_2)\beta_3 + u_i + \varepsilon_{it}, \quad (8)\end{aligned}$$

in which the independent variable can be shifted in line with the regime determined by the γ threshold value.

$$y_{it} = \mu + X_{it}(q_{it}, \gamma)\beta + u_i + \varepsilon_{it}, \quad (9)$$

Where

$$X_{it}(q_i t, \gamma) = \begin{pmatrix} X_{it}\mathbb{I}(q_{it} \leq \gamma) \\ X_{it}\mathbb{I}(q_{it} > \gamma) \end{pmatrix} \text{ and } \beta = (\beta_1^{'}\beta_2^{'})^{'}$$

Given γ, the estimator is

$$\hat{\beta} = \{X^*(\gamma)^{'}X^*(\gamma)\}^{-1}X^*(\gamma)^{'}y^* \quad (10)$$

The estimator determines the γ value that minimizes the Residual of Sum Square (RSS). The process of selecting the method refers to Hansen (1999) in Huang & Lai (2017). As $\hat{\gamma}$ is a consistent estimator, then we can form the following statistical likelihood-ratio (LR) test:

$$\mathrm{LR}_1(\gamma) = \frac{\mathrm{LR}_1(\gamma) - \mathrm{LR}_1(\hat{\gamma})}{\hat{\sigma}^2} \quad (11)$$

to measure the significance level α for the LR significance test. The quantile value of α is calculated from the following inverse function:

$$c(\alpha) = -2\log(1 - \sqrt{1-\alpha}) \quad (12)$$

Supposing $\mathrm{LR}_1(\gamma)$ exceeds $c(\alpha)$, we can reject H_0. The hypothesis for the single threshold model is:

$$H_0 : \beta_1 = \beta_2 \text{ and } H_1 : \beta_1 \neq \beta_2$$

In this study, the panel threshold regression can be developed by applying a dynamic model using the GMM estimator on the threshold model as presented by Seo, Kim & Kim (2019). Due to the restriction of the dynamic model, the research equation (Model 2) becomes

$$\begin{aligned}\mathrm{ISSK_{it}} &= \alpha_i + (\beta_{31}\mathrm{LnTrInnov_{it}} + \beta_{32}\mathrm{Credit} \\ &+\beta_{33}\mathrm{GDPR_{it}} + \beta_{34}\mathrm{gPriceIndx_{it}} \\ &+\beta_{35}\mathrm{Openness_{it}} + \beta_{36}\mathrm{USSI_t})\mathbb{I}(k_{it} \leq \tilde{k}) \\ &+(\delta_1\mathrm{LnTrInnov_{it}} + \delta_2\mathrm{Credit_{it}} \\ &+\delta_3\mathrm{GDPR_{it}} + \delta_4\mathrm{gPriceIndx_{it}} \\ &+\delta_5\mathrm{Openness_{it}} + \delta_6\mathrm{USSI_t})\mathbb{I}(k_{it} > \tilde{k}) \\ &+\varepsilon_{it} \quad (13)\end{aligned}$$

The Results and Analysis section is divided into four subsections. The first and second subsections cover the general description of financial system stability in ASEAN-4 based on the ISSK value as well as the general overview of the development of payment system innovation in ASEAN-4. The third subsection comprises a descriptive analysis of the relationship between the transaction value of payment system innovation and ISSK. The last subsection analyzes the results of the empirical model estimation that illustrates the impact of the development of cashless payment system innovation on ISSK, both ISSK with equal or with different weights according to the capitalization and assets of financial institutions.

PCA was conducted on the transaction value of the four variables of payment system innovation, namely debit cards, credit cards, electronic money, and RTGS. The transaction value used is the value that has been transformed into a natural logarithm form. The first step is to perform the Keyser-Meyer Olkin (KMO) test. The results of the KMO test on PCA with a correlation matrix (Table 2) show an average value of 0.6, meaning that the number of sample is feasible for PCA.

Table 2. The KMO Test Results

Variable	kmo
debitC	0.1
CreditC	0.5
RTGS	0.6
Em	0.7
Overall	0.6

The second step is to conduct PCA with a correlation matrix. Four components are obtained from the four variables of payment system innovation (Table 3). The first, second, third, and fourth components can separately explain 64%, 26%, 8%, and 1% of the diversity of variations in payment system innovation. These results point to the first component as a proxy for payment system innovation, as performed by Batuo, Mlambo, & Asongu (2018).

The third step is to form a new variable, a linear combination of the variables of payment system innovation weighted by the value of the loading component in the first component, which is none other than the eigenvector element that corresponds to the eigenvalue of the first component (table 4).

The value of the loading component reflects the variable correlation with the main component score formed. Table 5 reveals that the credit card and RTGS variables have the highest correlation with the main component, namely 0.6 and 0.59. The debit card variable has a minor correlation of 0.01.

4. Results and Analysis

The econometric test was conducted to examine the impact of the independent variable on the dependent variable. The independent variable in this study is the payment system innovation as measured by the value of debit card, credit card, electronic money, and RTGS transactions in the form of a natural logarithm. Meanwhile, the dependent variable in this study is ISSK. As discussed in the previous section, the sample adjustment was carried out due to limitations in the data on the payment system innovation in the Philippines, in which the available data on cashless payment systems merely cover credit card and RTGS transactions. Thus, the analysis on the instrument variables of debit cards and electronic money does not include the Philippines.

The development of the ASEAN-4 cashless payment systems within the study period demonstrates that electronic money transactions in Thailand increased by 146% to 6.3 million dollars in 2018. Unlike Indonesia and Thailand, the average debit card transactions in Malaysia reach merely 1.1 billion per quarter. Nevertheless, the growth trend in debit card transactions in Malaysia remains positive, even with the highest growth rate, reaching 40% per year.

Similar to debit cards, the average value of credit card transactions in Indonesia is smaller than Thailand and Malaysia, yet larger than the Philippines. During the study period, the transaction value is recorded at 5.2 billion dollars per quarter, less than Thailand with 12.2 billion dollars per quarter and Malaysia with 7.5 billion dollars per quarter. Considering the population of Indonesia, which is much larger than Thailand and Malaysia, this value shows that credit cards are still not widely used in Indone-

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Table 3. Principal Component Analysis Results

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.56	1.50	0.64	0.64
Comp2	1.06	0.73	0.26	0.91
Comp3	0.33	0.28	0.08	0.99
Comp4	0.05	.	0.01	1.00

Source: Bank Indonesia, Bank Negara Malaysia, Bank of Thailand, bangko Sentral ng Pilipinas, reprocessed by authors

Table 4. Loading Component Value (Eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Unexplained
debitC	0.60	0.14	-0.21	-0.75	0.00
CreditC	-0.01	0.96	0.26	0.10	0.00
em	0.54	-0.23	0.80	0.16	0.00
RTGS	0.59	0.07	-0.50	0.63	0.00

sia. Meanwhile, the average value of credit card transactions in the Philippines is the lowest among ASEAN-4, which is 4.5 billion dollars per quarter.

Table 6 displays the results of the panel data cointegration test as well as the long-term balance and correction of the cointegrated variables. Data series includes TrInnov, Credit, GDPR, d(PriceIndx), Openness, and USSI. The Null Hypothesis states no cointegration, indicating the Newey-West automatic bandwidth selection and Bartlett kernel. This study conducted a panel unit root test to ensure stationarity in all data. We referred to several researchers (Maddala & Wu 1999; Esfahani, Mohaddes & Pesaran 2014) in applying the method for a balanced panel data format. The unit root test panel adopted the Kao Residual Cointegration Test (results are presented in Table 4). The length of the lag is determined in the first lag. The results imply that the Null Hypothesis is rejected at the HAC variance of 0.003438 and the t statistic of -2.326731. Table 6 also shows the results of the non-panel data test. Levin, Lin and Chu test reveals cointegrated data.

This study employed non-linear regression estimation, hence the necessity to ensure the availability of non-linear forms in the data used (Seo & Shin 2016). Table 7 displays the results of the Linearity Tests. The test refers to Ahn & Lee (2012) and Ekananda (2016a). The test for one or two thresholds is presented at Column 2. Meanwhile, Columns 3 and 4 show the F-statistic values. The conclusion of the test is indicated by the * sign, meaning it is significant at the 0.05 level. The critical value adopts the Bai-Perron method as implemented by several researchers (Botev, Égert, & Jawadi 2019; Pati, Rajib & Barai 2017). The Bai-Perron test aims to identify structural breaks and volatility regimes in the time series of volatility indices and investigate the relationships of volatility index return during the periods of high, medium, and low volatility.

The results demonstrate that one threshold should be applied to the equation with GDPR and TrInnov thresholds. The equation with the Credit to GDP and ISSK thresholds should use two thresholds. The estimation results are described in the next section.

Table 7 explains the advantage of the application of thresholds. The results of all threshold variables indicate that the linear model is rejected. Supposing we use a linear equation, the coefficient shows a nonlinear impact. The nonlinear impact (threshold regression) can be interpreted as the dissimilar impact of the independent variable in all data conditions. The application of thresholds is able to explore the impact of the changing conditions of the threshold variables.

Further studies can be observed in Botev, Égert, & Jawadi (2019) and Ekananda (2022). The right method will produce a more efficient estimation of econometric equations. The sum of squared residuals (SSR) is used to determine which method is

Table 5. Descriptive Statistics

Variable	mean	Std. Dev.	Min	Max
ISSK (NonPL)	0.414	0.174	0.034	0.866
Weighted ISSK (NonPL)	0.385	0.178	0.046	0.926
ISSK (Zsco)	0.421	0.187	0.097	0.866
Weighted ISSK (Zsco)	0.392	0.187	0.054	0.858
Growth of Debit Card Transactions	9.901	2.159	5.784	11.75
Growth of Credit Card Transactions	8.812	0.416	7.951	9.765
Growth of Electronic Money Transactions	5.461	1.061	2.871	7.71
Growth of RTGS Transactions	14.878	0.524	13.828	15.83
GDP per capita growth (GDPR)	7.109	0.528	6.303	8027
Trade Openness (Openness)	81.252	40.689	27.005	145.703
Inflation (gPriceIndx)	4.684	0.099	4.491	4.908
USSI	-0.524	0.837	-1.717	1.638

Source: Bank Indonesia, Bank Negara Malaysia, Bank of Thailand, bangko Sentral ng Pilipinas

Table 6. Panel Unit Root Test

Kao-Engle Granger (Panel Data)	t-Statistic	Prob.
ADF	-2.326731	0.0100
Residual variance	0.009324	
HAC variance	0.003438	
Non-Panel Data		
Levin, Lin & Chu t*	-4.65357	0.0000
Im, Pesaran and Shin W-stat	-11.4281	0.0000
ADF - Fisher Chi-square	186.261	0.0000
PP - Fisher Chi-square	254.687	0.0000

Null Hypothesis: No cointegration

more efficient (Ekananda 2016b). Tables 8 and 9 summarize the SSR values of the various methods employed in the study.

The test results in Table 7 reveal structural changes in several regimes when measured at the threshold variables above. In the next section, we present the regression results to explain that a threshold model is more efficient than a linear model (Pati, Rajib & Barai 2017; Tan et al. 2020). The linear model assumes that the parameters obtained from the regression apply to all data during the study period, implying that structural changes can occur over a long period.

Next, we need to test the linear model. We attempted to find the best model between the common-effects (CE) and fixed-effects (FE) models. We applied the Redundant Fixed Effects Test, in which the results show the statistic of 14.352840 and probability of 0.00. The statistical results specify the common effects of the model. Similar to the nonlinear model processing, the following data processing applies the fixed-effects model. The test results of the FE model versus the CE model are presented in Table 8.

The FE test results explain the rejection of H0 (i.e., CE), thus the best model is the FE model. The FE model shows that all variables significantly impact and follow the sign. Generally, the FE model is more efficient than the CE model (Tan et al. 2020). We present the sum of squared residuals to show the difference compared to the nonlinear model.

An estimation using the random-effects (RE) model is not performed because of time constraints. The RE model requires more timing because the Error Correction Model (ECM) is insufficient. An explanation of the ECM structure is provided in Ekananda (2016b) and Greene (2018). Model 1 assumes that each ISSK in ASEAN countries has different characteristics. Based on the hypothesis, Innovation (TrInnov), Credit, GDPR, and Openness have a negative effect on ISSK. Other variables significantly affecting ISSK are Inflation (dLnCPI) and USSI. In the panel data analysis, it can be stated that an increase in the ratio of Credit to GDP (Credit) and System Innovation (TrInnov) will decrease ISSK.

Table 10 summarizes the estimation results of various models in the study according to linear and non-linear equations.

Table 10 also describes the comparison between the linear model and the nonlinear model (the threshold model). The primary reference is to ob-

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Table 7. Sequential F-statistics of Determined Thresholds

Threshold	Threshold Test	F-statistics	Scaled F-statistics	Critical Values**
GDPR	0 vs. 1*	5.438931	32.63359	20.08
	1 vs. 2	2.691518	16.14911	22.11
TrInnov	0 vs. 1*	5.251112	31.50667	20.08
	1 vs. 2	2.99.810	17.99886	22.11
Credit	0 vs. 1*	6.142817	36,8569	20.08
	1 vs. 2*	6.751159	40.50695	22.11
ISSK	0 vs. 1*	28.02960	168.1776	20.08
	1 vs. 2*	16.03789	96.22734	22.11

Table 8. Redundant Fixed Effects Test

Effects Test	Statistics	df	Prob.
Cross-section F	14.352840	(3,130)	0.0000
Cross-section Chi-square	40.053350	3	0.0000

Table 9. Fixed Effects and Common Effects

		Common Effect		Fixed Effect	
Variable		Coef.	t-stat	Coef.	t-stat
C		0.457711	8.997530	5.025096	5.191362
TrInnov	β_2	1.52E-09	0.158833	-0.256856	-4.193016
Credit	β_3	0.000115	0.274294	-0.009419	-5.918455
GDPR	β_4	-0.037792	-2.168620	-0.031155	-2.523084
d(PriceIndx)	β_5	6.080294	3.552862	4.754134	3.348713
Openness	β_6	0.000436	0.175453	-0.003252	-1.765221
USSI	β_7	0.103474	7.343874	0.052137	3.050513
		Weighted Statistics			
Adjusted R-squared		0.305126		0.533805	
F-stat		11.17270		18.68426	
Sum squared resid		2.609253		1.944121	

serve the SSR value, and the test results are presented in Table 7. Observed from the SSR value, the nonlinear model is more efficient as it has a smaller SSR value. Analyzed from the group of nonlinear models, the two-threshold model is more efficient. In this regard, the one-threshold model has more restrictions than the two-threshold model (Ekananda 2016b). However, examined from the selection of the number of thresholds (Table 7), the recommended model is the one-threshold model for the GDPR and Innovation variables, while the Credit and ISSK variables are recommended to apply the two-threshold model.

Subsequent to conducting a series of tests, the next step is to analyze the regression results according to Equation (13). Table 11 shows the regression results with GDPR as the threshold. Each country has a growth rate according to its characteristics. Not all GPD countries have a significant influence. Economic changes will have different impacts on ISSK at a certain level of GDPR (Park & Mercado 2014).

Table 11 displays the difference in results with the fixed-effects linear model. The nonlinear model suggests that not all variables significantly impact ISSK. Changes in the TrInnov and Credit ratio will have an impact on increasing ISSK. This finding follows the results of studies by Montes & Carlos (2015) and Nagayasu (2012). In other cases, Nagayasu (2012) describes a significant change at a certain level of innovation. He discovers instability in the simple credit relationship.

Table 12 presents similar results to Table 8. Changes in the TrInnova regime demonstrate a significant impact. In any situation of Innovation, the impact of the independent variable is similar. This result reveals that Innovation in the 4 ASEAN countries does not cause a significant change. Referring

Table 10. The Value of Sum Squared Residuals and F-stat

	linear		One Threshold			
	Common	Fixed	GDPR	TrInnov	Credit	ISSK
Adj R2	0.305126	0.533805	0.553159	0.597520	0.597520	0.783873
SSR	2.609253	1.944121	1.684086	1.696060	1.696060	0.910763
			Two Threshold s			
			GDPR	TrInnov	Credit	ISSK
Adj R2			0.647418	0.605553	0.657686	0.888259
SSR			1.485788	1.416386	1.229187	0.401243

Table 11. GDPR as Threshold

Threshold		GDPR $<$ 1.6621299 73 obs			1.6621299 $\leq$ GDPR 70 obs	
Variable		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.276869	-4.605158	δ_1	-0.308343	-5.300960
Credit	β_{32}	-0.010659	-7.194454	δ_2	-0.009112	-6.295789
GDPR	β_{33}	-0.022936	-1.276298	δ_3	0.136658	1.418910
d(PriceIndx)	β_{34}	1.654844	0.859933	δ_4	-0.225653	-0.700036
Openness	β_{35}	-0.001235	-0.427474	δ_5	-0.005966	-1.780011
USSI	β_{36}	0.024556	1.275881	δ_6	0.067025	3.748846
Adj R2		0.553159			SSR	1.684086

Table 12. Innovation as Threshold

Threshold		TrInnov $<$ 14.89672 – 68 obs			14.89672 $\leq$ TrInnov – 75 obs	
Variable		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.181016	-2.654060	δ_1	-0.165805	-2.386039
Credit	β_{32}	-0.004181	-2.379460	δ_2	-0.017056	-7.747342
GDPR	β_{33}	-0.096104	-1.163497	δ_3	-0.037613	-2.213571
d(PriceIndx)	β_{34}	0.500620	0.299320	δ_4	-0.324236	-1.120272
Openness	β_{35}	-0.011369	-2.450057	δ_5	-0.004969	-1.901558
USSI	β_{36}	0.057042	2.939894	δ_6	0.036151	1.914142
Adj R2		0.597520			SSR	1.696060

to the ASEAN data, this finding is supported by Chen & Siklos (2022) but not by Nagayasu (2012).

Chen & Siklos (2022) rely on evidence of past episodes of financial innovation and employ cross-country data, while we explored the hypothetical impact of Central Bank Digital Currency (CBDC) on inflation and financial stability. They suggest that CBDC needs to pay attention to changes in inflation. Innovation at various levels still consistently affects financial stability. In the case of the Credit level, we used the ratio of Credit to GDP. The Credit ratio describes the level of disbursement of funds from banks. A high credit level specifies an adequate level of financial transmission and increased development growth, in which interest rates and inflation tend to increase. On the other hand, at a low credit level, credit transmission is constrained.

Regression segregation by credit level shows similar results as Table 9. Innovation and Credit continue to affect ISSK significantly. Trade openness also increases ISSK. These results are in agreement with Montes & Carlos (2015) and Nagayasu (2012). They discover the persistence in credit latency and the significant influence of GDP growth and interbank interest rates on loan default rates. The expected default correlation is low across specifications, indicating a positive relationship between bank concentration and financial stability.

Financial stability also exhibits a change in structure (Table 14). At high ISSK, the financial sector provides conducive economic conditions and facilitates economic growth.

The distribution according to ISSK is not considerably different from the distribution according to

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Table 13. Credit as Threshold

Threshold		Credit $<$ 92.299999 – 72 obs			92.299999 $\leq$ Credit – 71 obs	
Variable		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.251488	-4.371334	δ_1	-0.166439	-2.673499
Credit	β_{32}	-0.004413	-2.611524	δ_2	-0.018724	-8.390356
GDPR	β_{33}	-0.121959	-1.536846	δ_3	-0.037142	-2.220851
d(PriceIndx)	β_{34}	0.605637	0.369441	δ_4	-0.247011	-0.871207
Openness	β_{35}	-0.010958	-2.405276	δ_5	-0.004792	-1.854034
USSI	β_{36}	0.050342	2.719274	δ_6	0.033096	1.786134
Adj R2		0.597520			SSR	1.696060

Table 14. Financial Stability (ISSK) as Threshold

Threshold		ISSK $<$ 0.38899499 – 72 obs			0.38899499 $\leq$ ISSK – 71 obs	
Variable		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.118509	-2.613013	δ_1	-0.104292	-2.233536
Credit	β_{32}	-0.003214	-2.753271	δ_2	-0.003198	-2.737223
GDPR	β_{33}	-0.030202	-0.997436	δ_3	0.001495	0.115114
d(PriceIndx)	β_{34}	1.810932	1.333746	δ_4	-0.487989	-2.331224
Openness	β_{35}	-0.004346	-1.392862	δ_5	-0.001347	-0.738150
USSI	β_{36}	0.008729	0.524682	δ_6	0.047017	3.733617
Adj R2		0.783873			SSR	0.910763

GDPR and Credit. Innovation and credit continue to affect ISSK at various levels significantly. Trade openness also increases ISSK. It is also in line with Montes & Carlos (2015) and Nagayasu (2012).

We need to compare the structural changes between one threshold and two thresholds. The linearity test addresses this issue. Several threshold variables indicate that two thresholds are more efficient, as stated by Tong & Lim (2009) and Van Anh (2022).

Compared to Table 9, the impact of TrInnov and Credit is unchanged at any levels of GDPR. Nevertheless, USSI seems to benefit from the ASEAN ISSK in a situation where GDPR is at a moderate level. At high and low GDPR levels, these two variables do not show a significant impact. At a moderate GDPR level, USSI will impact the ISSK. Each ASEAN country can anticipate every change in USSI, but it does not always affect the ISSK in ASEAN countries.

The same results are obtained in Table 14 that at various levels of Innovation, the independent variable does not affect the ISSK of each ASEAN country. The trade openness of ASEAN countries shows its effect on ISSK. The higher the Openness is, the lower the ISSK is. Observed from Table 13, the negative effect of Openness on ISSK occurs at a high level of Innovation. These findings are in agreement with Chen & Siklos (2022).

Tables 16 and 17 explain that the Credit and ISSK variables are the most suitable thresholds for analysis. Credit and ISSK are divided into three sections, namely low, medium, and high. This following table will elaborate the analysis results in Tables 12 and 13.

Table 16 reveals that Innovation, Credit, and Openness remain the determinants of ISSK in ASEAN countries. The direction of the impact does not change compared to the theoretical expectations. Similarly, this impact applies to the Credit level. The regression results with two thresholds strengthen the findings at the previous one threshold. Changes in Credit and ISSK do not affect the impact of USSI and inflation. In this regard, inflation in ASEAN countries does not affect ISSK in general.

Table 18 signifies that Innovation, Credit, and USSI as determinants affect ISSK in ASEAN countries. The direction of the impact does not change compared to the theoretical expectations. Likewise, this impact still applies to the ISSK level. The regression results with two thresholds strengthen the findings at the previous one threshold. Changes in Credit

Table 15. GDPR as Threshold (2)

Threshold		GDPR $<$ 1.6621299 73 obs			1.6621299 $\leq$ GDPR $<$ 1.8991499 49 obs			1.8991499 $\leq$ GDPR 21 obs	
Variable		Coef	t-stat		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.234283	-3.599461	δ_{11}	-0.303968	-4.839284	δ_{21}	-4.230280	2.774971
Credit	β_{32}	-0.011727	-7.513657	δ_{12}	-0.009126	-5.833884	δ_{22}	-6.271788	1.154453
GDPR	β_{33}	-0.022875	-1.318532	δ_{13}	0.370703	1.502922	δ_{23}	0.683607	1.555469
d(PriceIndx)	β_{34}	1.300946	0.700836	δ_{14}	8.051362	3.556103	δ_{24}	-1.561883	-0.551468
Openness	β_{35}	-0.001415	-0.508257	δ_{15}	-0.004586	-0.974200	δ_{25}	0.176908	-0.771460
USSI	β_{36}	0.018171	0.966611	δ_{16}	0.077704	4.033308	δ_{26}	1.876341	-0.485272
Adj R2		0.647418			SSR	1.485788			

Table 16. Innovation as Threshold (2)

Threshold		TrInnov $<$ 14.89672 68 obs			14.54785 $\leq$ TrInnov $<$ 14.76658 31 obs			14.76658 $\leq$ TrInnov 78 obs	
Variable		Coef	t-stat		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.290963	-3.239511	δ_{11}	-0.374505	-3.753885	δ_{21}	-0.257754	-2.849904
Credit	β_{32}	-0.005860	-2.945953	δ_{12}	0.022472	2.732689	δ_{22}	-0.017269	-8.360395
GDPR	β_{33}	-0.016642	-0.173185	δ_{13}	0.113770	0.461378	δ_{23}	-0.037253	-2.341280
d(PriceIndx)	β_{34}	0.634685	0.267163	δ_{14}	5.976027	2.043936	δ_{24}	-0.237731	-0.865486
Openness	β_{35}	-0.014383	-2.712175	δ_{15}	-0.010871	-1.352777	δ_{25}	-0.004812	-1.973636
USSI	β_{36}	0.077709	3.043.070	δ_{16}	0.072067	2.612861	δ_{26}	0.030077	1.708488
Adj R2		0.605553			SSR	1.416386			

Table 17. Credit ratio as Threshold (2)

Threshold		Credit ratio $<$ 35.899999 27 obs			35.899999 $\leq$ Credit ratio $<$ 92.299999 45 obs			92.299999 $\leq$ Credit ratio 71 obs	
Variable		Coef	t-stat		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.171563	-2.417255	δ_{11}	-0.123281	-1.900076	δ_{21}	-0.092715	-1.423983
Credit	β_{32}	-0.025777	-2.407456	δ_{12}	0.000963	0.349377	δ_{22}	-0.018470	-9.316634
GDPR	β_{33}	0.029184	0.344380	δ_{13}	-0.912011	-4.484621	δ_{23}	-0.038078	-2.566469
d(PriceIndx)	β_{34}	-2.757639	-1.180631	δ_{14}	3.749433	1.933389	δ_{24}	-0.306544	-1.211823
Openness	β_{35}	-0.009527	-1.903306	δ_{15}	0.000153	0.017341	δ_{25}	-0.004597	-2.004402
USSI	β_{36}	0.062587	2.484412	δ_{16}	0.057804	2.100621	δ_{26}	0.035341	2.146515
Adj R2		0.657686			SSR	1.229187			

Table 18. ISSK as Threshold (2)

Threshold		ISSK $<$ 0.32900199 54 obs			0.32900199 $\leq$ ISSK $<$ 0.5593439 54 obs			0.5593439 $\leq$ ISSK 35 obs	
Variable		Coef	t-stat		Coef	t-stat		Coef	t-stat
TrInnov	β_{31}	-0.094567	-2.970800	δ_{11}	-0.082014	-2.512230	δ_{21}	-0.076343	-2.339877
Credit	β_{32}	-0.001775	-2.198838	δ_{12}	-0.002025	-2.395500	δ_{22}	-0.001965	-2.318974
GDPR	β_{33}	-0.019145	-0.734480	δ_{13}	-0.014935	-1.692805	δ_{23}	0.049578	2.015.359
d(PriceIndx)	β_{34}	0.128166	0.098688	δ_{14}	0.761203	0.704730	δ_{24}	-0.167871	-1.028518
Openness	β_{35}	-0.003431	-1.362449	δ_{15}	-0.001340	-0.664427	δ_{25}	0.000381	0.237244
USSI	β_{36}	0.019759	1.381075	δ_{16}	0.027482	2.430601	δ_{26}	0.028643	2.609508
Adj R2		0.888259			SSR	0.401243			

and ISSK do not affect the impact of USSI and inflation. In this regard, inflation in ASEAN countries does not affect ISSK in general.

The development of the ASEAN-4 cashless payment systems demonstrates a positive trend in both transaction value and volume. Of the four cashless payment instruments, electronic money displays the most significant development during the study period. Observed from 2012 to 2020, electronic money transactions in Thailand increase by 146% to 6.3 million dollars in 2020, which is the highest compared to Indonesia and Malaysia. Meanwhile, the largest growth in the value of electronic

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money transactions during these years is experienced by Indonesia, which is 522% to 3.3 million dollars (Nasreen & Anwar 2020).

The value of debit card transactions also shows a positive trend. Indonesia has the largest average transaction value, which is 91 billion dollars per quarter, with an average growth of 24% per year. Thailand has an average debit card transaction value of 89 billion dollars per quarter, indicating an increase of 17% per quarter. Unlike Indonesia and Thailand, the average debit card transaction in Malaysia is only 1.1 billion per quarter. Nevertheless, the growth trend of debit card transactions in Malaysia remains positive, with the highest growth rate of 40% per year.

The estimation results demonstrate that financial system stability is strongly influenced by its determinants in various regimes. The impact of the determinants varies at the regime level. Financial authorities in ASEAN countries need to pay attention to regime changes that occur in different cases. The increase in the payment system can be predicted through equations (6) and (13) and the regression results (Table 9 to Table 18) in this study. Improved payment system innovation will improve financial system stability, Credit, GDPR, and Openness, reducing the level of financial system risk. The results obtained are in accordance with the statement of Greenspan (1996) that a digital-based payment system will reduce the risk of the payment system because the payment settlement process is carried out immediately. It means the recipient does no longer need to wait to receive payments, thereby increasing the smoothness of the payment system, which positively impacts financial system stability. An increase in each payment system innovation variable is expected to reduce risks to the financial system.

Macroprudential policies in Indonesia should be in line with the macroprudential policies of other ASEAN countries. Policy studies should be aimed at maintaining the overall financial system stability by limiting systemic risk. Systemic risk is the potential for instability due to contagion in part or all of the financial system in the ASEAN region (Jiang & Fan 2018). In the global financial system, there is an interaction of size factors, business complexity (complexity), inter-institutional linkages, financial markets (interconnectedness), as well as excessive behavioral tendencies of financial actors or institutions to follow the economic cycle (procyclicality). Monetary and banking authorities should respond to the development of trends in financial behavior and the interest of actors in the financial sector, thus Bank Indonesia continues to strengthen macroprudential policies with innovation in the digital aspect, financial inclusion, and environmentally sound policies (green central banking/green financing) (Al-Gasaymeh 2020).

5. Conclusion

This study has developed an analytical model that assumes a nonlinear impact at various regime levels. The selection of linear and nonlinear models proves that the nonlinear model is more efficient in producing smaller squared residuals than the linear model. The nonlinear model can also capture the specific impact at a certain regime level.

The financial system stability index is measured by calculating the composite indexes of non-performing loans, Z-score from ROA & CAR, price volatility, and yield bonds. The components of the indexes are structured to reflect risks from the banking, stock, and bond markets. The resulting index value indicates the level of risk in the financial system. A higher index specifies a higher risk and a more vulnerable financial system. We realize that the effects of the independent variable can change according to economic conditions. This study applied the panel threshold model to calculate the effects of various regimes, namely innovation, GDP, credit ratio, and stability index.

The independent variable in this study is the payment system innovation as measured by the transaction value of debit cards, credit cards, electronic money, and RTGS. The estimation results reveal that financial system stability is strongly influenced by its determinants in various regimes. The impact of the determinants varies at the regime level. Financial authorities in ASEAN countries need to pay attention to the regime changes that occur in different cases. The increase in the payment system can be predicted through equations (6) and (13) and the regression results (Table 9 to Table 18) in this study. Improved payment system innovation will encourage financial system stability, Credit, GDPR, and Openness, thus reducing the level of financial system risk.

Referring to the empirical results, the relationship between the indicators of payment system innovation, namely debit cards, credit cards, electronic money, and RTGS, with the financial system stability index is negative and significant. It indicates that the increased growth in transactions for cashless payment system instruments can reduce risks to the financial system. As stated by Greenspan (1996), payment system innovation will improve the smoothness of the payment settlement process to increase stability in the financial system.

A digital-based payment system will reduce the risk of the payment system because the payment settlement process is carried out immediately. It means the recipient does no longer need to wait to receive payments, thereby increasing the smoothness of the payment system, which positively impacts financial system stability. An increase in each payment system innovation variable is expected to reduce risks to the financial system. An analysis of the components that constitute the stability index concludes that an increase in transaction value growth in the payment system innovation indicators is expected to reduce risk in the financial system.

References

[1] Ahn, ES & Lee, JM 2012, 'The performance of nonlinearity tests on asymmetric nonlinear time series', *The Journal of Economic Asymmetries*, vol. 9, no. 2, pp. 11-44. doi: https://doi.org/10.1016/j.jeca.2012.02.002.

[2] Al-Gasaymeh, A 2020, 'Economic freedom, country risk and cost efficiency in Jordan and the GCC Countries', *Global Business Review*, vol. 21, no. 1, pp. 1-17. doi: https://doi.org/10.1177/0972150917749292.

[3] Albarran, P & Arellano, M 2019, 'GMM estimation from incomplete and rotating panels', *Annals of Economics and Statistics*, vol. 134, pp. 5-42. doi: https://doi.org/10.15609/annaeconstat2009.134.0005.

[4] Andini, SA & Falianty, TA, 2022, 'Property price, capital inflows, and financial system stability in ASEAN-5 economies: A simultaneous analysis', *Journal of Indonesian Economy and Business*, vol. 37, no. 1, pp. 15-38. doi: https://doi.org/10.22146/jieb.v37i1.1406.

[5] Arnaboldi, F & Rossignoli, B 2015, 'Financial innovation in Banking', In Beccalli, E & Poli, F (eds.), *Bank Risk, Governance and Regulation*, pp. 127-162, Palgrave Macmillan Studies in Banking and Financial Institutions, Palgrave Macmillan, London. doi: https://doi.org/10.1057/9781137530943_5.

[6] Asare, VS, Ding, G & Prince 2021, 'Central bank independence and economic growth of Ghana: What inflation and GDP per capita growth rates matter?', *The Economics and Finance Letters*, vol. 8, no. 1, pp. 104-116. doi: https://doi.org/10.18488/journal.29.2021.81.104.116.

[7] bangko Sentral ng Pilipinas 2021, *Bangko Sentral ng Pilipinas*, viewed 21 December 2022, <https://www.bsp.gov.ph/SitePages/Default.aspx>.

[8] Bank Negara Malaysia 2020, *Bank Negara Malaysia statistic*, viewed 21 December 2022, <https://www.bnm.gov.my/rates-statistics>.

[9] Bank of Indonesia 2022, *Bank of Indonesia statistics*, viewed 21 December 2022, <https://www.bi.go.id/id/statistik/Default.aspx>.

[10] Bank of Thailand 2021, *Bank of Thailand statistics*, viewed 21 December 2022, <https://www.bot.or.th/English/Statistics/Pages/default.aspx>.

[11] Barbosa, K, de Paula Rocha, B & Salazar, F 2015, 'Assessing competition in the banking industry: A multi-product approach', *Journal of Banking and Finance*, vol. 50, no. 1, pp. 340-362, doi: https://doi.org/10.1016/j.jbankfin.2014.05.003.

[12] Batuo, M, Mlambo, K & Asongu, S 2018, 'Linkages between financial development, financial instability, financial liberalisation and economic growth in Africa', *Research in International Business and Finance*, vol. 45, pp. 168-179. doi: https://doi.org/10.1016/j.ribaf.2017.07.148.

[13] Beck, T, Chen, T, Lin, C & Song, FM 2016, 'Financial innovation: The bright and the dark sides', *Journal of Banking and Finance*, vol. 72, pp. 28-51. doi: https://doi.org/10.1016/j.jbankfin.2016.06.012.

[14] Bernier, M & Plouffe, M 2019, 'Financial innovation, economic growth, and the consequences of macroprudential policies', *Research in Economics*, vol. 73, no. 2, pp. 162-173. doi: https://doi.org/10.1016/j.rie.2019.04.003.

[15] Boldea, O, Hall, AR & Han, S 2012, 'Asymptotic distribution theory for break point estimators in models estimated via 2SLS', *Econometric Reviews*, vol. 31, no. 1, pp. 1-33. doi: https://doi.org/10.1080/07474938.2011.607082.

[16] Botev, J, Égert, B & Jawadi, F 2019, 'The nonlinear rela-

https://scholarhub.ui.ac.id/efi/vol68/iss2/5
DOI: 10.47291/efi.2022.05

tionship between economic growth and financial development: Evidence from developing, emerging and advanced economies', *International Economics*, vol. 160, pp. 3-13. doi: https://doi.org/10.1016/j.inteco.2019.06.004.

[17] Carbó-Valverde, S & Rodríguez-Fernández, F 2014, 'ATM withdrawals, debit card transactions at the point of sale and the demand for currency', *SERIEs*, vol. 5, no. 4, pp. 399-417. doi: https://doi.org/10.1007/s13209-014-0107-9.

[18] Chaudhuri, S, Pal, J, Middey, A & Goswami, S 2013, 'Nowcasting Bordoichila with a composite stability index', *Natural Hazards*, vol. 66, no. 2, pp. 591-607. doi: https://doi.org/10.1007/s11069-012-0504-y.

[19] Chen, QA & Du, F 2016, 'Financial innovation, systematic risk and commercial banks' stability in China: Theory and evidence', *Applied Economics*, vol. 48, no. 41, pp. 3887-3898. doi: https://doi.org/10.1080/00036846.2016.1148255.

[20] Chen, H, & Siklos, PL 2022, 'Central bank digital currency: A review and some macro-financial implications', *Journal of Financial Stability*, vol. 60, p. 100985. doi: https://doi.org/10.1016/j.jfs.2022.100985.

[21] Choudhury, S 2015, 'Governmental decentralization and corruption revisited: Accounting for potential endogeneity', *Economics Letters*, vol. 136, pp. 218-222. doi: https://doi.org/10.1016/j.econlet.2015.09.040.

[22] De Portu, T 2022, 'New trends in retail payments: How technological changes are reshaping the payments system. Introducing a proposal for a new pan-European instant payment system', *Latin American Journal of Central Banking*, vol. 3, no. 4, p. 100075. doi: https://doi.org/10.1016/j.latcb.2022.100075.

[23] Denis, V & Ioana-Alina, N 2018, 'Analysis of financial stability: The construction of a new composite financial stability index for Euro Area', *MPRA Paper, 107625*, Munich Personal RePEc Archive, viewed 21 December 2022, <https://mpra.ub.uni-muenchen.de/107625/.

[24] Ekananda, M 2016a, *Analisis ekonometrika data panel* (Edisi 2), Mitra Wacana Media.

[25] Ekananda, M 2016b, *Time series analysis for research in economy and business* (2nd edition), Mitra Wacana Media.

[26] Ekananda, M 2017, 'Macroeconomic condition and banking industry performance in Indonesia', *Buletin Ekonomi Moneter dan Perbankan*, vol. 20, no. 1, pp. 71-98. doi: https://doi.org/10.21098/bemp.v20i1.725.

[27] Ekananda, M 2022, 'Role of macroeconomic determinants on the natural resource commodity prices: Indonesia futures volatility', Resources Policy, vol. 78, p. 102815. doi: https://doi.org/10.1016/j.resourpol.2022.102815.

[28] Ekananda, M & Suryanto, T 2021, 'The influence of global financial liquidity on the indonesian economy: Dynamic analysis with threshold var', *Economies*, vol. 9, no. 4, pp. 162-178. doi: https://doi.org/10.3390/economies9040162.

[29] El Khoury, R, Harb, E, & Nasrallah, N 2022, 'Triple vectorial analysis of financial development impact on economic growth: Evidence from the Middle East and Central Asia', *International Journal of Emerging Markets*, vol. ahead-of-print, no. ahead-of-print. doi: https://doi.org/10.1108/IJOEM-07-2021-1060.

[30] Elfakir, A & Tkiouat, M 2019, 'Adverse selection and moral hazards reduction in Corporate financing: A mechanism design model for PLS contracts', *Annals of Economics and Finance*, vol. 20, no. 1, pp. 163-179.

[31] Esfahani, HS, Mohaddes, K, & Pesaran, MH 2014, 'An empirical growth model for major oil exporters', *Journal of Applied Econometrics*, vol. 29, no. 1, pp. 1-21. doi: https://doi.org/10.1002/jae.2294.

[32] Frame, WS & White, LJ 2015, 'Technological change, financial innovation, and diffusion in banking' in AN Berger, P Molyneux, & JOS Wilson (eds.), *The Oxford handbook of Banking* (2nd edition), chapter 11, Oxford University Press.

[33] Ghassan, HB & Guendouz, AA 2019, 'Panel modeling of Z-score: Evidence from Islamic and conventional Saudi banks', *International Journal of Islamic and Middle Eastern Finance and Management*, vol. 12, no. 3, pp. 448-468. doi: https://doi.org/10.1108/IMEFM-04-2018-0122.

[34] Greene, WH 2018, *Econometric Analysis* (8th edition), Pearson Education.

[35] Greenspan, A 1996, 'Remarks on evolving payment system issues', *Journal of Money, Credit and Banking*, vol. 28, no. 4, pp. 689-695. doi: https://doi.org/10.2307/2077916.

[36] Gustiana, A & Nasrudin, 2021, 'Evaluating financial system stability using heatmap from aggregate financial stability index with change point analysis approach', *Asia-Pacific Financial Markets*, vol. 28, no. 3, pp. 367-396. doi: https://doi.org/10.1007/s10690-020-09326-0.

[37] Holpus, H, Alqatan, A & Arslan, M 2021, 'Investigating the viability of applying a lower bound risk metric for Altman's Z-score', in NM Alsharari (ed), *Accounting and finance innovations*, chapter 9, IntechOpen. doi: https://doi.org/10.5772/intechopen.97433.

[38] Huang, CJ & Lai, HP 2017, 'A note on the likelihood ratio test on the equality of group frontiers', *Economics Letters*, vol. 155, pp. 5-8. doi: https://doi.org/10.1016/j.econlet.2017.02.037.

[39] Hwang, J 2021, 'Simple and trustworthy cluster-robust GMM inference', *Journal of Econometrics*, vol. 222, no. 2, pp. 993-1023. doi: https://doi.org/10.1016/j.jeconom.2020.07.048.

[40] Jiang, S & Fan, H 2018, 'Credit risk contagion coupling with sentiment contagion', *Physica A: Statistical Mechanics and Its Applications*, vol. 512, pp. 186-202. doi: https://doi.org/10.1016/j.physa.2018.08.116.

[41] Jurgilas, M & Martin, A 2013, 'Liquidity-saving mechanisms in collateral-based RTGS payment systems', *Annals of Finance*, vol. 9, no. 1, pp. 29-60. doi: https://doi.org/10.1007/s10436-010-0160-8.

[42] Kim, T, Koo, B & Park, M 2013, 'Role of financial regulation and innovation in the financial crisis', *Journal of Financial Stability*, vol. 9, no. 4, pp. 662-672. doi: https://doi.org/10.1016/j.jfs.2012.07.002.

[43] Li, DD, Shi, J, Chen, D, Lu, L, Wang, X & Liu, K 2021, 'Financial deepening and financial stability', in Li, D.D. (eds), *Economic lessons from China's forty years of reform and opening-up*, pp. 67-117, Springer. doi:

https://doi.org/10.1007/978-981-33-4520-1_4.

[44] Liang, HY & Reichert, AK 2012, 'The impact of banks and non-bank financial institutions on economic growth', *Service Industries Journal*, vol. 32, no. 5, pp. 699-717. doi: https://doi.org/10.1080/02642069.2010.529437.

[45] Lu, J, Gan, W & Shi, L 2022, 'Local influence analysis for GMM estimation', *AStA Advances in Statistical Analysis*, vol. 106, no. 1, pp. 23-45. doi: https://doi.org/10.1007/s10182-021-00398-5.

[46] Ma, Y, Jiang, Y & Yao, C 2022, 'Trade openness, financial openness, and macroeconomic volatility', *Economic Systems*, vol. 46, no. 1, p. 100934. doi: https://doi.org/10.1016/j.ecosys.2021.100934.

[47] Maddala, GS & Wu, S 1999, 'A comparative study of unit root tests with panel data and a new simple test', *Oxford Bulletin of Economics and Statistics*, vol. 61, no. S1, pp. 631-652. doi: https://doi.org/10.1111/1468-0084.0610s1631.

[48] Mishkin, F 2016, *The Economics of money, banking, and financial markets* (11th edition), Pearson Education.

[49] Montes, P & Carlos 2015, 'Estimation of regulatory credit risk models', *Journal of Financial Services Research*, vol. 48, no. 2, pp. 161-191. doi: https://doi.org/10.1007/s10693-014-0209-3.

[50] Nagayasu, J 2012, 'Financial innovation and regional money', *Applied Economics*, vol. 44, no. 35, pp. 4617-4629. doi: https://doi.org/10.1080/00036846.2011.593500.

[51] Nasreen, S & Anwar, S 2020, 'Financial stability and the role of economic and financial integration in south Asia: Evidence from time-series data', *Singapore Economic Review*, vol. 65, no. 2, pp. 303-333. doi: https://doi.org/10.1142/S0217590817500011.

[52] Nguyen, YN, Brown, K & Skully, M 2019, 'Impact of finance on growth: Does it vary with development levels or cyclical conditions?', *Journal of Policy Modeling*, vol. 41, no. 6, pp. 1195-1209. doi: https://doi.org/10.1016/j.jpolmod.2019.05.006.

[53] Niankara, I 2023, 'The impact of financial inclusion on digital payment solution uptake within the Gulf Cooperation Council economies', *International Journal of Innovation Studies*, vol. 7, no. 1, pp. 1-17. doi: https://doi.org/10.1016/j.ijis.2022.09.004.

[54] Omri, A, Daly, S, Rault, C & Chaibi, A 2015, 'Financial development, environmental quality, trade and economic growth: What causes what in MENA countries', *Energy Economics*, vol. 48, pp. 242-252. doi: https://doi.org/10.1016/j.eneco.2015.01.008.

[55] Park, CY & Mercado, RV 2014, 'Determinants of financial stress in emerging market economies', *Journal of Banking and Finance*, vol. 45, no. 1, pp. 199-224. doi: https://doi.org/10.1016/j.jbankfin.2013.09.018.

[56] Parves, A 2019, 'Adoption of Real Time Gross Settlement in Bangladesh: A study on some selected banks', *International Journal of Science and Business*, vol. 3, no. 1, pp. 184-194. doi: https://doi.org/10.5281/zenodo.3368564.

[57] Pati, PC, Rajib, P & Barai, P 2017, 'A behavioural explanation to the asymmetric volatility phenomenon: Evidence from market volatility index', *Review of Financial Economics*, vol. 35, pp. 66-81. doi: https://doi.org/10.1016/j.rfe.2017.07.004.

[58] Próchniak, M & Wasiak, K 2016, 'The impact of macroeconomic performance on the stability of financial system in the EU countries', *Collegium of Economic Analysis*, no. 41, pp. 145-160.

[59] Ramlall, I 2018, *Understanding financial stability*, Emerald Group Publishing.

[60] Seo, MH & Shin, Y 2016, 'Dynamic panels with threshold effect and endogeneity', *Journal of Econometrics*, vol. 195, no. 2, pp. 169-186. doi: https://doi.org/10.1016/j.jeconom.2016.03.005.

[61] Seo, MH, Kim, S & Kim, YJ 2019, 'Estimation of dynamic panel threshold model using Stata', *Stata Journal*, vol. 19, no. 3, pp. 685-697. doi: https://doi.org/10.1177/1536867X19874243.

[62] Shiva, RK & Durai, RK 2017, 'Impact of credit cards and debit cards on currency demand and seigniorage: Evidence from India', *Academy of Accounting and Financial Studies Journal*, vol. 21, no. 3, pp. 1-15.

[63] Tan, X, Choi, Y, Wang, B & Huang, X 2020, 'Does China's carbon regulatory policy improve total factor carbon efficiency? A fixed-effect panel stochastic frontier analysis', *Technological Forecasting and Social Change*, vol. 160, p. 120222. doi: https://doi.org/10.1016/j.techfore.2020.120222.

[64] Tong, H & Lim, KS 2009, 'Threshold autoregression, limit cycles and cyclical data', in Chan, KS (ed.), *Exploration of a nonlinear world: an appreciation of Howell Tong's contributions to statistics*, pp. 9-56, World Scientific. doi: https://doi.org/10.1142/9789812836281_0002.

[65] Van Anh, D, 2022, 'Does better capitalization enhance bank efficiency and limit risk taking? Evidence from ASEAN commercial banks', Global Finance Journal, vol. 53, 100617. doi: https://doi.org/10.1016/j.gfj.2021.100617.

[66] Verbeek, M 2018, *A guide to modern econometrics* (5th edition), Wiley.

[67] Wang, Q 2015, 'Fixed-effect panel threshold model using stata', *The Stata Journal*, vol. 15, no. 1, pp. 121-134.

[68] Yu, P 2013, 'Inconsistency of 2SLS estimators in threshold regression with endogeneity', *Economics Letters*, vol. 120, no. 3, pp. 532-536. doi: https://doi.org/10.1016/j.econlet.2013.06.023.

[69] Zhang, K 2003, 'Does financial development promote economic growth in East Asia?', *China Journal of Finance*, vol. 10, no. 1, pp. 1–10.