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Revisiting The Finance-Innovation Nexus: Evidence from Asia

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Abstract
Since a few studies have analysed the long-run impact of monetary policy, this study aims to contribute to this gap by revisiting the Schumpeterian finance-innovation nexus and examining the influence of monetary policy, as well as the mediating function of bank lending, on technological innovation across Asian economies. This study employs a fixed-effect model (FEM) to analyse a cross-country dataset of Asian economies from 2002 to 2023. The finding reveals the direct and indirect correlation between monetary policy and innovation, as determined through mediating regression analysis. Furthermore, our study offers empirical evidence supporting a correlation between financial development and national innovation. This finding holds across several primary, robustness, and endogeneity analyses. Furthermore, this study also found that the direct and indirect effects of monetary policy on national innovation are more pronounced in upper-middle- and high-income countries. This study confirms that enhanced bank lending, facilitated by appropriate monetary policy, has a favourable and statistically significant impact on national innovation.

Introduction

The role of innovation as a pivotal element in improving the overall economic landscape has garnered significant attention from scholars aiming to discern the primary factors that influence innovation across various disciplines. Recent analyses that reexamine the relationship between finance and innovation have enhanced existing models by incorporating external determinants, including the impacts of financial crises, economic uncertainty, and policy implementation on the influence of financial market development on innovation. Giebel and Kraft (2020) analyse the effect of

the 2008/2009 global financial crisis on innovation activities, suggesting that the reduction, especially in product innovation, is in accordance with the credit supply shock caused by the economic downturn. Meanwhile, Tian et al. (2022) analyse the effect of uncertainties regarding bank lending on innovation activities, showcasing an adverse effect of economic policy uncertainty on corporate innovation. Moreover, they used bank lending as a mediating factor for innovation and reduced bank lending during economic policy uncertainty.

The banking system promotes innovation through financial intermediation. According to earlier research conducted by Schumpeter (1949), providing firms with adequate financial resources from financial institutions is crucial in promoting innovation. Hence, the linkage between financial development, regulation, and liquidity is inseparable from facilitating innovation. The existing literature, as demonstrated by the works of Bakhouche (2022), Lyu et al. (2023), Meierrieks (2014), and Wang (2023), indicates that the banking sector's liquidity can potentially increase the number of indicators of national competitiveness in innovation. Enhancing banking liquidity boosts the capacity of banks to extend loans, particularly for research and development (R&D) projects, ultimately encouraging innovation. Bank lending can significantly enhance national innovation by providing financial resources, facilitating resource allocation, and enabling companies to invest in research and development (R&D)(Salim et al., 2024). Enhanced bank lending can promote the spread of innovative technologies and techniques, especially in developing markets (T. Liu et al., 2022). Additionally, X. Liu & Zhao (2024) clarify that having access to credit can enable companies to enhance their innovation efforts, resulting in more extensive innovation and improved efficiency.

Banking credit is linked to the dynamics of macroeconomic policy and conditions, as well as changes in the home and global economies, beyond the relationship with innovation. Specifically, a monetary policy imposed by the government to regulate banks affects their liquidity for investment. Andrieş et al. (2022) note that monetary policy has a significant impact on three types of credit: investment, working capital, and consumption. Furthermore, Belgibayeva et al. (2022) reveal that the implementation of monetary policy tightening discourages innovation financing. In contrast, Olszak and Kowalska (2022) discovered that expansionary monetary policy enhances banks' credit growth. Thus, these studies conclude that imposing tightened (or loosened) monetary policy may lead to difficulties (or ease) in bank lending and limit the financing of innovative projects.

In certain Asian economies, particularly those with fixed or managed floating exchange rate systems, the focus is on sustaining stable exchange rates against the US dollar or other key currencies. Although occasionally regarded as a means to control inflationary pressures and encourage exports, this method may limit the effectiveness of monetary policy in meeting domestic economic needs (Kim

et al., 2020). In certain situations, the banking system might not be wholly integrated into the market, which can hinder central bank policies from effectively impacting lending rates and credit access for companies, especially those involved in innovation. Moreover, in Asian economies, monetary policy typically focuses on maintaining price stability and managing exchange rates, which can hinder innovation efforts by diminishing the effectiveness of monetary policy in fostering growth and causing distortions in financial markets (Feng et al., 2024). These policies may also foster an atmosphere that does not support innovation, resulting in a "middle-income trap" where nations reach a specific economic stage but struggle to advance further.

When examining prior research, it is common practice to categorise literature based on several causative factors. Previous studies have examined the relationship between monetary and credit in the banking system (Andrieş et al., 2018; Belgibayeva et al., 2022), as well as the link between the banking system's liquidity and innovation (T. Liu et al., 2022; X. Liu & Zhao, 2024). The preceding studies demonstrate the incremental impact of monetary policy and innovation, which are mediated via banking credit. Based on our comprehensive literature analysis, this study found several gaps as follows. First, limited studies have examined the direct relationship between monetary policy and innovation. Second, the correlation between monetary policy and innovation has been less studied in the context of Asian economies, particularly in cases where outdated policies are implemented, which may hinder innovation in Asia. Third, previous studies (Carvelli et al., 2024; Ma & Zimmermann, 2023) do not provide the mediating role of bank credit in the relationship between monetary policy and national innovation. Hence, the objective of this study is to address the existing knowledge gap by systematically examining the impact of monetary policy on innovation while also considering the intermediary function of liquidity within the banking system in selected Asian countries.

This study contributes to several developments in knowledge. First, since little attention was paid to the study correlating monetary policy due to the outdated nature of the policy in several economies, this study revisited it to examine its impact on the banking system's credit. This study employed selected economies in Asia where the policy is primarily implemented. Meanwhile, the present study employed different measures of innovation, building on the previous analysis by Ma et al. (2023) and Yang et al. (2024). Second, this study revisited the finance innovation nexus as proposed by Schumpeter (1949) and strengthened the argument that development in the banking system enhances national innovation. Third, by employing mediating regression, this study establishes a connection between the implementation of monetary policy and national innovation, using banking credit as a mediating variable. This approach builds upon the study by Ma et al. (2023), which suggests that financial institutions mediate the relationship between monetary innovation and

financial stability. As far as our current understanding goes, this research endeavour represents the inaugural attempt to examine and scrutinise the effect of monetary policy and the mediating role of credit of the banking system on national innovation. Besides aiding in advancing monetary economics and innovation research, this study provides a detailed examination of asset management and valuation, theoretically and empirically, to facilitate the progression of future research. Valuations in property and asset management reflect prevailing market conditions, encompassing interest rates and the overall state of the economy. Monetary policy may indirectly affect these valuations. For example, decreased interest rates may result in higher property values, as seen in the assessments. Moreover, intellectual property valuation, such as patents, considers the overall economic environment. Lower interest rates can aid companies in financing licensing deals or obtaining patented technology, thus increasing their innovation.

This study is structured as follows: Section 2 discusses monetary policy, bank lending, and innovation, and generates the hypothesis. Section 3 presents the empirical approach. Section 4 examines the impact of monetary policy on innovation and the mediation effect of banking credit. Section 5 presents the conclusion.

Literature Review

Monetary policy aims to manage prices and maintain economic stability. This objective leads to multiple avenues by regulating credit through financial institutions (Feng et al., 2024; Kim et al., 2020). Monetary policy influences bank lending by affecting the cost of funds for banks and the supply of loanable resources, ultimately shaping their lending practices. Increasing interest rates through tighter monetary policy raise borrowing costs for banks, which may lead to a decrease in their lending. Conversely, lowering rates through a looser policy could enhance the appeal of lending (Alper et al., 2018; de Bandt et al., 2021). When central banks increase interest rates, borrowing money becomes costlier for banks. It may cause banks to be more cautious with lending, as they encounter increased borrowing costs and may become more risk-averse. When banks are more hesitant to provide loans, it can become more difficult for companies, particularly start-ups and smaller firms, to obtain financing for innovation initiatives (X. Liu et al., 2018a). It may hinder innovation by limiting the funds available for research and development (Dou & Xu, 2021). The subsequent explanation clarifies the connection between monetary policy and innovation via the credit mechanism in the financial sector.

Monetary Policy and Innovation

As previously discussed, the direct correlation between monetary policy and innovation remains an underexplored area of research. There is a paucity of empirical evidence demonstrating a substantial relationship between these two variables. Ma et al. (2023) examine the response of innovation activity to various measures, including government and corporate spending on R&D, patents, and venture capital spending on start-ups, in response to monetary policy shocks. Their analysis results show that monetary policy shocks are negatively responded to by innovation activity on all measures. The study asserted that following a 100-basis-point tightening shock, R&D expenditures are projected to decrease by approximately 1% to 3%. Additionally, venture capital (VC) investments are expected to decline by around 25% within a one- to three-year timeframe. Furthermore, patents in critical technological domains, along with the patent-based aggregate innovation index, are expected to decline by up to 9% over the subsequent two to four years. They conclude that monetary policy affects innovation in various ways by influencing interest rates and financial conditions, mainly through its impact on overall demand and profitability. A stricter monetary policy, characterized by increased interest rates, can lower overall demand, potentially diminishing the motivation for companies to invest in research and development (R&D) and other innovative pursuits. Moreover, stricter financial conditions and diminished risk tolerance may result in reduced funding for innovation, especially for early-stage start-ups. Conversely, expansionary monetary policy (e.g., lowering interest rates) can boost demand and make it easier for companies to finance innovative projects.

Using a different method, Yang et al. (2024) tested the effect of monetary policy on innovation efficiency. The analysis results showed that tight monetary policy had a negative and significant effect on innovation efficiency. The results remained consistent even after they were retested with several robustness test schemes. It confirms the findings of Ma et al. (2023) that increasingly tighter monetary policy can reduce innovation activity. Increasing monetary policy can result in elevated borrowing costs, causing higher expenses for companies to invest in research and development, as well as innovation. It may decrease the quantity of new products and services, lowering the need for innovation, such as trademarks. Monetary policy may indirectly influence the economy's long-term productive capacity, affecting trademark efficiency. For instance, an extended period of low interest rates could lead to an increase in innovation and the creation of new products, resulting in a higher number of trademark applications. Based on previous research studies, the following hypothesis can be derived:

H1: Tightening (loosening) monetary policy negatively (positively) affects national innovation.

Monetary Policy and Bank Lending

A nation's entire money supply is governed by monetary policy, a set of laws designed to foster economic growth. Monetary policy includes changes to bank reserve requirements and adjustments to interest rates. The two main definitions of monetary policy are contractionary and expansionary. The study conducted by Alper et al. (2018) provides evidence supporting the notion that monetary adjustment substantially affects the composition of banks' liquid capital. The research revealed a discernible association between an increase in monetary policy tightening and a reduction in bank liquidity, leading to a decline in bank loans. Consistent with prior research, de Bandt et al. (2021) elucidate the influential role played by several factors in shaping the composition of banks' liquid capital.

Bianco (2021) adopts an alternative viewpoint to analyse the significance of theoretical monetary policy transmission mechanisms and the effects of monetary policy shocks on the redistribution of lending. The study reveals a correlation between expansionary monetary policy and an increase in both the establishment and dissolution of long-term borrowing. This effect is particularly pronounced among financially constrained firms and those deemed high-risk by lenders. Such findings align with the balance sheet channel of monetary policy, as well as with elements that mitigate lenders' risk perceptions and enhance their inclination to pursue yield. Hence, according to the aforementioned findings, it can be decided that adopting a monetary policy harms the banking system's credit. Therefore, this study proposes a hypothesis as follows:

H2: Tightening (loosening) monetary policy negatively (positively) affects bank lending.

Bank Lending and Innovation Under the Finance-Innovation Nexus

Following the financial intermediation theory, which explains the function of markets and financial organisations, it was argued that the most essential role of financial institutions is to tackle moral hazards and adverse selection issues, thereby minimising the borrower's cost of external finance. Thus, the financial sector plays a crucial role in promoting technological innovation through financial intermediation, which catalyzes economic growth. According to the earlier work of Schumpeter (1912), adequate lending from financial institutions to firms supports the development of innovation. Therefore, financial development and institutions, along with their lending, cannot be separated from the source of easing creativity. Their availability is correlated to business process dynamism and innovation creation (Ang, 2014; Brancati, 2015; J. Tian et al., 2022). Lending by the financial sector provides advantages for resource allocation and risk mitigation.

Specifically, concerning financial innovation (Dou & Xu, 2021; P. Liu & Li, 2020), there is a strong connection between how banks conduct lending practices and the innovative activities of

businesses in most countries, due to their significant influence. While recent scholarly work has examined the relationship between bank lending and technological innovation, the discourse surrounding the advantages and disadvantages of bank lending in relation to the dynamics of technological innovation remains ongoing. The study by X. Liu et al. (2018) stated that bank loans can stimulate the innovation process of enterprises primarily by providing financial support. Besides, banks mitigate inherent weaknesses by privatising their information, forming long-term relationships, and promoting corporate governance. Therefore, this study provides a hypothesis as follows:

H3: Higher (lower) bank lending improves (worsens) national innovation.

Method

Data

This study utilises annual panel data encompassing 25 Asian economies at the cross-country level from 2002 to 2021. Both methodological and empirical justifications drive the utilisation of research data. Asian economies employ diverse monetary policy frameworks, such as inflation targeting or fixed exchange rate systems, that can influence the impact of policy adjustments on innovation. According to the research presented in the background, the old monetary policies employed in various Asian nations, particularly those still in development, require a long-term analysis. The selection of the study scope is influenced by the availability of data, which in turn affects the approach employed. The primary source of the dataset was primarily derived from reputable sources such as the official website of the World Intellectual Property Organisation (WIPO) statistics database and the Integrated Macroprudential Policy (iMaPP) Database.

Estimation Strategy

A more detailed analysis of the relationship between monetary policy and innovation is needed. For this reason, this research used the mediating effect paradigm (Baron & Kenny, 1986). The analytical approach is a well-established and validated technique for demonstrating how an independent variable influences a dependent variable through an intervening (mediator) variable. This approach is a standard in social and behavioural sciences, facilitating comprehension and application across various research settings. Moreover, the approach provides a straightforward three-step procedure for evaluating mediation, making it easy to understand and implement. This method is employed to assess the impact of monetary policy and the intermediary function of banking credit on national innovation. The empirical specifications utilised to estimate the primary analysis are elucidated as follows:

$$\text{Innovation}_{i,t} = \alpha_0 + \alpha_1 \text{MP}_{i,t} + \alpha_2 \text{Macroeconomic}_{i,t} + \mu_i + \upsilon_t + \varepsilon_{i,t} \qquad (1)$$

$$\text{Credit}_{i,t} = \beta_0 + \beta_1 \text{MP}_{i,t} + \beta_2 \text{Macroeconomic}_{i,t} + \mu_i + \upsilon_t + \varphi_{i,t} \qquad (2)$$

$$\text{Innovation}_{i,t} = \gamma_0 + \gamma_1 \text{MP}_{i,t} + \gamma_2 \text{Credit}_{i,t} + \gamma_3 \text{Macroeconomic}_{i,t} + \mu_i + \upsilon_t + \delta_{i,t} \qquad (3)$$

Where *i* denotes countries and *t* is the year. $\text{Innovation}_{i,t}$ represents the national innovation of country *i* at time *t*. $\text{MP}_{i,t}$ means monetary policy implemented by country *i* at time *t*, and $\text{Macroeconomic}_{i,t}$ shows macroeconomic controls of country *i* at time *t*. $\text{Credit}_{i,t}$ represents the banking credit of country *i* at time *t*. Finally, μ_i denotes country-specific and υ_t represents unchanging and unobservable traits, as well as variations that exist across different points in time, and $\varepsilon_{i,t}$, $\varphi_{i,t}$, and $\delta_{i,t}$ is the disturbance terms of the direct effect model, respectively.

This study analyses the three models in stages using the fixed-effects method. This study is divided into several stages for analysis. First, test the basic model equations (1) to (3). Second, strengthen the analysis results by using different innovation measures. This section explains the results, and the robustness check shows them. Third, test the possibility of endogeneity of the monetary policy variable using the fixed effect-two-stage least squares (FE-2SLS) method. The combination of Fixed Effects (FE) and Two-Stage Least Squares (2SLS) methodologies, referred to as FE-2SLS, enables researchers to simultaneously address both time-invariant unobserved heterogeneity and endogeneity within panel data contexts. This approach is particularly advantageous when certain explanatory variables are potentially endogenous, while also accounting for time-invariant unobserved factors that require control. Finally, this study examines the possibility of differences in the effects of monetary policy on national innovation across various country groups through heterogeneity analysis.

Variable Measurements

This study utilises the number of applied trademarks, which effectively assesses the outcomes of national innovation and the productivity of R&D to measure national innovations (Yang et al., 2024). Additionally, this study includes examining trademark registration as a factor in our robustness test. The monetary policy is the primary independent variable provided by the IMF. The model incorporates monetary policy in this analysis by employing the lending rate. In addition, we incorporate the concept of banking credit as a mediating variable to facilitate an analytical examination of the correlation between monetary policy and national innovation. We employ private credit by depositing money from banks and other financial institutions. It is a widely utilised indicator in various contexts, as Anwar et al. (2023) and Carvelli et al. (2024) suggested. Furthermore,

this observation highlights the presence of banks and their crucial role as intermediaries in facilitating lending activities to meet overall financial needs.

Moreover, the private credit by deposit money banks and other financial institutions to GDP ratio indicates a country's financial development, which is influenced by factors such as the lending rate to the private sector and national innovation. To address the endogenous problem resulting from omitted variables and enhance the accuracy of regression estimates, this study incorporates controls for R&D, including R&D expenditure, the number of researchers, and royalties. This study also employs macroeconomic variables, including inflation indicators such as gross domestic product (GDP), exchange rate, foreign direct investment (FDI), and the Headline Consumer Price Index.

Result and Discussion

Descriptive Statistics and Serial Correlation

Table 1 presents a comprehensive set of descriptive statistics for all variables analysed in this study. The mean value of the variable is 9.5988, accompanied by a standard deviation of 1.5674, indicating a degree of variability within the data. It suggests a noticeable disparity in the level of national innovation across different nations. In the aforementioned computation, the variable denoted as $Credit_{i,t}$ exhibited values of 4.1324 and 0.7685, indicating a substantially elevated level of credit inside the banking system.

Table 1. Descriptive Statistic

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
$Innovation_{,t}$	500	9.5988	1.5674	5.3890	15.0441
MP_t	500	2.0030	0.8857	-1.3862	3.7841
$Credit_{,t}$	500	4.1324	0.7685	2.4571	6.1195
$R\&D\ Expenditure_{,t}$	458	-0.8433	1.1089	-3.1629	1.5953
$Researcher_{,t}$	369	6.5789	1.4321	-0.3427	9.1140
$Royalties_{i,t}$	383	17.3871	3.5464	5.2983	24.6009
$GDP_{,t}$	500	25.8331	1.8926	21.1970	30.5113
$FDI_{,t}$	477	8.3465	1.8158	1.5400	12.1060
$Exchange\ Rate_{,t}$	500	4.6704	0.1924	3.9265	5.4748
$Infaltion_{,t}$	466	1.4035	0.9635	-2.8127	3.8219

Furthermore, the variable MP_t has a 2.0030 mean and 0.8857 standard deviation. The variation in the primary data, including monetary policy, bank lending, and innovation, indicates the diverse effects of economic policy on patenting and credit activities. In particular, stricter monetary policy (such as increasing interest rates) may decrease patenting activity and overall innovation. However, it may have a more negligible effect on countries that possess substantial intangible assets

and are not highly dependent on external funding. This difference occurs as companies and sectors react differently to monetary policy changes. This difference has implications for policy formulation, necessitating a thorough understanding of how monetary policy affects various levels of the economy.

Main Result

Table 2 presents a summary of the primary estimation results. The findings generally indicate a statistically significant relationship between the monetary policy variable and national innovation. The coefficient of $MP_{i,t}$ (α_1=-0.1898, s.d.=0.0442) suggests evidence of the substantial total effect of monetary policy on national innovation. This result suggests that monetary policy's influence on national innovation may occur directly or be mediated by other variables. To find out, we divide our analysis into three parts. First, this study tests the direct relationship between monetary policy and national innovation. The analysis results are shown in column (Eq. 3) of Table 2, where the coefficient MP_t (γ_1=-0.1792, s.d.=0.0433) indicates a significant direct effect of monetary policy on national innovation. The results confirm the hypothesis of H1, which states that tightening (or loosening) monetary policy has a negative (or positive) effect on national innovation, ceteris paribus. This result aligns with previous findings (Yang et al., 2024), which indicate that contractionary monetary policy directly reduces innovation activity. Conversely, expansionary monetary policy can support the creation of financing for innovation activities. However, it cannot be concluded that the policy has a thorough and direct impact on innovation in our sample. Consequently, we will extend our analysis to investigate further and reinforce the findings of the prior total effect analysis, which suggests the presence of a mediating variable affecting the relationship between monetary policy and national innovation, as discussed in the subsequent section.

Second, the analysis results of the monetary policy's influence on bank credit in column 2 of Table 2 show a negative and significant influence of the coefficient MP_t (β_1=-0.1254, s.d.=0.0417). It implies that a one percentage point increase in the interest rate in response to monetary policy will decrease bank lending by 12.54 percent. The results confirm Hypothesis 2, which states that tightening (or loosening) monetary policy has a negative (or positive) effect on bank lending. These results also confirm the findings of previous researchers regarding the role of monetary policy in influencing price stability through the interest rate channel. In line with the previous finding (Bianco, 2021), the results validate how monetary policy affects financial activity through the interest rate channel. Third, there is a significant and beneficial connection between financing and national innovation, according to the analysis results in column (eq. 3). It can be noticed from the variable $Credit_{i,t}$ (γ_2=0.2701, s.d.=0.0768), which indicates the acceptance of hypothesis H3 that higher

(lower) bank lending improves (worsens) national innovation. In addition, these results have previously confirmed a positive relationship between bank financing and innovation activities (Dou & Xu, 2021; P. Liu & Li, 2020).

Table 2. Main Result

	(Eq. 1)	(Eq. 2)	(Eq. 3)
$MP_{i,t}$	-0.1898***	-0.1254***	-0.1792***
	(0.0442)	(0.0417)	(0.0433)
$Credit_{,t}$			0.2701***
			(0.0768)
R&D Control			
$R\&D\ Expenditure_{,t}$	0.0205	0.2900***	-0.0160
	(0.0433)	(0.0408)	(0.0436)
$Researcher_{,t}$	0.1156***	-0.1241***	0.1209***
	(0.0262)	(0.0247)	(0.0256)
$Royalties_{i,t}$	0.0152	0.0198*	0.0090
	(0.0108)	(0.0102)	(0.0107)
Macroeconomic Control			
$GDP_{,t}$	0.5186***	0.4753***	0.4985***
	(0.0391)	(0.0368)	(0.0386)
$FDI_{,t}$	0.0062	0.0752***	0.0101
	(0.0203)	(0.0191)	(0.0198)
$Exchange\ Rate_{,t}$	-0.3216***	-1.0456***	-0.3776***
	(0.1168)	(0.1101)	(0.1154)
$Infaltion_{,t}$	0.0013	-0.0253	0.0045
	(0.0212)	(0.0200)	(0.0525)
c	-2.4297***	-3.5157***	-0.6958
	(0.7545)	(0.7114)	(0.0208)
Country	YES	YES	YES
Year	YES	YES	YES
Obs.	277	277	277
Adjusted R2	0.7113	0.6585	0.7249
F	77.61	60.75	73.47
	[0.000]	[0.000]	[0.000]

Notes: The stated figures in the parentheses are standard errors. The asterisks (***, **, and *) denote 1%, 5%, and 10% significance levels, respectively.

The present analysis also confirms the findings of Evers et al. (2020), Meierrieks (2014), and Spatareanu et al. (2019), which provide empirical evidence supporting the notion that banks' liquidity has a substantial influence on a company's ability to engage in technological innovation. This research further corroborates Schumpete's (1949) finance-innovation nexus, which posits that adequate funding is crucial in facilitating and fostering innovation. Elevated liquidity inside the banking sector can effectively foster prospects for domestic innovation.

Overall, monetary policy tightening can have a direct impact on the decline in national innovation. Additionally, the stepwise regression analysis results indicate a gradual relationship, where monetary policy tightening, which affects lending in the banking sector, is associated with a decline in national innovation. Based on these results, the results also revealed that bank credit plays an intermediary role in the connection between national innovation and monetary policy.

Robustness Check

In light of the inconclusive findings from the previous analysis, this study conducts a robustness test employing an alternative innovation indicator, the number of trademark registrations. Table 3 shows the coefficient of $MP_{i,t}$ which implies that implementing a monetary policy harms the number of trademark registrations. The findings continuously support the notion that a significant correlation exists between the implementation of monetary policy and innovation. Furthermore, the coefficient of $Credit_{i,t}$ (γ_2 =0.2447, s.d. 0.1330) demonstrates that financial development and innovation are correlated, a finding that Schumpeter (1949) also reaffirmed. After employing various measures of innovation, we confirm that our main results are consistent and establish the significant direct effect of monetary policy on national innovation. Finally, this study also demonstrates the mediating role of bank lending in this relationship.

Table 3. The result of the Robustness Test

	(Eq. 1)	(Eq. 3)
$MP_{i,t}$	-0.3382***	-0.3297***
	(0.0751)	(0.0749)
$Credit_{,t}$		0.2447*
		(0.1330)
R&D Control	YES	YES
Macroeconomic Control	YES	YES
c	-8.0358***	-8.3501***
	(1.2877)	(1.2928)
Country	YES	YES
Year	YES	YES
Obs.	272	272
Adjusted R2	0.6539	0.6586
F	58.34	52.73
	[0.000]	[0.000]

Notes: The stated figures in the parentheses are standard errors. The asterisks (***, **, and *) are markers of 1%, 5%, and 10% significance levels, respectively.

Endogeneity Issue

This section examines the impact of monetary policy on national innovation in Asian countries, employing the FE-2SLS method. Given the significant variation in economic characteristics of Asian countries, the inclusion of country dummies in our regressions is necessary to control for individual country characteristics, using fixed effects as our primary analytical tool. To address potential endogeneity issues in Equations (1) to (3), this study regresses $\widehat{MP_{i,t}}$ and estimate it using a one-year lag $MP_{i,t}$ as an instrumental variable, as shown in Equation (4). The predicted value of $\widehat{MP_{i,t}}$ is then used in the second stage to reduce the estimation bias in Equations (5)–(7).

$$MP_{i,t} = \partial_0 + \partial_1 MP_{i,t-1} + \partial_2 \text{Macroeconomic}_{i,t} + \mu_i + \upsilon_t + \varepsilon_{i,t} \tag{4}$$

$$\text{Innovation}_{i,t} = \alpha_0 + \alpha_1 \widehat{MP_{i,t}} + \alpha_2 \text{Macroeconomic}_{i,t} + \mu_i + \upsilon_t + \varepsilon_{i,t} \tag{5}$$

$$\text{Credit}_{i,t} = \beta_0 + \beta_1 \widehat{MP_{i,t}} + \beta_2 \text{Macroeconomic}_{i,t} + \mu_i + \upsilon_t + \varphi_{i,t} \tag{6}$$

$$\text{Innovation}_{i,t} = \gamma_0 + \gamma_1 \widehat{MP_{i,t}} + \gamma_2 \text{Credit}_{i,t} + \gamma_3 \text{Macroeconomic}_{i,t} + \mu_i + \upsilon_t + \delta_{i,t} \tag{7}$$

Table 4. Endogeneity Test

	(Eq. 4)	(Eq. 5)	(Eq. 6)	(Eq. 7)
$MP_{i,t-1}$	0.5984*** (0.0383)			
$\widehat{MP_{i,t}}$		-0.3332*** (0.0725)	-0.0852* (0.0378)	-0.3109*** (0.0714)
$\text{Credit}_{,t}$				0.2616*** (0.0786)
R&D Control	YES	YES	YES	YES
Macroeconomic Control	YES	YES	YES	YES
c	2.9126*** (0.6958)	-1.8939*** (0.8447)	1.7564*** (0.6738)	-2.3535*** (0.8392)
Country	YES	YES	YES	YES
Year	YES	YES	YES	YES
Obs.	269	269	269	269
Adjusted R2	0.5807	0.6999	0.2541	0.7130
F	42.24 [0.000]	71.13 [0.0000]	10.39 [0.0000]	67.07 [0.0000]

Notes: The stated figures in the parentheses are standard errors. The asterisks (***, **, and *) are markers of 1%, 5%, and 10% significance levels, respectively.

This paper initially regresses Equation (4) and demonstrates a correlation between the monetary policy and its lags (see Column 1 of Table 4). The findings indicate that the coefficient of MP_i is statistically significant. Furthermore, this study applies the predicted value of $\widehat{MP_{i,t}}$ as an

instrument using the two-stage least squares (2SLS) method in equations (5) - (7). The findings indicate that the results remain consistent. The correlation between monetary policy and national innovation has been discovered. Furthermore, we provide a consistent mediation effect of bank lending in the relationship between monetary policy and national innovation. Nevertheless, we continue to endorse the prior research conducted by Evers et al. (2020), Meierrieks (2014), and Spatareanu et al. (2019), which provides further confirmation of the existence of Schumpete's (1949) finance-innovation nexus.

Heterogeneity Test

Although all monetary policy objectives are directed at achieving price stability and economic growth, this study suggests that monetary policy in each country has distinct impacts. It includes differences between high—and low-income countries. In this section, we analyse heterogeneity using dummy variables. This study assigns a score of 1 to upper-middle-income and high-income countries; otherwise, it assigns a score of 0. This research employs a fixed effects model to analyse the heterogeneity issue.

Table 5. The result of the Heterogeneity Test

	(Eq. 1)	(Eq. 2)	(Eq. 3)
$MP_{i,t} \times$ High Income	-0.1612***	-0.1457***	-0.1459***
	(0.0464)	(0.0430)	(0.0456)
$Credit_{,t}$			0.2677***
			(0.0779)
R&D Control	YES	YES	YES
Macroeconomic Control	YES	YES	YES
c	-2.8961***	-3.7977***	-3.2318***
	(0.7521)	(0.6975)	(0.7429)
Country	YES	YES	YES
Year	YES	YES	YES
Obs.	277	277	277
Adjusted R2	0.7043	0.6617	0.7176
F	75.04	61.61	70.87
	[0.000]	[0.000]	[0.000]

Notes: The stated figures in the parentheses are standard errors. The asterisks of ***, **, and * are markers of 1, 5, and 10 percent significance levels, respectively.

Table 5 presents the findings of the heterogeneity analysis. It indicates that the adverse effects of monetary policy on national innovation are more pronounced in upper-middle and high-income countries compared to their lower-middle and low-income counterparts. It can be witnessed from the coefficient $MP_{i,t} \times$ High Income (γ_1=-0.1459, s.d.=0.0456), which is negatively and significantly

correlated with the innovation variable. Furthermore, the indirect effect mediated by bank credit exhibits a similar trend, demonstrating greater intensity in upper-middle-income and high-income nations. The implementation of tighter monetary policy in these countries is likely to lead to a decrease in bank credit, prompting investors to curtail their innovation activities in response.

Discussion

Prior research has yielded valuable insights through empirical studies regarding the influence of monetary policy on price levels and the broader economy. Investigations into the role of monetary policy should encompass both short-term and long-term analyses to offer a comprehensive understanding of its effects. This study examines the impact of monetary policy on the long-term economy. The findings of our analysis contribute to the existing body of knowledge on the role of monetary policy in fostering innovation activities, as elaborated in the preceding four sections. The results of our analysis contribute to the view, as in previous research (Carvelli et al., 2024; Ma et al., 2023; Yang et al., 2024), that in conditions where other factors are held constant, tightening monetary policy can reduce innovation activity. Conversely, loosening monetary policy can provide relaxation that encourages the creation of many innovations. An increase in interest rates as a form of monetary policy tightening has significant long-term implications. Although the purpose of tight monetary policy is to stabilise prices and the economy, other impacts have emerged, including a reduction in innovation activities.

The results found that tightening monetary policy reduces bank loans and innovation activity. In line with these findings, Ma et al. (2023) explain that tightening monetary policy will reduce bank credit capacity, reducing financing for innovation activities. Innovation companies then respond to it by reducing their innovation activities and output. In contrast, the relaxation of monetary policy enhances the financial sector's ability to extend credit for innovative activities. Conversely, the implementation of a tighter monetary policy, exemplified by an increase in the policy interest rate, elevates the borrowing costs for banks, thereby diminishing their propensity to lend. Furthermore, higher interest rates may increase the risk of loan defaults, prompting banks to adopt a more conservative lending strategy. Financial institutions might enhance their lending criteria, necessitating increased collateral or more rigorous approval procedures, which could hinder companies from obtaining loans, particularly for high-risk or novel projects. Consequently, decreased bank lending can directly limit the financial resources accessible to companies for financing innovative endeavours.

The results suggest that the relationship between monetary policy, bank credit, and innovation is more pronounced in middle-income and high-income countries. In these contexts, a stringent monetary policy has a substantial impact on reducing bank credit activity. Consequently, countries that rely on external financing for innovation respond by curtailing their innovation activities and outputs. Middle and high-income countries generally possess stronger financial institutions and advanced capital markets, facilitating effective capital distribution, including loans for innovative companies. Conversely, nations with lower incomes often exhibit underdeveloped financial systems, less robust legal structures, and reduced economic literacy, which can impede the efficient implementation of monetary policy and credit availability for innovative businesses. It may result in a diminished connection among these economies' monetary policy, bank lending, and innovation.

Conclusion

This study concludes the results of the analysis into three parts. First, the results revealed a direct effect of monetary policy tightening that reduces national innovation. Second, an indirect effect also appears, where a tight monetary policy will reduce bank credit and national innovation activity. Furthermore, these research findings substantiate the significance of banking as a component of financial development in fostering national innovation growth, thereby providing additional evidence to support the relationship between finance and innovation. In the context of public policy, several recommendations can be formulated based on the analysis' results. First, it is essential to implement a complementary policy, which refers to a public policy framework that promotes competition, safeguards intellectual property rights, and streamlines regulations. Such measures can incentivise companies to innovate by fostering an environment of equitable competition and lowering barriers to market entry. Second, a countervailing policy is necessary; this may include government subsidies for research and development (R&D), tax incentives for innovative activities, or initiatives that support the development of human resources. These strategies can mitigate the adverse effects of restrictive monetary policies on innovation. Third, a balancing action is required, whereby public policy must strive to achieve equilibrium. It ensures that regulations do not obstruct innovation while simultaneously preventing market failures or the abuse of market power that could impede innovative efforts. The research is still limited in several ways. First, this research utilises the interest rate solely as a monetary policy tool, representing a tight monetary policy stance. In the future, further research can utilise other monetary policy measures that represent a loosening of monetary policy to produce a more robust analysis of the effects of tightening and loosening monetary policy on innovation activities. Second, the innovation measure used is a trademark that

shows output. There is a possibility that monetary policy affects the innovation process. Finally, further research can add variables that show the innovation process.

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