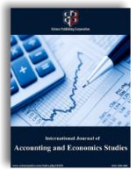
International Journal of Accounting and Economics Studies, 12 (2) (2025) 232-241

International Journal of Accounting and Economics Studies

Website: www.sciencepubco.com/index.php/IJAES
https://doi.org/10.14419/hmcxbd30
Research paper



Navigating Interest Rate Flux: Evidence from South and Southeast Asia

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Received: April 26, 2025, Accepted: May 30, 2025, Published: June 25, 2025

Abstract

As a driver of savings, consumption, and investment, interest rate plays a crucial role in an economy, while the fluctuation of lending interest rate depends on many factors. Various studies explored the impacts of different factors on lending interest rate flux and found heterogeneous results. Moreover, most of the earlier studies applied diverse predetermined research methods, either linear or non-linear, without aiming at any automated or self-regulated research technique. Therefore, this study explores the influencing factors of lending interest rate using symbolic regression, an automated research technique, in the case of South and Southeast Asian countries for the period 1985-2022. The applied method digs out the dominant factors that influence lending interest rate and reveals that economic growth is the most influential factor in South and Southeast Asian countries, followed by broad money growth, inflation, real interest rate, and others. Some policy implications are also discussed based on the results.

Keywords: *Determinants of interest rate, Lending interest rate, South and Southeast Asia, Symbolic regression.*

1. Introduction

In an economy, interest rates are closely connected to the dynamics of deposits or savings, consumptions and investment where they serve as the fundamental lever of economic machinery (Maverick, 2023). The fluctuation of lending interest rates not only influences the domestic economic conditions but also impacts the exchange rates, global capital flows, trade balances etc. (World Economic Forum, 2023). Understanding the determinants in the fluctuations of lending interest rate is a key to fostering economic stability along with the economic growth (FRED, 2024). Characterized by a diversified economic structure, countries in South and Southeast Asia have witnessed notable and continuous transformations over the previous years, driven by mass industrialization, policy shifts, and of course globalization. For domestic policymakers and international investors, the volatility of interest rates in those economies has asserted challenges. Hence, the correlation between different macroeconomic variables and lending interest rate movements remains a matter of intense scrutiny, especially in the countries where the financial markets are continuously evolving (FRED, 2024). Therefore, this region appears to have a unique landscape to study the behavior of lending interest rates.

Existing literature has broadly explored the determinants of lending interest rates like inflation, exchange rates, economic growth, and so on. Traditionally, econometric approaches depending upon either linear or non-linear models have provided different insights and philosophies to the determinants of lending interest rates, nonetheless, these methods are mostly constraint by the underlying assumptions and limited ability to detect the complex interactions between the variables. In addition, most of the previous studies focused on developed countries or the impact of different individual variables on lending interest rates. Therefore, this study targets to apply symbolic regression, an automated data discovery research technique, to dig out the most dominant factors of lending interest rate in South and Southeast Asian countries for the period 1985-2022. In other words, the main objective of this study is to find out the most important determinants or factors, and how these determinants shape lending interest rates in South and Southeast Asia. Hence, the study contributes to existing literature in the following ways. First, as per the authors' knowledge, this study deploys symbolic regression technique for the first time to excavate the significant determinants of lending interest rate while earlier studies applied various predetermined research techniques in their analyses. The applied method digs out the dominant factors that influence lending interest rate and reveals that economic growth is the most influential factor in South and Southeast Asian countries, followed by broad money growth, inflation, real interest rate, and others. Second, the study focuses on South and Southeast Asia, a strategically and economically significant region that has received inadequate attention in earlier studies investigating the determinants of lending interest rates. In addition, as the diversified economic conditions across the region reveal an extra layer of complexity, the influential factors of interest rate in a country may significantly vary from those of others. Therefore, this study focuses on 19 countries across South and Southeast Asia, offering country-specific insights into the dominant factors influencing lending interest rates. The identification of varying primary determinants across countries like economic growth in Pakistan, Malaysia, and others, broad money growth in Indonesia, and trade openness in Bangladesh, highlights the need for tailored monetary policies rather than

one-size-fits-all solutions. Hence, the study provides valuable input for policymakers in designing adaptive monetary and fiscal policies that align with national economic structures.
The remainder of the article follows the following structure. Section two discusses the relevant literature, while section three provides the materials and methods used in this study. Section four represents the results and discussion, while section five concludes the paper with some policy suggestions.

2. Literature Review

During the development of various theories, several factors that determine interest lending rates and their consequences have been identified. The classical theory of interest rates, advanced by Adam Smith and David Ricardo, holds that interest rates are determined by the supply (savings) and demand (investment) of capital in an economy. This theory stresses real factors, including productivity and time preference, as the key determinants of interest rates (Marshall, 1890). On the contrary, John Maynard Keynes in his book "The General Theory of Employment, Interest, and Money," published in 1936, offered a different view. According to Keynesian theory, interest rates are mostly determined by the demand and supply of money, and not capital. The lending interest rate is hence the price for giving up liquidity. In this framework, macroeconomic factors like income levels and inflation play crucial roles. Higher income increases the demand for money, thus potentially raising lending interest rates, while inflation expectations influence nominal interest rates as lenders demand higher rates to compensate for expected inflation. The Loanable Funds Theory is a synthesis of both the Classical and the Keynesian theory of interest rate determination, where the rate is determined by the supply of loanable funds and the demand for such funds. In its view, the natural interest rate is at which the amount of loanable funds demanded equals that supplied (Wicksell, 1936).
The analysis of the real and nominal interest rates is the basis of Irving Fisher's Theory of Interest, which takes into consideration the expectations of inflation rates. Fisher (1930) stated that the nominal interest rate equals the real interest rate plus the expected inflation rate. The Fisher Effect has been empirically supported, and this means that nominal interest rates respond to changes in expected inflation. The relationship between inflation and lending interest rates is central to monetary policy. Central banks manipulate interest lending rates to control inflation. According to the Taylor Rule, an econometric model developed by John B. Taylor (1993), the central bank adjusts nominal interest rates in response to deviations of actual inflation from the target inflation and actual GDP from potential one.
The Rational Expectations Theory and the Efficient Market Hypothesis (EMH) build up lending interest rate theory by including the aspect of information and expectations. Muth (1961) and Fama (1970) have postulated that when markets are efficient and agents have rational expectations, then lending interest rates are perfect reflections of all available information. This means that any likely shift in economic policy or the economic climate is already reflected in the current interest rates. These theories have important responses regarding the stability and fluctuation of interest rates, and it is only when the changes in macroeconomic conditions like inflation, exchange rate, FDI, and others are unexpected and they impact interest rates.
To some extent, each of the theories has its empirical evidence and shortcomings, which makes it possible to gain a more profound understanding of the lending interest rate mechanisms in various economic conditions. The current study adopts Rational Expectations and EMH theory of interest rate and examines the effect of different macroeconomic variables on interest rate in South and Southeast Asian countries by using data over the period 1985 to 2022.

2.1 Effect of Real Interest Rate on Lending Rate

Real interest rates and lending rates have been a critical issue in the literature for some time now. Some of the current research works have attempted to establish this relationship, and there is a variety of opinions on the closeness and the nature of the association. According to Borio and Gambacorta (2017), real interest rates are highly positively related to bank lending rates. According to their research on 14 developed countries, employing the vector autoregressive model (VAR), the authors found that when real rates go up, banks increase lending rates to cover their profits. This relationship is more evident in situations where interest rates are low. However, Claessens et al. (2018) argue that the real lending rates relationship could be less pronounced than previously estimated. In their 47-country panel data analysis employing fixed effect models, they establish that though there is a correlation, other factors like monetary policy, bank competition, and financial regulations have a greater influence on lending rates. However, Altunbas et al. (2014) give a more detailed picture showing that the impact of real rates on lending rates depends on the types of credits. They establish a higher pass-through for corporate loans than for household loans, explaining this by the differences in the levels of competition and risk perception in various segments of lending. The Study employed a probit model on 495 banks across 10 countries. These contrasting findings present the fact that there is a positive link between real interest rates and lending rates, as a complex one. As with most things, there is an overall positive relationship between economic growth and the volume of loans and yet the strength and significance of this relationship can be influenced by other factors like the state of the economy, the financial sector, and types of loans.

2.2 Effect of Inflation on Lending Rate

Inflation and lending rates have been studied over many years, and with new innovative approaches, various views have been developed. According to Tillmann (2008), inflation causes an increase in lending rates because banks must set real rates. In their papers in the cases of the US, the UK, and the European countries, they found out that inflation expectations and lending rates are highly positively correlated. The Study used a Vector autoregression-based approach to analyze the data. On the other hand, Van Dinh (2020) argues that the effect of inflation on the lending rates might not be straightforward. Analyzing the data using OLS regression techniques on China and Vietnam, they realized that although inflation is generally associated with the increase in lending rates, the impact of such an increase can be offset by the increase in competition in the banking industry. Another study on the Southeast Asian region conducted by Tjandrasa, Siagian, and Jie (2020) found the combined effect of inflation along with the stock market index and credit default swap on lending rate. Employing dynamic modelling techniques, Chang and Zhang (2020) also showed that the role of inflation and lending rate differ depending on the economic environment. While in low inflation countries they estimate that the coefficient is lower than one, indicating a weak relationship between inflation and lending rates, in high inflation countries the value is higher than one, indicating a higher positive relationship between inflation and lending rates. Such opposite results show that there is a complicated interconnection between inflation and the lending rate. Although inflation has a way of influencing the rates of credit facilities upwards, the strength of this is subject to the market structure, monetary policy, and the general economic conditions.

2.3 Effect of Exchange Rate on Lending Rate

There has been a lot of research done on the link between exchange rates and lending rates, and recent papers offer different views. As noted by Gopinath and Stein (2021), exchange rate volatility affects the lending rates, especially in emerging economies. They also discovered that a devaluation of a currency leads to an increase in the lending rates since banks adjust to higher perceived risks and balance sheet consequences. The authors employ a combination of theoretical modelling and equilibrium analysis to derive their conclusions. However, Obstfeld et al. (2019) consider how the global financial cycle impacts both the exchange rate and the lending rate. They opine that international capital flows are instrumental in influencing both the variables, resulting in a close and highly interactive, though not always linear or straightforward, relationship between exchange rate and lending rate. Such disparities also explain why there is a complex relationship between the exchange rate and lending rate. In most cases, movements in exchange rates affect the lending rates, but the strength and direction of this relationship depend on factors like the structure of the economy, financial sector development, and global economic environment.

2.4 Effect of Broad Money Growth on Lending Rate

Recent studies have focused on the effect of broad money growth and lending rates, and various views have been put forward. According to Kilinc and Tunc (2019), the enhancement in the broad money growth hurts the lending rate. they found out that there is a negative relationship between broad money growth induced by expansionary monetary policy in Turkey and lending rates. On the contrary, Bhattarai and Neely (2022) have argued that the effect of broad money growth on the lending rates may be more nuanced and possibly inflationary. They discover that though the initial broad money growth is associated with a decline in rates, sustained growth could cause expectations of inflation and thus increase lending rates. In contrast, Borio and Gambacorta (2017) consider how the impact of monetary policy, and in particular broad money growth, on lending rates differs depending on the interest rate regime. They opine that, while the relationship between broad money growth and lending rates is not necessarily direct, the effect of the former on the latter reduces in low-interest rate regimes. These conflicting results underscore the fact that the link between money growth and lending rate is not a straightforward affair. In general, broad money growth affects lending rates, but the strength and direction of this relationship depend on the economic conditions, inflation expectations, and the general monetary policy regime.

2.5 Effect of Economic Growth on Lending Rate

The literature review on the link between economic growth and lending rates has been conducted, and recent trends have been presented in the following view. According to Borio et al. (2017), higher economic growth results in higher lending rates. They discover that during the periods of economic expansion, demand for credit increases, and the economic conditions become favorable, and hence, the banks increase the rates of interest on loans. However, Claessens et al. (2018) opine that the effect of economic growth on the lending rate can be more complex. From their cross-country comparison, they establish that though lending rates tend to rise with economic growth, the extent of the increase can be checked by increased competition within the banking industry and technological progress, which lowers intermediation costs. These results indicate that it is not easy to establish the relationship between economic growth and lending rate, as seen earlier from the contrasting results above. Even though economic development in most cases leads to raising the lending rates, the degree and nature of this impact fully depends on the existence of certain conditions such as market conditions, technological advancement, and the type of loans.

2.6 Effect of Trade Openness on Lending Rate

Trade openness and lending rates have received attention in the current literature concerning economic growth, and the findings are mixed in nature. According to Delis et al. (2018), credit interest rates tend to reduce with the expansion of trade openness. Based on their cross-country study, the authors posit that increased globalization of banking business improves competition in the banking industry, hence the ability to lower the interest rates on loans as banks fight for market share. On the other hand, Eichler and Littke (2018) posit that the effect of trade openness on the lending rate may not necessarily be a straightforward one. They discovered that though raising trade openness lowers lending rates in developed countries, it may raise the rates in emerging economies because of higher perceived risk and volatility connected with greater integration with the global economy. Unlike the previous study, Bremus and Neugebauer (2018) analyze how the link between trade openness and lending rates depends on financial integration. They opine that the relationship between trade openness and lending rates is more pronounced in countries with higher degrees of financial integration since the increase in capital inflows exerts additional competitive pressure on the domestic banking system. Thus, these contrasting results shed light on the complexity of the trade openness-lending rate nexus. In most cases, trade openness affects the lending rates, but the impact may be positive or negative depending on factors such as the level of economic development, financial integration, and the nature of the banking system.

After the discussion above, it can be summarized that previous studies found varying results by deploying various research methods that were predefined, such as linear or non-linear. This study aims to make some significant contributions to the existing literature on the determinants of lending interest rates, particularly in the context of South and Southeast Asia, offering country-specific insights into the dominant factors influencing lending interest rates. This study also draws on recent regional literature exploring the implications of monetary policy in South and Southeast Asian contexts. Notable examples include Hasan et al. (2021) on the monetary policy effects in Bangladesh, and Basri and Rahardja (2022) examining Indonesia's central bank strategies under macroeconomic shocks. These references situate within the most up-to-date regional debates. Given the evolving global economic landscape, the findings offer fresh insights that enhance the understanding of interest rate dynamics in this region.

Unlike previous studies that focused on traditional economic determinants, this study examines lending interest rate fluctuations amid recent global economic shocks, including post-pandemic recovery, inflationary pressures, and geopolitical uncertainties. The findings highlight how factors like economic growth, broad money supply, inflation, evolving trade policies, and others influence lending interest rates in South and Southeast Asian economies, providing updated insights for policymakers. Also, there is a great scope for working in detail on the facts of how gender and class dynamics affect access to credit and exposure to lending interest rate volatility. Lower-income borrowers and women-led businesses are often disproportionately impacted by the restrictive monetary policy. These dynamics merit attention, especially in economies with uneven financial inclusion. The study recognizes the fact that financial systems are not being operated in a vacuum. The role of political economy is essential. Regulatory independence, governance structures, along fiscal-monetary coordination significantly shape monetary transmission mechanisms. In emerging markets, political stability and institutional trust often

influence central banks' capacity to implement effective interest rate policies. Also, the regulatory framework, including financial liberalization, banking supervision, capital adequacy norms, etc., can influence how monetary policy translates into lending behavior. Siregar and Goo (2020) demonstrated how prudential regulations affect interest rates passed through in ASEAN markets.

Finally, this research pioneers the use of symbolic regression, a self-regulated machine learning technique, to uncover the determinants of lending interest rate movements. Unlike the conventional econometric models, which rely on predefined assumptions of linearity or non-linearity, symbolic regression autonomously discovers functional relationships among variables, allowing for a more data-driven and adaptive analysis. The study's findings reveal complex, nonlinear interactions that traditional models may overlook, making this methodology highly relevant for dynamic financial environments. From the regional perspective, studying lending interest rate dynamics in South and Southeast Asia is particularly significant due to the region's shared economic challenges, trade dependencies, and financial market structures. Countries in this region benefit from comparative insights into lending interest rate determinants across their regional counterparts, informing domestic policy formulation, financial development and cross-border economic strategies. In short, these help set the study as a valuable reference for policymakers, financial analysts, and researchers seeking to navigate the complexities of lending interest rate fluctuations in emerging economies. To associate the gap between theory and methodology, the symbolic regression framework was introduced as a natural extension of the literature's call for models that can handle complex and nonlinear macroeconomic interactions.

3. Materials and Methods

3.1 Variables' Description

Following the existing literature on the determinants of interest rate, lending interest rate (LIR) is considered as a predicting variable (Mishkin, 2019; World Bank, 2023) and real interest rate (RIR), inflation (INF), exchange rate (EXR), broad money growth (BMG), economic growth (EG), and trade openness (TO) are used as explained variables. A description of the variables is presented in Table 1.

Table 1: Description of the variables

Type of Variable	Name of Variable	Description
Dependent Variable	Lending Interest Rate (LIR)	Lending interest rate of the respective countries over the years.
Independent Variable	Real Interest Rate (RIR)	Real interest rate adjusting for inflation reflects the real cost of funds to the borrower.
	Inflation (INF)	Inflation is directly involved with the risk premium of interest rates.
	Exchange Rate (EXR)	Exchange rate of the respective countries against the USD.
	Broad Money Growth (BMG)	The annual growth of broad money in an economy.
	Economic Growth (EG)	The annual GDP of the selected countries is in million USD.
	Trade Openness (TO)	Ratio of the sum of export and import to GDP.

3.2 Sample and Data Source

The study focuses on 19 countries (Table 2) located in South and Southeast Asia. Data were collected from the World Bank World Development Indicators (WDI) for the period 1985-2022. This period is chosen based on the availability of data for every single variable.

Table 2: Description of the sample

Region	Countries
South Asia	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.
Southeast Asia	Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, and Vietnam.

To remove the heterogeneity regarding the magnitudes and the units of the variables, data were standardized following equation (1), where X represents a variable's value and X' represents its standardized value each year, respectively.

$$X' = \frac{X - Mean}{Standard\ deviation} \quad (1)$$

The study also tested the data for correlation for each country and found that they are correlated with each other, but not to a higher degree than can cause a multicollinearity problem. A descriptive statistic of the variables is added in Appendix A.

3.3 Symbolic Regression Method

Symbolic regression is a very powerful machine-learning tool to discover the hidden relations or interactions between variables. It can unearth the complex patterns or relationships among the variables, either linear or non-linear, as well as the interactions or combinations of predictors to impact the response. As this study aims to find out the most dominant factors of lending interest rate among inflation, real interest rate, exchange rate, broad money growth, economic growth, and trade openness, a traditional research technique may fail to capture the complex interactions among the variables. In this case, the symbolic regression method can act as an impressive tool to reveal the combinations of factors to explain the lending interest rate without imposing any assumptions on the structure of the functional models. With the assistance of genetic programming (a type of evolutionary algorithm known for greater flexibility in discovering functional relationships among variables without relying on predefined model structures), this method has turned out to be a significant method for empirical modelling (Kotanchek et al., 2003). It is an entrance or gateway to machine learning with optimization of both the parameters and structure of the analytical model (Vladislavleva et al., 2009) and is different from the conventional regression methods. It can explore the functional structures of a dataset behaving like a robot-scientist for automated knowledge invention concerning accuracy, along with the simplicity (Khu et al., 2001) and Koza (1992) is the mastermind behind this revolutionary function discovery regression method.

Usually, the functional forms among the variables are predefined in the case of regular regression models (e.g., linear, non-linear, or polynomial). Hence, there is a chance to miss out on the more subtle relationships or interactions among the factors. However, in symbolic regression, the relationships among the variables are solely formed according to the inherent characteristics of data, providing chances to discover deeper or more nuanced insights that the traditional models might overlook. Using symbolic regression, a proper and precise functional model can be found to represent the relationship between the variables, whether it is linear or non-linear. It can also measure the coefficients of the functions. Many scholars like Duffy and Engle-Warnick (2002), Schmidt and Lipson (2009), Can and Heavey (2011),

Yang et al. (2015b, 2016), and Pan et al. (2019) appreciated this method as an efficient and intelligent tool for computation for discovering data.

Symbolic regression is backed by the concept of Darwinian evolution, positing that more competitive individuals have a greater likelihood of survival, whereas less competitive performers, as well as poor performers, are more likely to disappear gradually. This method of natural selection or survival of the fittest is the core to genetic programming, which usually employs three main operators, i.e. selection, crossover, and mutation (see Fig. 1). In certain individuals, whenever a higher quality gene arises, it is selected, copied, and propagated among the population. The retention of a gene (or factor, in the context of this paper) in an individual (or model) is determined by its contribution to the individual's survival (model fitness). Thus, only the significant factors are progressively selected to form the models, while the insignificant ones are automatically excluded. The identification of a particular factor aids researchers in determining which elements significantly impact the functions discovered by symbolic regression. The presence of each factor reflects its capability to represent the data, with higher frequency indicating a prominent consideration (Yang et al., 2016).

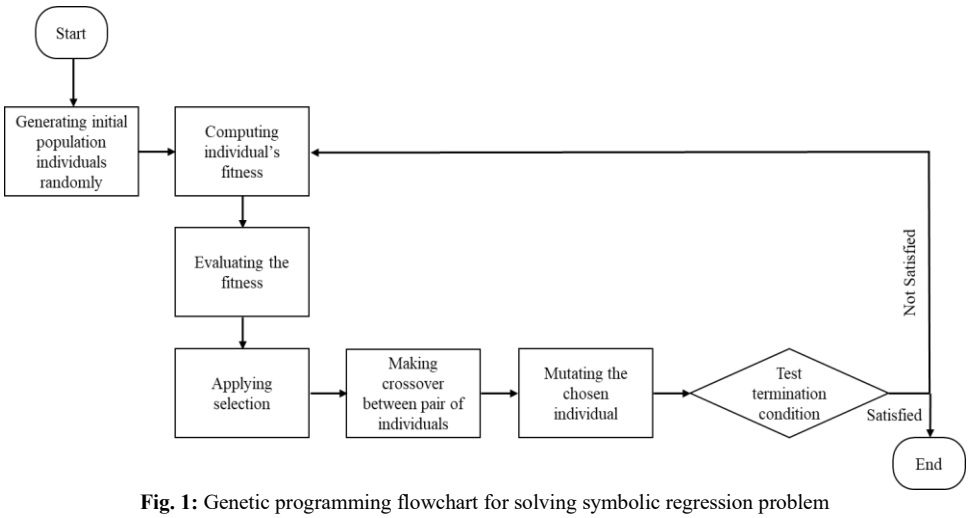

Fig. 1: Genetic programming flowchart for solving symbolic regression problem

Symbolic regression involves a broad search space and significant computation time to find potential results, leading to many generated solutions. This makes it challenging to assess the entire solution space to identify key factors. It can be computationally intensive, especially in the case of large datasets, and it carries a risk of overfitting if not tuned carefully. So, to manage this, researchers often select models with the least errors and complexities by creating a Pareto frontier (a concept of optimization theory – represents a set of solutions that offer the best possible trade-off between model accuracy and complexity), then picking models from different Pareto points. The models that appear in different Pareto points represent a good balance between the predictive power and the simplicity, without overfitting the data. This helps in easily identifying the most frequently appearing factors, which are deemed more important for further decisions. Compared to traditional regression methods like linear regression, symbolic regression is more straightforward. While a full benchmarking against traditional methods is beyond this study's scope, symbolic regression offers deeper structural flexibility, which may complement or improve upon the linear constraints of models like OLS regression. In linear regression, researchers focus on variable coefficients and significance tests, whereas in symbolic regression, the emphasis is on the frequency of occurrences of variables. The higher the frequency, the greater the significance. In this methodology, the research approach involves three key steps: Firstly, the data is gathered and equipped for each variable, and performed symbolic regression is performed with specific orders, like which explanatory variables are going to explain the dependent variable and what building blocks the candidate models may use. This process produces numerous candidate models with associated errors and complications. Secondly, a Pareto front for each country is developed to select models with minimal errors and complexities (see Fig. 2 in section 4.1). Thirdly, all factors are being analyzed and recognized as the ones that appear most frequently within the selected models (Fig. 3 in section 4.1).

4. Analysis, Results, and Discussion

4.1 Results of Symbolic Regression

At this stage, standardized data were inserted into the system to run the intended model- symbolic regression. To do so, the study defined lending interest rate as an explained variable and real interest rate, inflation, exchange rate, broad money growth, economic growth, and trade openness as explanatory variables. At the same time, the study recommended constant, input variables, addition, subtraction, and multiplication as the building blocks that the system could use to dig out the relationship between variables. As it is common for symbolic regression that produce numerous candidate models, not all models can be considered. The most used and the most reliable technique is to build a Pareto frontier consisting of the models having less complexity and more accuracy. Hence, for 19 countries, the study found a total of 19 Pareto frontiers showing the less erratic models for their respective countries. For a better understanding, Bangladesh is taken as an example here. Table 3 shows the models that appear in various Pareto points of the Pareto frontier in Fig. 2 (18 representative models are illustrated by 18 black squares).

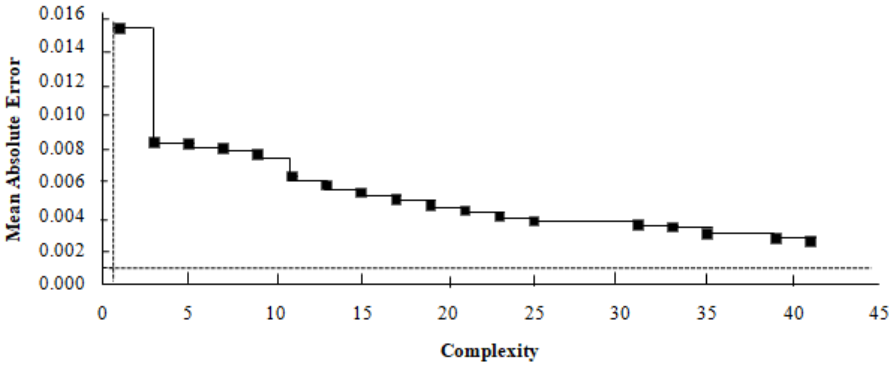

Fig. 2: Pareto frontier (Bangladesh is taken as an example)

The relative complexity and the mean absolute error (MAE) of every model appeared in every point of the Pareto frontier built for Bangladesh are compiled in Table 3, which shows that the higher the complexity of a model, the lower the mean absolute error.

Table 3: Symbolic regression models appear in the Pareto frontier (Bangladesh is taken as an example)

Complexity	MAE	Models
1	0.0151	LIR = 0.1293 BMG
3	0.0083	LIR = 0.1409 - 1.515 EG
5	0.0082	LIR = 0.1424 + 1.642 EG*BMG - 1.64 EG - 0.019 BMG
7	0.0080	LIR = 0.1466 + 1.642 EG*TO - 1.989 EG - 0.0198 TO
9	0.0073	LIR = 0.1726 + 8.55 EG*TO - 4.131 EG - 0.103 TO
11	0.0063	LIR = 0.1928 + 0.002 EXR*TO - 0.0019 EXR
13	0.0058	LIR = 0.1942 + 0.0034 EXR*TO^2 - 0.0015 EXR
15	0.0051	LIR = 0.2267 + 0.892 TO^2 - 1.368 EG - 0.575 TO
17	0.0049	LIR = 0.2257 + 0.019 RIR + 0.894 TO^2 - 1.338 EG - 0.578 TO
19	0.0046	LIR = 0.2320 + 0.195 RIR + 0.006 EXR*TO - 0.0026 EXR - 0.255 TO
21	0.0043	LIR = 0.2366 + 7.42 EG + 0.005 EXR*TO - 0.002 EXR - 0.26 TO - 3.06 EG^2
23	0.0039	LIR = 0.2165 + 0.0039 RIR*EXR + 0.006 EXR*TO^2 - 0.0012 EXR - 0.17 TO
25	0.0037	LIR = 0.1794 + 0.673 INF + 0.230 RIR + 1.03 TO^2 - 0.54 TO - 0.01 INF*EXR
31	0.0034	LIR = 0.2248 + 0.102 RIR + 7.25 EG*EXR + 0.67 TO^2 - 3.75 EG - 0.0008 EXR - 0.40 TO - 6.99 EG^2
33	0.0033	LIR = 0.2341 + 0.487 RIR*TO + 5.66 EG*EXR + 0.77 TO^2 - 3.33 EG - 0.0007 EXR - 0.50 TO - 5.11 EG^2
35	0.0033	LIR = 0.2348 + 0.561 RIR*TO + 5.70 EG*EXR + 0.77 TO^2- 3.35 EG - 0.0006 EXR - 0.019 RIR - 0.50 TO - 5.11 EG^2
39	0.0033	LIR = 0.2348 + 0.611 RIR*TO + 5.74 EG*EXR + 0.77 TO^2- 3.36 EG - 0.0006 EXR - 0.50 TO - 5.13 EG^2 - 0.20 RIR^2
41	0.0032	LIR = 0.2360 + 0.658 RIR*TO + 5.78 EG*EXR + 0.77 TO^2+ 2.81 EG*RIR^2 - 3.55 EG - 0.0006 EXR - 0.51 TO - 4.79 EG^2 - 0.34 RIR^2

In Fig. 3, we compiled the relative importance of the determinants of lending interest rate. It is a coincidence that the appearances of the determinants of lending interest in the two panels of the figure follow an identical order. However, it might not be the same for other countries. The left panel of Fig. 3 represents the number of models each variable shows up. For instance, trade openness shows up in 15 models while inflation appears only in 1 out of the 18 models that appeared in the Pareto frontier of Bangladesh. The right panel of Fig. 3 illustrates the number of times each variable appears across all regression models. The most frequently appearing variable is trade openness, while inflation is the least frequently appearing one. Trade openness appeared a total of 32 times through all regression models, while inflation showed up only twice in the case of Bangladesh. Therefore, it can be claimed that the most dominant determinant of lending interest rate in Bangladesh is trade openness, while inflation is the least important one.

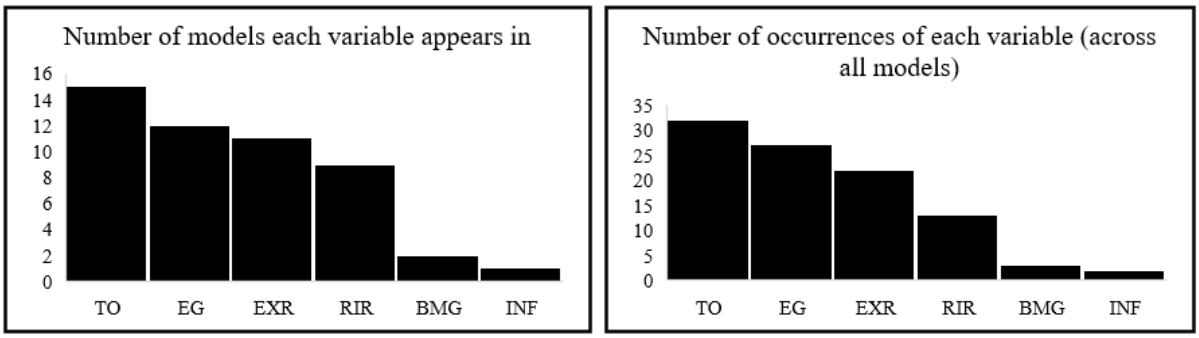

Fig. 3: Relative importance of determinants in symbolic regression models for Bangladesh, showing frequency of variables' appearances

4.2 Country and Variable Level Discussion

The study discovers 19 Pareto frontiers for 19 countries, consisting of the most representative regression models to excavate the leading determinants of lending interest rates. Then the determinants of lending interest rate are graded in Table 4 based on their occurrences in the Pareto optimal models. Seven classes are used to grade them, such as A, B, C, D, E, F, and 0, where A represents the most frequent determinant, F represents the least frequent one, and 0 represents no occurrence of a determinant. Then this study categorizes the sample countries based on the most frequent factor, showing up on the regression models, called primary factors. And this categorization of the countries is done only to make it clear which determinant is most influential in determining lending interest rate in a country.

In Table 4, it is shown that there are six types of countries. Economic growth is the most crucial and repeated factor of lending interest rate in 7 countries (i.e., Pakistan, Singapore, Bhutan, Laos, Malaysia, Cambodia, and India). When these economies grow, people and businesses tend to borrow more, resulting in the push up of demand for loans and, in turn, leading to higher lending rates. When the economy is booming, banks can charge more as everyone wants a piece of the action. Borio et al. (2017) pointed out that during good economic times, banks often raise rates to keep up with loan demand. But the twist is how strongly this effect depends on how competitive the banking sector is, along with the overall economic climate. Like in Singapore with a super advanced and competitive financial system, things like technology and lower costs help to keep lending rates from skyrocketing even when the economy is growing fast. On the other hand, in places like Pakistan and Laos, with not that many developed financial markets, economic growth has a much bigger impact on lending rates.

Broad money growth is found as the primary determinant of lending interest rate in 5 countries (i.e., Maldives, Myanmar, Nepal, Brunei, and Indonesia). Because of loose monetary policies, when there's more money circulating in the economy, lending rates tend to drop at first. But if this keeps up for too long, it can lead to inflation, which might eventually push rates back up. This is in line with what Bhattarai and Neely (2022) found. As per their findings, while more money supply can lower rates initially, it can also lead to inflation fears, which drives rates higher later. For instance, in Indonesia, the central bank plays a big role in managing this balance between inflation and lending rates. Interestingly, this isn't always the case everywhere. Kilinc and Tunc (2019) found that in Turkey, more money supply led to lower lending rates, showing that the impact of BMG really depends on the specific economic context.

Table 4: Category of countries based on the primary factor of lending interest rate

Country	A	B	C	D	E	F	0
Type-1: Primary determinant: EG							
Pakistan	EG	BMG	TO	INF	RIR	—	EXR
Singapore	EG	BMG	RIR	TO	EXR	INF	—
Bhutan	EG	EXR	TO	RIR	—	—	INF, BMG
Laos	EG	EXR	BMG	INF	TO	RIR	—
Malaysia	EG	EXR	BMG	TO	RIR	INF	—
Cambodia	EG	INF	TO	BMG	EXR	RIR	—
India	EG	INF	RIR	TO	EXR	—	BMG
Type-2: Primary determinant: BMG							
Maldives	BMG	EXR	INF	EG	RIR	TO	—
Myanmar	BMG	EXR	INF	TO	EG	RIR	—
Nepal	BMG	INF	RIR	EXR	—	—	EG, TO
Brunei	BMG	TO	INF	RIR	—	—	EG, EXR
Indonesia	BMG	TO	EG	INF	EXR	RIR	—
Type-3: Primary determinant: INF							
Philippines	INF	EG	RIR	TO	EXR	BMG	—
Thailand	INF	RIR	EG	EXR	TO	BMG	—
Timor-Leste	INF	TO	RIR	EG	—	—	EXR, BMG
Type-4: Primary determinant: RIR							
Sri Lanka	RIR	INF	BMG	EXR	EG	TO	—
Vietnam	RIR	INF	EXR	TO	—	—	EG, BMG
Type-5: Primary determinant: EXR							
Afghanistan	EXR	INF	BMG	TO	EG	—	RIR
Type-6: Primary determinant: TO							
Bangladesh	TO	EG	EXR	RIR	BMG	INF	—

In the Philippines, Thailand, and Timor-Leste, inflation was the main driver of lending rates. When prices rise, banks bump up their lending rates to make sure they're still earning real returns. This matches the findings of Tillmann (2008) that inflation expectations are a big deal when it comes to setting lending rates. But it's not always straightforward. Things like how competitive the banking sector is and how well the central bank manages inflation can soften the blow. For example, in Thailand, the central bank's ability to keep inflation expectations in check plays a huge role in keeping lending rates stable. This is also like what Chang and Zhang (2020) found: the link between inflation and lending rates is stronger in countries where inflation is already high

Real interest rate is found dominant in 2 countries, Sri Lanka and Vietnam. When real interest rates go up, banks pass those higher costs on to borrowers, leading to higher lending rates. This matches what Borio and Gambacorta (2017) found in developed economies. But the strength of this effect depends on the type of loans and how competitive the banking sector is. For example, in Vietnam, corporate loans feel the impact of higher real interest rates more than household loans do, which lines up with Altunbas et al. (2014). Also, exchange rate and trade openness play a proactive role in an individual economy. Exchange rate volatility was the main factor influencing lending rates in Afghanistan. When the local currency is all over the place, banks adjust their rates to account for the risk, which makes borrowing more expensive. This is in line with Gopinath and Stein (2021), who pointed out that exchange rate swings can really affect lending rates, especially in emerging economies. Meanwhile, in Bangladesh, trade openness was the main factor, but it had the opposite effect. More trade integration led to lower lending rates because it increased competition in the banking sector. This matches what Delis et al. (2018) found in developed countries, but it's different from Eichler and Littke (2018), who argued that in some emerging economies, trade openness can raise lending rates because of higher perceived risks.

Table 5 shows the degree of importance of all determinants of lending interest rate across different countries. It is observed that economic growth is the most important factor of lending rate as it appears as a primary factor in 7 economies, while broad money growth occupies the second place, appearing as a primary factor in 5 countries. Inflation appears to be the third important factor, followed by real interest rate, exchange rate and trade openness, respectively.

Table 5: Degree of importance of all factors across different countries

Factors	A	B	C	D	E	F	0
EG	7	2	2	2	3	—	3
BMG	5	2	4	1	1	2	4
INF	3	6	3	3	—	3	1
RIR	2	1	5	3	3	4	1
EXR	1	5	2	3	5	—	3
TO	1	3	3	7	2	2	1

Basically, this study both confirms and challenges what we've seen in earlier research. While it's no surprise that economic growth, inflation, and real interest rates play big roles, this study used a more nuanced approach (symbolic regression) to uncover some country-specific relationships that traditional models might miss. For example, it found that trade openness has a big impact on lending rates in Bangladesh, which earlier studies (mostly focused on developed economies) didn't pick up on. Similarly, the importance of broad money growth in Indonesia and Nepal highlights how crucial monetary policy is in shaping lending rates, which aligns with Bhattarai and Neely (2022) but differs from Kilinc and Tunc (2019). Overall, the big takeaway here is that policymakers need to tailor their strategies to each country's unique economic situation. There's no one-size-fits-all solution. The study also shows that we need more research into how different economic factors interact with lending rates, especially in emerging economies where things can get complicated.

5. Conclusion

Focusing on 19 countries in South and Southeast Asia for the period 1985-2022, this study explores the determinants of lending interest rate, applying an automated data discovery technique called symbolic regression. Without any human intervention, the applied technique digs out the representative models that show the relationships between lending interest rate and its determinants. After analysing the data, it is confirmed that economic growth is the main factor that determines lending interest rate in South and Southeast Asian countries, followed by broad money growth, inflation, real interest rate, exchange rate, and trade openness. So, as per the results and discussions, the following suggestions can be drafted for the policymakers for future implications:

First, the governments of the respective countries may ensure more focus on and prioritize the policies oriented to economic growth, as it is an influential factor across many countries. For stable economic growth, investment in different technologies, startups, and inventions can be targeted to enhance the level of productivity. The stability in economic growth will ensure a predictable lending rate, which will encourage an upward trend in long-term investments through international investors, along with the locals. Second, since broad money growth is another significant determinant, the regional central banks need to keep a symmetry in amplifying the money supply to stimulate respective economies, controlling and monitoring inflation. Interventions like open-market operations (based on real-time economic conditions) and other mechanism can be accustomed to eliminating hyper-inflation while supporting economic growth. Third, in the case of global value chains, repeatedly modified regional trade agreements between or among countries may boost trade openness. To lower the lending rates, countries where trade openness has a significant impact (like Bangladesh), may approach policies to lessen the trade barriers by facilitating foreign trade. Policies that encourage exports and diversify the trade partners may contribute to a durable and lower interest rate environment. Fourth, to mitigate the exchange rate risk, policymakers need to pay attention to stabilizing the exchange rate since it influences the lending interest rate noticeably. Controlling acts like money laundering and stuff aggressively, strengthening the reserve and ensuring a stable macroeconomic environment, may control the risks associated with the exchange rate and thereby the interest rate. Apart from these, the policymakers may tailor the sector-specific growth policies as the sectors contributing significantly to GDP may have a positive residual effect on the lending interest rate. So, the respective governments may provide incentives for the high-value productions in production-oriented economies. On the other hand, service-oriented economies may benefit from innovation and digital systems.

Regarding future perspective, this study could explore the facts that how lending interest rate dynamics have broader implications beyond economics. For instance, the volatility of lending interest rates affects financial reporting, specifically in how firms disclose risks, estimate debt servicing costs, and manage provisions. The study also lays a foundation for future research exploring the interaction between ESG factors and lending interest rates. Given the rise in green finance and sustainable investment strategies, financial inclusion will need to reassess the risk-pricing mechanisms based on ESG considerations. ESG-focused monetary policies and financial regulations may shape the lending environments of emerging markets like South and South Asian countries. Apart from these, considering governance quality, credibility of fiscal policy, regulatory independence etc., and incorporation of these perspectives will align the research with broader interdisciplinary economic policy analysis.

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Appendix-A: Descriptive statistics

No.	Country	LIR Mean (Stdev.)	RIR Mean (Stdev.)	INF Mean (Stdev.)	EXR Mean (Stdev.)	BMG Mean (Stdev.)	EG Mean (Stdev.)	TO Mean (Stdev.)
1.	Afghanistan	0.144	0.065	0.072	48.07	0.211	8749.85	4.04
		(0.031)	(0.058)	(0.056)	(13.13)	(0.125)	(7369.77)	(6.23)
2.	Bangladesh	0.123	0.053 (0.049)	0.062 (0.022)	58.85	0.153	121008.65	0.31
		(0.020)			(19.66)	(0.057)	(123131.06)	(0.09)
3.	Bhutan	0.149	0.078	(0.069	43.88	0.186	1082.71	59.20
		(0.010)	(0.028)	(0.032	(18.80)	(0.124)	(922.92)	(161.11)
4.	Brunei	0.080	0.040	0.011	1.58	0.057	8961.12	2.06
		(0.062)	(0.127)	(0.015	(0.26)	(0.103)	(5260.39)	(3.37)
5.	Cambodia	0.165	5.600	0.045	3832.65	0.246	12034.48	1.15
		(0.089)	(8.463)	(0.051	(499.36)	(0.127)	(8799.91)	(0.22)
6.	India	0.127	0.055	0.073	43.88	0.155	1164240.10	0.34
		(0.030)	(0.027)	(0.029	(18.80)	(0.036)	(985019.72)	(0.14)
7.	Indonesia	0.169	0.062	0.084	7850.36	0.180	474609.68	0.52
		(0.056)	(0.072)	(0.091	(4722.27)	(0.113)	(402417.12)	(0.11)
8.	Laos	0.222	0.090	0.160	6013.51	0.271	6337.02	0.98
		(0.089)	(0.135)	(0.251	(4223.00)	(0.223)	(6501.03)	(1.06)
9.	Malaysia	0.072	0.041	0.024	3.36	0.054	174942.10	1.61
		(0.026)	(0.050)	(0.014	(0.63)	(0.041)	(124140.48)	(0.34)
10.	Maldives	0.114	0.044	0.050	12.53	0.166	1932.56	59.01
		(0.019)	(0.070)	(0.053	(2.41)	(0.087)	(1880.49)	(182.85)
11.	Myanmar	0.179	0.038	0.170	286.67	0.266	27545.21	0.96
		(0.029)	(0.080)	(0.138	(522.93)	(0.136)	(28088.74)	(1.39)
12.	Nepal	0.131	0.055	0.078	70.32	0.181	13221.57	0.46
		(0.031)	(0.040)	(0.038	(29.80)	(0.067)	(11635.76)	(0.09)
13.	Pakistan	0.122	0.041	0.085	69.14	0.149	158053.95	0.33
		(0.029)	(0.030)	(0.042	(46.50)	(0.067)	(114412.34)	(0.06)
14.	Philippines	0.118	0.056	0.062	39.87	0.139	163965.12	0.63
		(0.058)	(0.027)	(0.048	(12.23)	(0.077)	(121547.22)	(0.16)
15.	Singapore	0.059	0.041	0.016	1.58	0.100	173018.28	3.48
		(0.010)	(0.030)	(0.018	(0.26)	(0.070)	(132635.15)	(0.35)
16.	Sri Lanka	0.132	0.039	0.099	90.80	0.162	38580.73	0.64
		(0.036)	(0.047)	(0.082	(49.50)	(0.077)	(32739.80)	(0.15)
17.	Thailand	0.080	0.047	0.030	32.34	0.105	244566.48	1.06
		(0.042)	(0.035)	(0.023	(5.83)	(0.065)	(159569.73)	(0.27)
18.	Tomore-Leste	0.159	0.075	0.077	1.00	0.169	859.94	552.06
		(0.060)	(0.105)	(0.204	(0.00)	(0.150)	(830.82)	(1193.23)
19.	Vietnam	0.154	0.055	0.091	14624.87	0.213	115502.78	1.43
		(0.083)	(0.070)	(0.115	(6990.75)	(0.126)	(123388.56)	(1.87)