Innovation, Institutions, and Financial Structure*

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Abstract

This paper studies how innovation shapes the financial structure of the economy. Using a panel of 75 countries from 1982 to 2021, we find that innovation activity fosters a shift from bank-based to market-based financing, but this relationship is amplified by both a country's level of development and institutional quality. Several institutional indicators support this transition only at intermediate levels, with excessively high or low institutional quality sometimes dampening the effect of innovation. Furthermore, innovation's impact on financial structure is both immediate and persistent. However, the positive role of institutional quality, while significant in the early stages, gradually fades by around the tenth year. These findings highlight that innovation acts as a catalyst for a change in financial structure, with its effects shaped by the stage of development and institutional context.

Keywords: innovation; financial structure; institutional quality; stages of development

JEL Codes: G15, O31, E44

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1 Introduction

Over the past 30 years, a stronger growth of stock markets than banking development has been observed, especially in developed countries (Boyd and Smith, 1998; Beck and Levine, 2002; Bose, 2005; Demirgüç-Kunt et al., 2013). However, there is no consensus on the main underlying factors behind this phenomenon. In this paper, we examine the role of innovation in shaping the financial structure in both developed and developing countries. Our hypothesis builds on existing literature showing that technology-based industries (e.g., pharmaceuticals) are more dependent on external financing, especially for seeking equity financing, due to their limited access to traditional collateral (Rajan and Zingales, 1998; Brown et al., 2013). This is because the distinct risk-bearing roles of banks (risk-averse) and stock markets (risk-taking) result in heterogeneous financing preferences (Allen and Gale, 1999). Furthermore, this perspective is consistent with endogenous growth theory developed by Romer (1990) and Aghion and Howitt (1992), where innovation fosters growth and capital accumulation, and further leads to financial market evolution, by reducing monitoring and bankruptcy costs (Boyd and Smith, 1998; Bose, 2005).

Figure 1 provides a historical example how innovation can act as a catalyst for financial evolution. We can see that the UK stock prices remained relatively flat during the period of the British Industrial Revolution (1760–1840), despite landmark technological breakthroughs such as textile mechanization, steam power, iron and steel development, and railways. However, a substantial acceleration in stock prices is observed in the subsequent decades. This pattern suggests that while financial markets may not instantly respond to technological progress, the accumulation and diffusion of innovation can eventually reshape financing demands, prompting a structural transformation in financial systems. In this case, the industrial innovations likely generated increasing demand for large-scale, risk-tolerant capital, a need more effectively met by market-based financing. The delayed but steep rise in stock prices highlights how innovation can reshape capital demand structures over time, triggering a boom in market-based financing. This historical example suggests that the impact of innovation on financial systems depends not only on its occurrence, but also on the ability of financial institutions to recognize and respond to it.

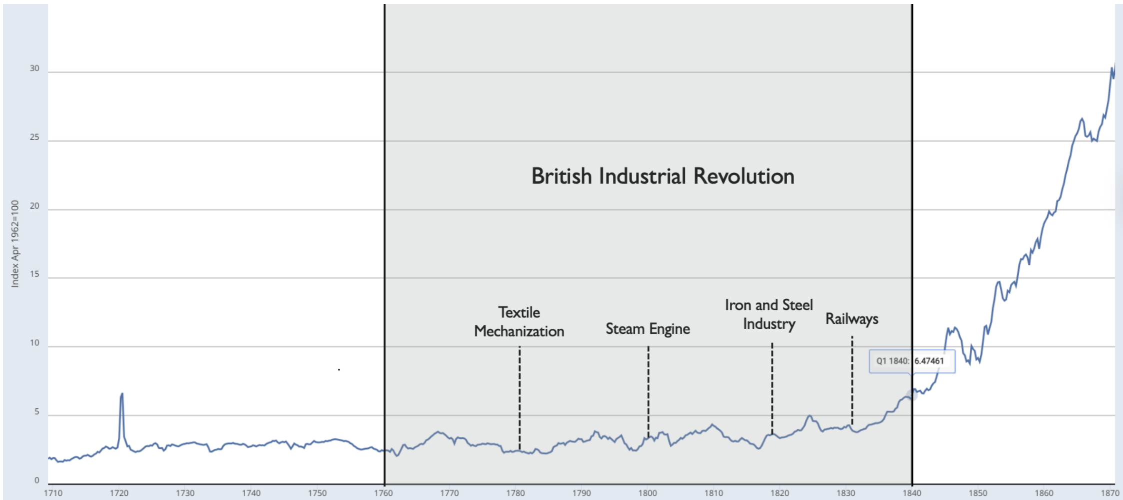

Figure 1: The UK stock price before and after British Industrial Revolution (1760-1840)

Conceptually, the patenting activity can be viewed as a supply-side innovation shock that reveals the potential demand for external financing, particularly from the stock market. Patents make innovation outputs observable and verifiable, reducing information asymmetry and enabling capital markets to reassess the value of firms. However, the extent to which the stock market responds to this shock depends critically on the institutional environment. In countries with weak investor protection, poor legal enforcement, or limited disclosure, markets may fail to process innovation signals effectively, despite rising innovative activity (La Porta et al., 2000; Brown et al., 2009). By contrast, strong institutions enhance the ability of investors to interpret innovation signals and ensure contract enforcement, resulting in a more responsive capital allocation and higher trading volumes (Levine, 1997). Institutional quality thus shapes the transmission of innovation into financial outcomes. This framework helps explain our finding that innovation exerts a greater impact on stock market development, relative to bank development, only in countries that combine high productivity with strong institutional quality. It is also consistent with the broader view that financial responses to innovation are governed not solely by technological fundamentals, but also by the institutional context under which capital is allocated (Aghion et al., 2005a).

More importantly, global trends in patenting activity and financial market evolution exhibit a broadly parallel evolution except for the period of the global financial crisis (GFC). Figure 2 plots the number of patent applications alongside the logarithm of the ratio of stock value traded to bank credit from 1980 to 2015. Notably, patenting activity tends to lead to increases in the ratio of stock value traded to bank credit. The divergence observed during the GFC highlights that even sustained innovation activity cannot translate into financial market expansion without well-functioning institutional and financial infrastructure, underscoring the role of institutional quality as a key transmission mechanism.

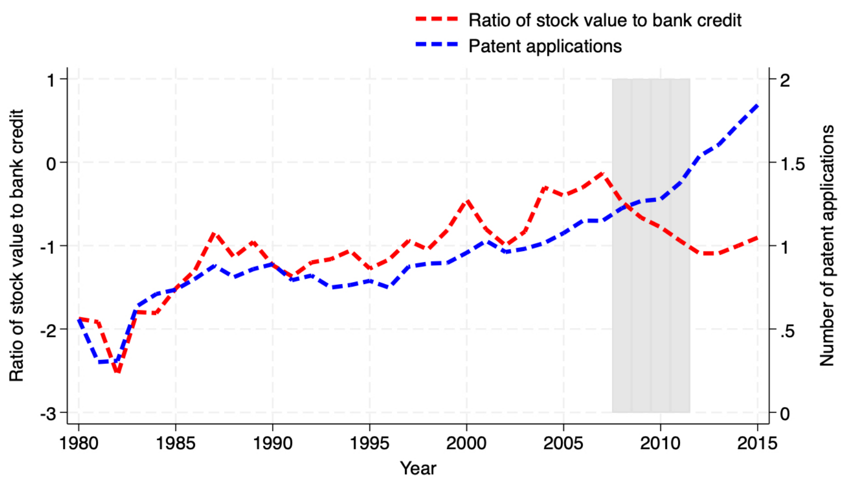

Figure 2: Patent applications and the ratio of stock value to bank credit

Note: This figure plots the sum of the number of patent applications globally against the average ratio of stock value traded to private credit globally from 1980 to 2015.

More relevant to our analysis in this paper, Figure 3 examines the relationship between the innovation at the country level between 1980 and 2020 (measured as the number of patent applications per country) and the logged ratio of stock markets to banks in that country over the sample period. We find a significant positive correlation between these two variables.

We start our empirical analysis by exploring the relationship between patent applications and financial structure using instrumental variable (IV) regressions estimated via two-stage least squares (2SLS). Our findings can be summarized as follows. First, in a given year, all three dimensions of financial structure—activity, size, and efficiency—are positively and significantly associated with the number of patent applications in a country. These results

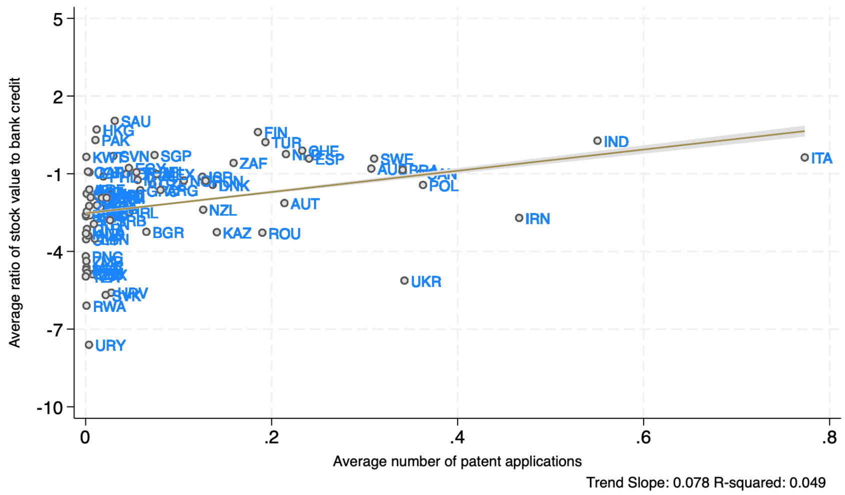

Figure 3: Correlation between patent applications and the ratio of stock value to bank credit

Note: This figure plots the average annual number of patent applications globally against the average logged ratio of stock value traded to private credit globally from 1980 to 2015 in 75 advanced and emerging economies.

remain robust when instrumenting innovation using an interacted IV constructed from the geographical distance to the regional innovation leader multiplied by the average regional innovation growth, as well as regional dummies. Second, we observe an amplification effect whereby countries closer to the global technological frontier experience stronger shifts toward market-based financial structures in response to innovation. Furthermore, our analysis highlights the critical role of institutional quality in moderating this relationship. We uncover nonlinear effects across institutional indicators such as regulatory quality, voice and accountability, rule of law, political stability, and control of corruption, showing that moderate levels of institutional quality generally enhance the impact of innovation, while excessively low or high levels can dampen it. Third, local projection estimates with IVs reveal that the financial effects of innovation are both immediate and persistent, typically intensifying around the fifth year after an innovation shock. Moreover, stronger institutional environments amplify innovation's influence in the initial years, but this effect diminishes over longer horizons. Fourth, we replace patent applications with several alternative innovation measures, including intellectual property receipts, scientific publications, and high-tech exports, and find consistent positive relationships with financial structure. Fifth, similar results hold when we estimate dynamic panel data models using two-step system generalized method of moments (GMM), confirming the robustness of our findings. Finally, additional robustness checks, such as replacing bank credit with private credit by all financial corporations and winsorizing the sample to mitigate the influence of outliers, yield consistent results, further reinforcing our conclusions.

A large body of literature examines the relationship between innovation and financial development, with most studies focusing on how financial systems support innovation. Theoretical work has emphasized the functional differences between banks and equity markets in financing innovation. Due to its intangible nature, high uncertainty, and long-term payoff structure, innovation is poorly suited to collateral-based bank lending. As highlighted by Allen and Gale (1999) and Holmström and Tirole (1993), stock markets, with their greater risk tolerance and ability to diversify, are better positioned to fund innovative activity. Endogenous growth models further support this view: for instance, Acemoglu and Zilibotti (1997) and Aghion et al. (2005b) argue that well-functioning financial systems enable economies to adopt and push the technological frontier. Empirically, Hsu et al. (2014) find that innovation in financially dependent, high-tech industries is significantly higher in countries with developed stock markets, whereas credit expansion may even discourage innovation. At the firm level, Brown et al. (2009, 2013) show that strong shareholder protections and active equity markets are associated with greater R&D intensity, while credit market development has limited influence. Historical evidence from Nanda and Nicholas (2014) indicates that financial distress, particularly in the banking sector, can reduce both the quantity and quality of innovation.

While these studies highlight the importance of market-based financial systems in fostering innovation, they largely frame innovation as a dependent variable—an outcome shaped by financial conditions. Our paper is closely related to this literature but takes a distinct perspective. We examine how innovation, particularly in the form of patenting activity, can act as a catalyst for financial market structural change. Rather than arguing that innovation facilitates financial systems from the ground up, we show that surges in innovation generate financing needs that banks are less equipped to meet. This largely encourages a country's financial system shift toward market-based financing structures. In doing so, our work complements studies on the evolution of financial structures (Boyd and Smith, 1998; Demirgüç-Kunt et al., 2013), by introducing innovation as a conditional trigger for structural transformation in financial intermediation.

To establish this relationship, we follow the empirical tradition of finance-growth studies while addressing key identification challenges. Specifically, we mitigate endogeneity concerns using an IV strategy based on an IV that captures regional innovation spillover and regional dummy variables, following the approach of Levine et al. (2000) and extending the idea of Liu et al. (2023). We further implement a two-step GMM procedure to account for potential reverse causality and omitted variables. Importantly, we go beyond the standard reliance on patent counts by incorporating a broader set of innovation proxies, including charges for the authorized use of intellectual property, counts of scientific and technical articles, and high-tech exports. This multi-dimensional approach allows us to capture not only the quantity but also the quality, scientific intensity, and commercial reach of innovation. By using these five alternative indicators, we ensure that our findings are not driven by any single proxy and offer more robust and generalizable evidence on the role of innovation in influencing financial structure.

In addition, our findings reveal that the effect of innovation on financial structure is conditional and varies across country characteristics. First, we identify an amplification effect, where the influence of innovation is magnified in countries with higher productivity. By interacting innovation with productivity, we find that economies closer to the global technology frontier are more likely to experience innovation-led shifts toward market-based finance, paralleling findings by Aghion et al. (2005b) on how absorptive capacity conditions the returns to innovation. This is also consistent with earlier research showing that financial markets in advanced economies are better positioned to respond to complex, high-risk capital demands, particularly under conditions of strong investor protection and legal enforcement (Levine, 1997; Porta et al., 1998). Second, using interaction models and nonlinear specifications for grouped institutional indicators, we document a complex relationship between institutional quality, innovation, and financial structure. An amplification effect of institutions is observed primarily for the activity dimension, where moderate levels of institutional quality strengthen the positive impact of innovation on shifting financial systems toward market-based channels. However, for size and efficiency, we find evidence of diminishing returns and potential crowding-out effects at very high institutional levels. In some cases, excessively strong institutional environments may introduce rigidity or excessive regulation that dampens the capacity of innovation to reshape financial structures. This nuanced pattern aligns with the story of institutions proposed by Acemoglu et al. (2006), which emphasizes that innovation can generate transformative effects only when embedded within supportive yet flexible institutional frameworks that balance enforcement with adaptability. These results suggest that innovation does not reshape financial systems in a uniform or monotonic way. Its effects are stronger in contexts characterized by higher productivity and proximity to the technological frontier and are realized most effectively when institutional quality provides sufficient support without imposing excessive constraints.

Finally, we extend the literature by examining the dynamic effects of innovation on financial structure. While most prior studies rely on static specifications, we employ the local projection method with an instrumental variable approach, following Jordà (2005), to trace how financial indicators respond to innovation over time. Our results show that innovation has an immediate and persistent effect, gradually shifting financial systems toward greater reliance on market-based finance relative to bank-based channels. Moreover, we find that institutional quality significantly conditions these dynamics. Stronger institutional environments amplify the initial impact of innovation on financial structure, though this positive influence diminishes over time and tends to fade by around the tenth year after the innovation shock. This dynamic perspective provides new insights into how innovation interacts with institutional contexts to drive long-term structural change in financial systems.

In sum, our study provides a new perspective on the innovation–finance nexus by shifting the focus from viewing financial structure solely as an enabler of innovation to recognizing innovation as a catalyst that actively reshapes financial structure. By employing methods that address endogeneity and capture dynamic effects, we not only identify systematic patterns in how innovation influences the shift from bank-based to market-based financial systems, but also uncover complex relationships showing that this influence depends critically on institutional quality. Our findings demonstrate that institutional indicators can either amplify or constrain the impact of innovation, with positive effects often strongest at moderate levels of institutional strength. These insights contribute to a deeper understanding of how innovation shapes financial structure in diverse contexts over time.

The rest of the paper is organized as follows. Section 2 introduces the data description. Section 3 presents the main results. Section 4 demonstrates the dynamic effects of innovation. Section 5 concludes.

2 Data

We examine the impact of innovation on financial structure using an unbalanced panel of 159 advanced and emerging market economies, with annual data from 1960 to 2021. After including necessary instrumental control variables, the estimated sample shrinks to 75 countries. We measure the innovation of each country by the number of patent applications and the financial structure in three dimensions: activity (ratio of stock value traded to the domestic credit to the private sector by banks), size (ratio of stock market capitalization to deposit money banks' assets), and efficiency (ratio of the stock market turnover ratio to the banking sector's net interest margin). We describe the data and their sources in Table 1.

Table 2 reports the summary statistics for the full sample and for advanced and emerging economies. The average number of patent applications per year is 2.31, with a high standard deviation of 9.83 and a maximum of 139.4. This indicates substantial cross-country heterogeneity, with innovation concentrated in a few technologically advanced nations. The distribution of patents is more stable in advanced economies (standard deviation of 8.29) compared to emerging markets (10.69), suggesting more uniform innovation activity in developed countries, while emerging economies experience extreme disparities. Notably, the maximum number of patents in emerging economies (139.4) far exceeds that in advanced countries (38.74), likely driven by rapidly industrializing nations such as China.

Notation	Description	Data Source
Dependent variables		
$y_{i,t}^{act}$	The ratio of stock value traded to the domestic credit to the private sector by banks.	World Bank Database Beck et al. (2009)
$y_{i,t}^{size}$	The ratio of stock market capitalization to deposit money banks' assets.	World Bank Database Beck et al. (1999)
$y_{i,t}^{eff}$	The ratio of the stock market turnover ratio to the banking sector's net interest margin.	World Bank Database Čihák et al. (2012)
Independent variables		
$x_{i,t}$	The number of patent applications filed through the Patent Cooperation Treaty or national offices.	World Bank Database
Instruments		
$z_{i,t}$	The interaction term between the logarithm of the geographical distance between country i and regional technological leader and average regional patent growth excluding country i.	GeoDist Database World Bank Database
$\mathbf{D}_{i,r}$	The set of regional dummies that equals 1 if the country belongs to region r, and 0 otherwise. Regions include Asia, Africa, and the Western Hemisphere.	Liu et al. (2023)
Control variables		
$Prod_{i,t}$	Total factor productivity level measured at current PPPs (USA=1).	Penn World Tables 10.01
$Finopen_{i,t}$	Index measuring capital account openness.	Chinn and Ito (2008)
$Tradopen_{i,t}$	Sum of exports and imports of goods and services measured as a share of GDP.	OECD National Accounts & World Bank Database
$Hci_{i,t}$	Years of schooling and returns to education.	Penn World Tables 10.01
$Goversize_{i,t}$	Government final consumption expenditure excluding capital formation in defense and security.	World Bank Database
$Inflat_{i,t}$	Inflation measured by annual percentage change in consumer price index (Laspeyres formula).	World Bank Database
$Gdpgrow_{i,t}$	Real GDP growth rate.	IMF World Economic Outlook Database
$Bankcri_{i,t}$	Dummy indicating banking crisis: 1 if crisis, 0 otherwise. Defined by significant financial distress and policy intervention.	Laeven and Valencia (2018)

Table 1: Definition and notation of variables

Beyond innovation, Table 2 reveals important patterns in financial structure. For financial structure (activity), the less negative mean in advanced economies suggests relatively stronger market-based financing compared to emerging markets, consistent with the notion that higher innovation activity aligns with deeper stock markets. For financial structure (size), both advanced and emerging countries exhibit similar mean values around -0.47, but emerging economies display slightly lower stock market-based levels. For financial structure (efficiency), advanced economies show a higher mean value (3.169) compared to emerging markets (1.737), indicating that stock markets in advanced countries tend to operate more efficiently relative to banks.

Together, these summary statistics underscore that while innovation activity is strongly linked to development levels, differences also emerge across activity, size, and efficiency dimensions of financial structure. Advanced economies not only innovate more but also maintain relatively more active, larger, and more efficient market-based financial systems, whereas emerging markets remain more bank-centric.

Variable	N	Mean	S.D.	Min	Max
Full sample					
Patents	1366	2.312	9.826	0.000	139.4
Financial structure (activity)	1366	-1.664	1.729	-10.58	2.488
Financial structure (size)	1184	-0.475	0.842	-7.455	2.115
Financial structure (efficiency)	821	2.330	1.666	-3.413	6.078
Financial Open	1366	0.824	1.470	-1.927	2.311
GDP growth	1366	1.209	0.790	-2.303	2.674
Trade open	1366	4.198	0.623	2.667	6.093
Inflation	1366	0.070	0.181	-0.041	3.080
Government spend	1366	2.690	0.342	1.482	3.378
Human capital	1366	2.796	0.571	1.408	4.352
Sub sample					
Advanced countries					
Patents	567	3.610	8.291	0.000	38.74
Financial structure (activity)	567	-1.383	1.749	-8.500	2.488
Financial structure (size)	535	-0.470	0.707	-2.621	1.148
Financial structure (efficiency)	340	3.169	1.575	-2.867	6.078
Emerging countries					
Patents	799	1.390	10.69	0.000	139.4
Financial structure (activity)	799	-1.864	1.688	-10.58	2.401
Financial structure (size)	649	-0.478	0.940	-7.455	2.115
Financial structure (efficiency)	481	1.737	1.463	-3.413	5.152

Note: Summary statistics of the data sample for the baseline regressions.

Table 2: Summary Statistics

3 The panel instrumental variable approach

This section presents our main empirical results. We employ an instrumental variable (IV) approach to address several sources of endogeneity inherent in the relationship between innovation and financial structure. These potential endogeneity concerns include reverse causality, omitted variable bias, and measurement error.

Reverse causality arises because while we hypothesize that increased innovation activity, proxied by patent applications, fosters a shift from bank-based to market-based financing, it is also plausible that deeper financial markets may themselves promote innovation by easing access to equity capital and reducing financing constraints. Additionally, omitted variable bias is a concern due to unobserved factors such as institutional reforms, variations in legal enforcement, or broader economic liberalization, all of which may simultaneously influence innovation and financial development. Finally, measurement error in innovation metrics, such as patent applications, can occur because of country-level differences in reporting standards, incentives to patent, or informal innovation not captured by official data.

To address these concerns, we construct a robust instrument based on regional innovation spillovers. Specifically, we utilize an interaction term as our IV, constructed as follows. Let S_{r_k} denote the set of all countries in region r_k. We separate the entire world into four regions, thus k is Asia, Europe, the Western Hemisphere, or Africa. We first identify the regional innovation leader l_k in each region r_k as the country with the highest absolute number of patent applications in a chosen base year t_{1960}, formally defined as:

$$l_k = \arg\max_{j \in S_{r_k}} \text{pat}_{j,t_{1960}} \tag{1}$$

The regional leaders calculated from Eq. (1) are Japan (Asia), Germany (Europe), the United States (Western Hemisphere), and South Africa (Africa). For each country i in region r_k, we compute the average patent growth rate among all other countries in the same region except i. Formally, the average regional patent growth rate excluding country i is defined as:

$$g_{r_k,t}^{-i} = \frac{1}{|S_{r_k}|-1} \sum_{j \in S_{r_k}, j \neq i} \Delta \text{pat}_{j,t} \tag{2}$$

We then define d_{i,l_k} as the logarithm of the geographical distance between country i and the regional leader l_k. Finally, the instrument for country i in year t is constructed as:

$$z_{i,t} = d_{i,l_k} \times g_{r_k,t}^{-i} \tag{3}$$

This IV captures regional knowledge spillovers, influencing domestic innovation activities while remaining plausibly exogenous to local financial market structures. The instrument exploits exogenous variations arising from geographically localized innovation spillovers, which are less likely to directly affect domestic financial structures.

In addition to the above interaction-based IV, we incorporate regional dummy variables indicating countries from Asia (ASIA), Africa (AFRICA), and the Western Hemisphere (WESTHEM). Including these regional dummies as additional instruments is important because they capture broader regional technological spillover effects documented extensively in the innovation literature. Prior studies such as Jaffe et al. (1993) and Audretsch and Feldman (1996) highlight that innovation diffusion is frequently region-specific due to geographic proximity and trade linkages. Additional support from Keller (2002), Moretti (2004), and Bloom et al. (2013) underscores that regional characteristics significantly influence technological spillovers, strengthening the justification for including regional dummy variables as instruments.

By combining our constructed interaction IV with regional dummy instruments, our empirical strategy isolates exogenous variation in innovation, mitigating the risks associated with reverse causality, omitted variables, and measurement errors. Moreover, introducing these regional dummy variables provides further robustness against measurement errors potentially introduced by relying solely on lagged patents, especially in cases where regional innovation persistence occurs.

We employ a two-stage least squares (2SLS) estimator to estimate the causal impact of innovation on financial structure evolution. In the first stage, we regress current innovation activity (patent applications) on our constructed IV, regional dummies, control variables, and time-fixed effects, excluding country-fixed effects due to their collinearity with regional dummies. The fitted values obtained represent the exogenous variation in innovation activity. In the second stage, we regress our measures of financial structure on these fitted innovation values. This panel IV regression provides a structural interpretation, identifying the causal relationship between innovation and shifts in financial market structure.

The weak-instrument diagnostics reported later confirm the validity and strength of our IV strategy. Furthermore, the coefficient estimates on innovation remain stable and statistically significant across specifications. This consistency suggests our IV approach effectively captures the intended exogenous variation, enhancing confidence in the causal inference drawn from our empirical analysis.

We consider an empirical specification to examine how innovation shapes a country's financial structure, shifting the balance from bank-based to market-based financing channels. Our baseline second-stage specification is given by:

$$y_{i,t} = \eta \, x_{i,t} + \gamma \mathbf{W}_{i,t} + \mu_t + \epsilon_{i,t} \tag{4}$$

where $y_{i,t}$ denotes one of three measures of financial structure for country i in year t. Specifically, we analyze activity, defined as the ratio of stock value traded to private credit by banks; size, defined as the ratio of stock market capitalization to deposit money banks' assets; and efficiency, defined as the ratio of the stock market turnover ratio to the banking sector's net interest margin. $x_{i,t}$ denote numbers of patent applications for country i in year t. We introduce a battery of conditioning variables denoted by $X_{i,t}$ to control for other characteristics that may influence financial market structure. We include the years of schooling and returns to education, the banking crisis dummy, the Chinn and Ito (2008) measure of financial openness, the general government consumption, the annual change of CPI, the real GDP growth rate, and the sum of exports and imports of goods and services. Since the number of patents is likely to influence the domestic financial market conditions, we also control for time μ_t. $\epsilon_{i,t}$ represents the regression residual, with standard errors clustered by year. The first stage regression equation becomes as following format:

$$x_{i,t} = \lambda\, z_{i,t} + \sum_r \phi_r \mathbf{D}_{r,i} + \gamma \mathbf{W}_{i,t} + \theta_t + \varepsilon_{i,t} \tag{5}$$

where r indexes the set of regional dummies (e.g., Asia, Africa, Western Hemisphere), ϕ_r represents the coefficient for each region, $\mathbf{D}_{r,i}$ is a dummy variable that equals 1 if country i belongs to region r, and 0 otherwise.

Table 3 reports the results from our baseline IV estimations. The first-stage regressions confirm the strength of our instruments, as indicated by significant negative coefficients on the constructed instrument across specifications and first-stage F-statistics generally above conventional thresholds for instrument relevance.

In the second stage, the estimated coefficients on patent applications are positive and statistically significant across all three dimensions of financial structure: Activity, size, and efficiency. Specifically, the results in Columns (1) and (2) indicate that higher patent activity is associated with an increase in market-based financing relative to bank credit, as measured by the ratio of stock value traded to private bank credit. The magnitude of the coefficients ranges from approximately 0.11 to 0.18 and remains significant at the 5% or 1% levels.

Considering financial structure from the perspective of size, shown in Columns (3) and (4), patent applications positively correlate with the ratio of stock market capitalization to deposit money banks' assets. Coefficients are around 0.15 to 0.36 and significant for both with and without control groups. Furthermore, financial structure regarding the efficiency, captured in Columns (5) and (6), displays the strongest relationship. Higher innovation activity is associated with substantial increases in the ratio of stock market turnover to bank net interest margins, with coefficients between 0.57 and 0.70, both significant at the 1% level.

Collectively, these results indicate that innovation contributes meaningfully to the shift in financial structure towards a more market-based system. The consistent significance and positive signs of the estimated coefficients across multiple financial dimensions reinforce the hypothesis that innovation, proxied by patent activity, plays a crucial role in deepening and transforming financial markets beyond traditional bank-based intermediation. Moreover, our CLR, AR, and Wald statistics continue to reject the null hypothesis of weak instruments at 5% significance level.

	Activity		Size		Efficiency	
	(1)	(2)	(3)	(4)	(5)	(6)
2nd Stage						
Patents	0.113**	0.177***	0.148**	0.365***	0.571***	0.698***
	(0.054)	(0.061)	(0.069)	(0.092)	(0.114)	(0.166)
1st Stage						
IV	-1.313***	-0.956**	-0.257***	-0.146**	-0.427***	-0.208*
	(0.250)	(0.381)	(0.087)	(0.065)	(0.134)	(0.113)
Weak IV Test						
CLR	0.000	0.000	0.000	0.000	0.001	0.000
AR	0.000	0.000	0.000	0.000	0.001	0.000
Wald	0.038	0.003	0.033	0.000	0.000	0.000
1st F-statistic	10.392	4.957	14.692	34.711	8.066	9.192
Period	1982-2021	1982-2021	1982-2021	1982-2021	1991-2021	1991-2020
Time FE	YES	YES	YES	YES	YES	YES
Controls	YES	NO	YES	NO	YES	NO
Obs.	1,125	1,499	1,114	1,479	693	959
R-squared	0.039	0.063	0.178	0.527	0.004	0.096

The dependent variable is one of three measures for financial structure. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Numbers in parentheses are standard errors clustered by year. AR and Wald tests follow the procedures in Olea and Pflueger (2013). Multiple IVs yield extra CLR statistics; see Pflueger and Wang (2015) for discussions of weak instrument tests in linear IV regressions and Finlay et al. (2014) for Stata implementations. P-values are reported for CLR, AR, and Wald tests.

Table 3: Effect of innovation on financial structure: Full sample

3.1 Levels of development

Following the work of Acemoglu et al. (2006), we construct an indicator called proximity to frontier (PTF) to show the distance of a country to the world technological frontier, which makes us to identify whether the effect of innovation varies based on a country's levels of development. To measure a country's technological distance relative to the global technological frontier, we use the data defined as the value of country's total factor productivity to the highest observed productivity in the dataset in any given year. Specifically, we define PTF as follows:

$$\text{PTF}_{i,t} = \frac{Prod_{i,t}}{\max_{j \in \mathcal{C}} Prod_{j,t}} \tag{6}$$

where $\text{PTF}_{i,t}$ represents the proximity to the world technological frontier for country i in year t. $Prod_{i,t}$ is the productivity of country i in year time t, the data obtained from the world bank database. $\mathcal{C}$ denotes the set of all countries in the dataset. The PTF indicator takes values in the range $(0, 100]$ since it multiply by 100, where a value of 100 indicates that the country is on the world technological frontier, while lower values indicate that the country is further away from the technological frontier. This measure allows us to quantify how closely a country follows the frontier economy over time.

We consider a regression with an interacting PTF indicator with IV application, the second-stage equation is as follows:

$$y_{i,t} = \omega_1 x_{i,t} + \omega_2 \text{PTF}_{i,t} + \omega_3 x_{i,t} \times \text{PTF}_{i,t} + \gamma \mathbf{W}_{i,t} + \mu_t + \epsilon_{i,t} \tag{7}$$

The results we see in Table 4 indicate that innovation positively influences all three dimensions of financial structure: activity, size, and efficiency, even after accounting for differences in PTF. In particular, the interaction term between patent applications and PTF is positive and statistically significant across all specifications. For the dimension of activity (column 1), the coefficient in the interaction term is 0.099 and is highly significant at the level 1%, suggesting that the effect of innovation on shifting financing to market-based channels strengthens as countries approach the technological frontier.

Regarding the size dimension of financial structure (Column 2), the estimated coefficient on the interaction term is smaller, at 0.015, but remains significant at the 10% level. This result implies that while innovation contributes to the expansion of market-based financing relative to banking sector size, the effect is more modest in magnitude compared to the activity dimension. The efficiency dimension (Column 3) shows the largest amplification effect, with an interaction coefficient of 0.124, significant at the 1% level. This finding indicates that in economies closer to the technological frontier, innovation substantially enhances the efficiency of stock markets relative to the performance of the banking sector.

In general, these results confirm an amplification effect of innovation that becomes stronger as countries advance toward the global technological frontier. This pattern suggests that innovation not only promotes the shift from bank-based to market-based financing, but also increasingly reshapes the financial structure itself in more developed economies

	Activity	Size	Efficiency
	(1)	(2)	(3)
2nd Stage			
Patents*PTF	0.099*** (0.008)	0.015* (0.009)	0.124*** (0.034)
Weak IV Test			
CLR	0.000	0.000	0.003
AR	0.000	0.000	0.003
Wald	0.000	0.000	0.000
Period	1982-2021	1982-2021	1991-2021
Time FE	YES	YES	YES
Controls	YES	YES	YES
Obs.	1,072	1,044	656
R-squared	0.143	0.158	0.233

The dependent variable is one of three measures for financial structure. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Numbers in parentheses are standard errors clustered by year. AR and Wald tests follow the procedures in Olea and Pflueger (2013). Multiple IVs yield extra CLR statistics; see Pflueger and Wang (2015) for discussions of weak instrument tests in linear IV regressions and Finlay et al. (2014) for Stata implementations. P-values are reported for CLR, AR, and Wald tests. F-statistics may have questionable accuracy in regressions with more than one endogenous regressor; thus, we rely on weak IV test results for our interaction regressions.

Table 4: Effect of innovation on financial structure: Levels of development

3.2 Institutional quality channel

The preceding analysis shows that the effect of innovation on financial structure intensifies as countries move closer to the global technological frontier, reflecting differences in technological capacity and absorptive potential across economies. However, proximity to the frontier alone may not be fully helpful to understand how innovation shapes financial systems. Even countries with similar levels of innovation capability can exhibit different outcomes if institutional environments diverge.

Institutions influence how effectively innovations are translated into economic activity and whether financial systems can adapt to support market-based financing. Strong institutions promote legal certainty, regulatory quality, and transparency, all of which are crucial for fostering investor confidence and enabling financial markets to follow innovative activities.

Therefore, in this section, we extend our empirical framework to examine whether institutional quality moderates the impact of innovation on financial structure. We analyze five key institutional dimensions: Voice and accountability, political stability, regulatory quality, the rule of law, and control of corruption. Our second-stage empirical specification remains consistent with the approach used in the levels of development analysis:

$$y_{i,t} = \sigma_1 x_{i,t} + \sigma_2 q_{i,t} + \sigma_3 x_{i,t} \times q_{i,t} + \gamma \mathbf{W}_{i,t} + \mu_t + \epsilon_{i,t} \tag{8}$$

where $q_{i,t}$ represents the one of institutional quality indicators. Specifically, they are voice and accountability, political stability, regulatory quality, the rule of law, or control of corruption.

Table 5 reports the results from the instrumental variable regressions examining how institutional quality moderates the effect of innovation on financial structure. The analysis focuses on three institutional dimensions—regulatory quality, voice and accountability, and control of corruption—using interaction terms between patent applications and each institutional indicator. The dependent variables reflect two dimensions of financial structure: activity and efficiency.

For the activity dimension (Columns 1 to 3), all three institutional indicators exhibit significant positive coefficients on their interaction terms. Specifically, the interaction between patents and regulatory quality yields a coefficient of 1.230, indicating that stronger regulatory frameworks amplify the effect of innovation in shifting financing toward market-based channels. Similarly, voice and accountability show a positive and significant interaction coefficient of 0.393, suggesting that countries with greater political freedoms and civic participation experience a stronger link between innovation and market-based financial activity. Control of corruption demonstrates the largest effect, with a coefficient of 1.731, significant at the 1% level, highlighting that low corruption environments significantly enhance the influence of innovation on stock market activity relative to bank credit.

For the efficiency dimension (columns 4 to 6), results are likewise positive and statistically significant, though somewhat smaller in magnitude. The regulatory quality's interaction term is 0.901 and significant at the 5% level, suggesting that robust regulatory environments not only promote financial structure in terms of activity but also improve the efficiency of market-based relative to banking sector performance. Voice and accountability remain significant at the 1% level, with a coefficient of 0.321, reinforcing that democratic institutions facilitate the translation of innovation into more efficient market-based financial systems. Finally, control of corruption shows a significant coefficient of 0.752, indicating that reducing corruption helps ensure that innovation translates into more efficient stock market-based operations. The weak-instrument tests (CLR, AR, and Wald) uniformly produce low p-values across all specifications, supporting the strength of the instruments used.

The other two institutional indicators examined are the rule of law and political stability. Our results indicate that a significant linear relationship is detected only when analyzing the activity dimension of financial structure. As shown in Table 6, both institutional measures exhibit positive and statistically significant interaction effects with innovation. Specifically, the interaction term between patents and the rule of law yields a coefficient of 0.903, significant at the 1% level, suggesting that stronger legal environments enhance the ability of innovation to shift financial resources toward market-based channels. Similarly, political stability shows an even larger interaction effect, with a coefficient of 1.416, also significant at

	Activity			Efficiency		
	(1)	(2)	(3)	(4)	(5)	(6)
2nd Stage						
Patents*Regulation	1.230***			0.901**		
	(0.131)			(0.357)		
Patents*Voice		0.393***			0.321***	
		(0.030)			(0.108)	
Patents*Corruption			1.731***			0.752**
			(0.233)			(0.304)
Weak IV Test						
CLR	0.004	0.004	0.004	0.007	0.006	0.008
AR	0.003	0.003	0.003	0.006	0.005	0.007
Wald	0.000	0.000	0.000	0.000	0.000	0.000
Period	1998-2021	1998-2021	1998-2021	1998-2021	1998-2021	1998-2021
Time FE	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES
Obs.	805	808	808	645	649	1,276
R-squared	0.136	0.212	0.186	0.152	0.216	0.159

The dependent variable is one of two measures (activity and efficiency) for financial structure. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Numbers in parentheses are standard errors clustered by year. AR and Wald tests follow the procedures in Olea and Pflueger (2013). Multiple IVs yield extra CLR statistics; see Pflueger and Wang (2015) for discussions of weak instrument tests in linear IV regressions and Finlay et al. (2014) for Stata implementations. P-values are reported for CLR, AR, and Wald tests. F-statistics may have questionable accuracy in regressions with more than one endogenous regressor; thus, we rely on weak IV test results for our interaction regressions.

Table 5: Regulation quality, voice accountability, and corruption controls

the 1% level, indicating that stable political conditions amplify the impact of innovation on the stock market relative to bank activity. However, we do not observe significant results for these institutional variables when analyzing other dimensions of financial structure, such as efficiency or size, under the same linear interaction framework. This pattern suggests that the relationship between innovation and financial structure may not be uniform across the entire distribution of institutional quality. In other words, the influence of institutions could vary depending on whether countries exhibit relatively low or high levels of institutional development.

To capture potential nonlinearities and heterogeneous effects, we extend our empirical ap-

	Activity	
	(1)	(2)
2nd Stage		
Patents*Law	0.903*** (0.103)	
Patents*Politics		1.416*** (0.198)
Weak IV Test		
Wald	0.005	0.003
AR	0.004	0.003
CLR	0.000	0.000
Period	1998-2021	1998-2021
Time FE	YES	YES
Controls	YES	YES
Obs.	808	808
R-squared	0.155	0.174

The dependent variable is stock value traded divided by private credit by banks. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Numbers in parentheses are White's heteroskedasticity-robust standard errors. AR and Wald tests follow the procedures in Olea and Pflueger (2013). Multiple IVs yield extra CLR statistics; see Pflueger and Wang (2015) for discussions of weak instrument tests in linear IV regressions and Finlay et al. (2014) for Stata implementations. P-values are reported for CLR, AR, and Wald tests. F-statistics may have questionable accuracy in regressions with more than one endogenous regressor; thus, we rely on weak IV test results for our interaction regressions.

Table 6: Rule of law and political stability

proach by estimating a model that interacts innovation with institution-related indicators defined over discrete intervals of institutional quality. Specifically, we divide the institutional indicators into four groups based on their sample quantiles and investigate whether the effect of innovation differs across these segments. The regression specification takes the following form:

$$y_{it} = \sum_{q=1}^{4} \beta_q \cdot (x_{it} \cdot \mathbb{I}(q_{it} \in G_q)) + \gamma \mathbf{W}_{it} + \delta_t + \varepsilon_{it} \tag{9}$$

where q_{it} indicates the value of the institutional indicator for country i in year t. The expression $\mathbb{I}(q_{it} \in G_q)$ is an indicator function equal to one if q_{it} falls into institutional group G_q, and zero otherwise. Here, G_q denotes the set of countries whose institutional indicator values lie within the q-th quantile interval of the full sample distribution. Specifically, the groups are defined as follows: the first group includes observations below the 25th percentile; the second group covers the 25th to 50th percentiles; the third group spans the 50th to 75th percentiles; and the fourth group includes the top 25th percentile, from the 75th to 100th percentiles. The coefficients β_q, therefore, capture the differential effect of innovation on financial structure within each institutional segment. By adopting this nonlinear framework, we aim to identify whether innovation's influence on financial structure intensifies, diminishes, or changes direction at different levels of institutional quality, offering a more nuanced understanding of the institutional channels through which innovation reshapes financial systems.

Figure 4 illustrates the heterogeneous effects of innovation on the size dimension of financial structure across four institutional quality groups for regulation quality, voice and accountability, and control of corruption. For regulation quality (left panel), the effect of innovation is only positive and significant in the mid-high group, indicating that modest improvements in regulatory quality enable innovation to contribute positively to financial structure in size. However, in the highest quartile of regulation quality, the effect turns negative again and significant, suggesting diminishing returns or possibly crowding-out effects when regulatory environments are already strong.

For voice and accountability (middle panel), innovation shows a pronounced positive effect only in the mid-low group, where the coefficient is both large and statistically significant. This indicates that moderate levels of political rights and civil liberties significantly enhance innovation's role in expanding market-based financial size. Interestingly, the effect in the highest quartile turns negative and significant.

For control of corruption (right panel), the effect of innovation remains modestly positive and statistically significant across the middle groups. However, in both the highly corrupt and clean groups, the impact of innovation becomes negative, suggesting that in highly corrupt or clean institutional environments, additional innovation may not further promote the economy's transformation to a stock market-based financial structure.

The above findings suggest that moderate institutional strength, especially in terms of regulation, voice, accountability, and corruption controls, provides an optimal environment for innovation to promote a shift toward a market-based financial structure, whereas very weak or very strong institutional contexts may limit or even reverse this influence.

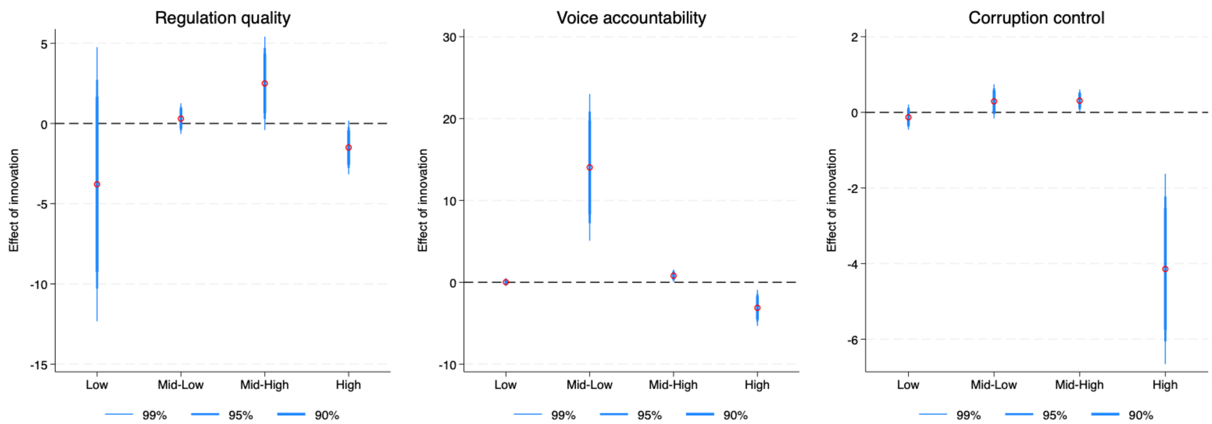

Figure 4: Regulation, accountability, and corruption control for financial structure (size)

Note: The dependent variable is the logged ratio of stock market capitalization to deposit money banks' assets. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. The gray shadow band represents the 95% confidence interval calculated based on the clustered standard error by year. The horizontal axis represents the estimated coefficient for the variable of interest.

Figures 5 and 6 reveal several interesting similarities and differences in how the rule of law and political stability moderate the effect of innovation on both the size and efficiency dimensions of financial structure. A common pattern emerges for the rule of law across both financial dimensions: innovation exerts its strongest positive effects in the mid-high institutional group. For size, the mid-high group displays the highest positive coefficient, while the effect turns negative in the highest quartile. Similarly, for efficiency, the mid-high group again records the largest positive effect, suggesting that moderately strong legal institutions provide the most supportive environment for innovation to influence financial structure. This indicates potential diminishing returns or institutional rigidity at very high levels of the rule of law, where additional improvements may no longer amplify financial market development and might even constrain stock market development.

Political stability, however, presents a more nuanced and somewhat counterintuitive finding. For size, innovation has small positive effects in the lower and middle groups, but becomes sharply negative and highly volatile in the highest quartile, suggesting that extremely stable political environments might not translate into greater market-based financial size and may even coincide with excessive conservatism or risk aversion that dampens market expansion. Conversely, for efficiency, political stability shows a surprising spike in the highest quartile, where the effect of innovation becomes both large and significantly positive. This contrast suggests that while highly stable political systems may restrain financial market growth in size, they could simultaneously foster more efficient allocation and functioning within existing financial markets, possibly by reducing uncertainty and improving governance quality.

Overall, these findings emphasize that institutions are crucial in determining whether innovation fosters a shift toward market-based financial systems, with moderate institutional quality generally yielding the strongest and most consistent benefits, while very high institutional strength can produce countervailing effects depending on the dimension of financial structure examined.

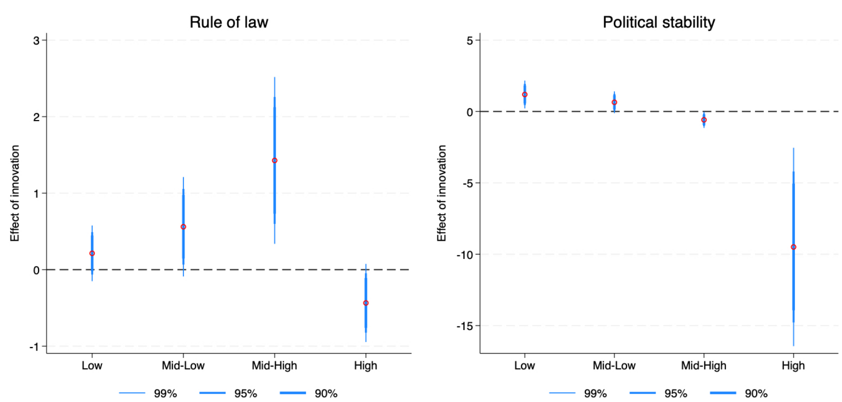

Figure 5: Law and political stability for financial structure (size)

Note: The dependent variable is the logged ratio of stock market capitalization to deposit money banks' assets. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. The gray shadow band represents the 95% confidence interval calculated based on the clustered standard error by year. The horizontal axis represents the estimated coefficient for the variable of interest.

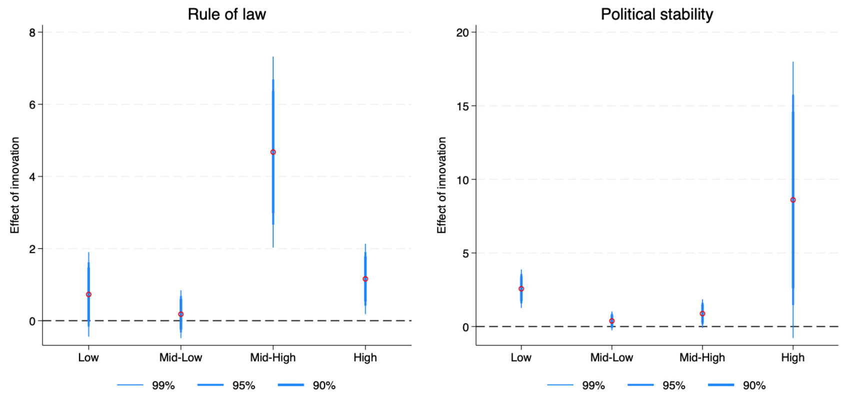

Figure 6: Law and political stability for financial structure (efficiency)

Note: The dependent variable is the logged ratio of stock market turnover to bank net interest margin. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. The gray shadow band represents the 95% confidence interval calculated based on the clustered standard error by year. The horizontal axis represents the estimated coefficient for the variable of interest.

3.3 Robustness

3.3.1 Alternative innovation proxies

To avoid relying solely on patent applications as the measure of innovation, we further incorporate a broader set of innovation proxies at the national level in Table 7. Specifically, we employ four alternative indicators: (1) total charges (in billion USD) for the authorized use of intellectual property (IP) rights, including patents, trademarks, copyrights, trade secrets, and industrial processes; (2) high-technology exports (in billion USD), encompassing products with high R&D intensity, such as aerospace, computers, pharmaceuticals, and scientific instruments; (3) the number of scientific and technical publications indexed in SCI and SSCI journals, calculated using fractional author attribution across countries; and (4) an extended measure of patent applications that includes both resident and non-resident filings. Across all these alternative measures, our findings remain robust and consistent with the baseline results using the same identification strategy, which reinforces the role of innovation in shaping financial structure.

Table 7 shows that alternative innovation measures—IP receipts, high-tech exports, and scientific papers—consistently exhibit positive and significant effects on financial structure, though magnitudes vary. IP receipts and scientific papers display strong impacts across activity, size, and efficiency, reinforcing patents' robustness as an innovation proxy. High-tech exports yield smaller, yet significant effects, suggesting weaker direct links to financial structure shifts. Overall, comprehensive innovation indicators capture that innovation robustly promotes the transition toward market-based financial structures.

	IP Receive			High-tech Exports			Scientific Papers			Total Patents		
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)	(4a)	(4b)	(4c)
2nd Stage												
Activity	0.946***			0.008***			0.736***			0.101**		
	(0.110)			(0.003)			(0.073)			(0.039)		
Size		0.214***			0.005***			0.101*			0.208***	
		(0.050)			(0.002)			(0.055)			(0.037)	
Efficiency			0.874***			0.019***			1.240***			0.276***
			(0.071)			(0.004)			(0.058)			(0.047)
Weak IV Test												
CLR	0.000	0.000	0.001	0.046	0.046	0.039	0.000	0.000	0.001	0.000	0.000	0.001
AR	0.000	0.000	0.001	0.042	0.041	0.037	0.000	0.000	0.001	0.000	0.000	0.001
Wald	0.000	0.000	0.001	0.006	0.069	0.000	0.000	0.066	0.000	0.010	0.000	0.000
Observations	843	847	576	429	406	384	890	854	668	1,125	1,114	693
Time period	1982-2021	1982-2021	1997-2020	2008-2021	2008-2021	2008-2021	1997-2021	1997-2021	1997-2021	1982-2021	1982-2021	1991-2021
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.471	0.338	0.141	0.214	0.221	0.286	0.446	0.236	0.449	0.056	0.058	0.227

The dependent variable is one of three measures for financial structure. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Columns (1a) to (1c) show receipts for intellectual property rights in billion USD. Column (2a) to (2c) reports high-tech exports in billion USD. Column (3a) to (3c) reports counts of scientific and technical articles. Columns (4a) to (4c) show total patent applications for both residents and non-residents. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses. AR and Wald tests follow Olea and Pflueger (2013). See Pflueger and Wang (2015) for discussions of weak instrument tests and Finlay et al. (2014) for Stata implementations. *P*-values are reported for CLR, AR, and Wald tests of weak instruments.

Table 7: Alternative measures of innovation

3.3.2 Alternative financial structure measures

To test the robustness of our findings, we employ alternative measures for the three dimensions of financial structure. For activity, we replace private credit by deposit money banks as a share of GDP with total private credit extended by both deposit money banks and other financial institutions relative to GDP. For size, we redefine the measure as the combined assets of deposit money banks and other financial institutions relative to GDP, rather than considering deposit money banks alone. For efficiency, we use banks' overhead costs as a share of total assets, providing an alternative perspective to bank net interest margins as a proxy for operational efficiency.

Table 8 presents the results using these alternative financial structure indicators. The second-stage estimates show that innovation, proxied by patent applications, remains positively and significantly associated with all three dimensions. Specifically, the coefficient for patents is significant and positive for activity (0.125, significant at the 5% level), for size (0.643, significant at the 5% level), and for efficiency (0.618, significant at the 1% level). These results suggest that higher innovation activity continues to promote a shift toward market-based financial structures, even under alternative definitions of financial system components. The first-stage coefficients for the instrumental variable remain significant for activity and efficiency dimensions, indicating relevance and strength of the instruments, though the estimate is not significant for size in this specification. Weak-instrument tests (CLR, AR, and Wald) yield p-values close to zero in most cases, supporting the validity of the instruments employed.

Overall, the findings confirm that the positive impact of innovation on financial structure is robust to alternative financial structure definitions, reinforcing the conclusion that innovation contributes to transforming financial systems from bank-based to a more market-based system across multiple dimensions of financial activity, size, and efficiency.

	Activity	Size	Efficiency
	(1)	(2)	(3)
2nd Stage			
Patents	0.125** (0.060)	0.643** (0.249)	0.618*** (0.124)
1st Stage			
IV	-1.489*** (0.285)	-0.036 (0.035)	-0.433*** (0.135)
Weak IV Test			
CLR	0.000	0.000	0.001
AR	0.000	0.000	0.001
Wald	0.038	0.009	0.000
Period	1982-2021	1982-2021	1991-2021
Time FE	YES	YES	YES
Controls	YES	YES	YES
Obs.	957	318	698
R-squared	0.009	0.271	0.215

The dependent variable is one of three alternative measures for financial structure. The endogenous variable is the number of patent applications instrumented with the interacted IV and regional dummies. Control variables are in Table 1. Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Numbers in parentheses are standard errors clustered by year. AR and Wald tests follow the procedures in Olea and Pflueger (2013). Multiple IVs yield extra CLR statistics; see Pflueger and Wang (2015) for discussions of weak instrument tests in linear IV regressions and Finlay et al. (2014) for Stata implementations. *P*-values are reported for CLR, AR, and Wald tests.

Table 8: Effect of innovation on alternative measures of financial structure

3.3.3 System generalized methods of moments

Since financial conditions are typically persistent, the previous year's condition is likely to affect the current year's outcome. We further reduce the concern of the endogeneity problem between innovation and financial market evolution using a dynamic panel model estimated by a two-step system generalized method of moments (GMM) estimator. Our following regression equation takes the form of dynamic panel data and our study employs the two-step system GMM for the estimation of dynamic unbalanced panel data:

$$y_{i,t} = \kappa\, y_{i,t-1} + \lambda\, x_{i,t} + \gamma \mathbf{W}_{i,t} + \mu_t + \epsilon_{i,t} \tag{10}$$

When estimating dynamic panel data models, endogeneity is a common concern, especially when the model includes a lagged dependent variable among the regressors. Such a setup introduces potential reverse causality, as the dependent variable may influence the independent variables over time. To address this issue, the GMM estimator developed by Nickell (1981) has been widely adopted. Early literature laid the foundation by proposing difference GMM estimators to account for the dynamic structure and endogenous regressors (Anderson and Hsiao, 1982; Arellano and Bond, 1991). Building on this, the system GMM estimator introduced by Arellano and Bover (1995) and Blundell and Bond (1998), which combines equations in levels and differences. This approach improves efficiency and helps reduce the bias arising from fixed effects and short time spans, making it particularly well-suited for our empirical setting involving dynamic relationships and unbalanced panel data. As the financial structure regarding size and efficiency shows limited dynamic persistence in our data, we concentrate on the activity dimension for the dynamic panel GMM estimations.

The results we obtain from Eq. (10) are presented in Table 9. Across all specifications, the coefficient on the lagged dependent variable is positive and highly significant, ranging between 0.511 and 0.656. This indicates moderate persistence in financial structure, suggesting that prior levels of market activity shape current outcomes. A key result is that the coefficient on patents remains consistently positive and statistically significant across all models, with estimates generally between 0.011 and 0.017. This implies that higher innovation activity contributes to a shift toward market-based financial structure, as reflected in greater stock market activity relative to bank credit. Notably, the magnitude of the effect remains stable under various robustness checks, including dropping extreme observations and banking crisis years, applying robust standard errors, and winsorizing the sample, reinforcing confidence in the link between innovation and financial structure transformation. Furthermore, all AR(2) and Hansen tests are not statistically significant, indicating that our results are consistent and unbiased (Roodman, 2009).

	(1)	(2)	(3)	(4)	(5)	(6)
Lagged dependent variable	0.511***	0.511***	0.522***	0.656***	0.511**	0.572***
	(0.077)	(0.077)	(0.044)	(0.099)	(0.209)	(0.068)
Patents	0.017***	0.017***	0.015***	0.011***	0.017*	0.015***
	(0.004)	(0.004)	(0.005)	(0.002)	(0.010)	(0.004)
Financial openness	0.152*	0.152*	0.044	-0.011	0.152	0.107
	(0.081)	(0.081)	(0.075)	(0.067)	(0.178)	(0.092)
GDP growth	0.289	0.289	0.218	-0.022	0.289	0.100
	(0.209)	(0.209)	(0.151)	(0.159)	(0.470)	(0.180)
Trade openness	0.456	0.456	0.470	0.342	0.456	0.239
	(0.318)	(0.318)	(0.327)	(0.343)	(0.601)	(0.324)
Inflation	-0.643	-0.643	-0.027	-0.874	-0.643	-0.011
	(0.740)	(0.740)	(0.644)	(0.901)	(1.503)	(0.858)
Government spending	-0.447	-0.447	-0.344	-0.358	-0.447	-0.646
	(0.419)	(0.419)	(0.453)	(0.416)	(0.614)	(0.425)
Human capital	-0.035	-0.035	0.135	0.054	-0.035	0.180
	(0.253)	(0.253)	(0.246)	(0.271)	(0.421)	(0.267)
Bank Crisis	0.193	0.193	0.193		0.193	0.060
	(0.130)	(0.130)	(0.116)		(0.221)	(0.140)
Observations	1082	1082	1076	1161	1082	1082
Number of countries	68	68	67	68	68	68
Serial correlation test, AR(2)	0.323	0.323	0.526	0.234	0.561	0.821
Hansen test	0.967	0.967	0.889	0.917	0.967	0.984
Time-fixed effect	YES	YES	YES	YES	YES	YES

Note: The dependent variable is the logged ratio of stock value traded to bank credit. Column (1) reports baseline results. Columns (2) and (3) report results by dropping large and small dependent variables. Column (4) reports results with the dropping banking crisis years. Column (5) reports results estimated by robust standard errors. Column (6) shows estimated coefficients with the winsorized sample. Statistical significance levels are indicated by the asterisks: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Numbers in parentheses are the standard errors.

Table 9: Two-step system GMM estimation with robustness checks

4 Local projection with instrumental variable

4.1 The dynamic effects of innovation

While the previous analysis establishes the mean effect of innovation on financial structure, it remains unclear how quickly or persistently these effects unfold over time. Stock markets and banking systems may respond to innovation with delays due to adjustment costs, institutional frictions, or the time required for new technologies to diffuse. Static models capture only the contemporaneous average impact, potentially overlooking important dynamic adjustment paths. In this section, we focus solely on the dynamic responses for activity, as it is the most widely used indicator for capturing changes in financial structure.

To address this limitation, we implement a LP framework following Jordà (2005), extended with the same instrumental variables to address endogeneity in the innovation. Unlike vector autoregressions (VARs), the LP method does not require imposing strong assumptions on the joint dynamics of the system and is well-suited for estimating impulse response functions in panel data with heterogeneous units. We estimate the following specification for each horizon $h = 0, 1, \ldots, H$:

$$y_{i,t+h} = \beta^h x_{i,t} + \gamma^h \mathbf{W}_{it} + \lambda_t^h + \varepsilon_{i,t+h}^h \tag{11}$$

where $y_{i,t+h}$ denotes the ratio of stock value traded to bank credit or private credit from all financial corporations in country i at time $t + h$, $x_{i,t}$ is the instrumented value of innovation activity (e.g., patent applications) at time t, and $\mathbf{W}_{it}$ represents a vector of control variables. Time fixed effects λ_t^h control for the common shocks. The coefficient of interest, β^h, captures the period-specific response of the financial structure indicator h periods after an innovation shock at time t. To account for endogeneity, $Inno_{i,t}$ is instrumented using $z_{i,t}$ regional dummies, consistent with the baseline IV strategy. We estimate using White's heteroskedasticity-robust standard errors.

Figure 7 displays impulse response functions tracing the dynamic effects of innovation shocks on the activity dimension of financial structure over a 10-year horizon. The left panel uses the ratio of stock value traded to bank credit, while the right panel adopts a broader measure based on stock value traded relative to private credit from all financial institutions. The results in Figure 7 show that innovation shocks lead to a gradual and persistent increase in market-based financing relative to bank credit. The effect begins modestly in the early years, becomes more pronounced from around year 5 onward, and reaches approximately 0.7 percentage points by year 10, depending on the credit definition used. The upward trajectory indicates that innovation progressively strengthens the role of stock markets compared to traditional banking channels.

These findings suggest that innovation exerts not only a significant average effect but also a steadily accumulating influence on market-based finance over time, reflecting how financial systems dynamically reallocate resources in response to the innovation.

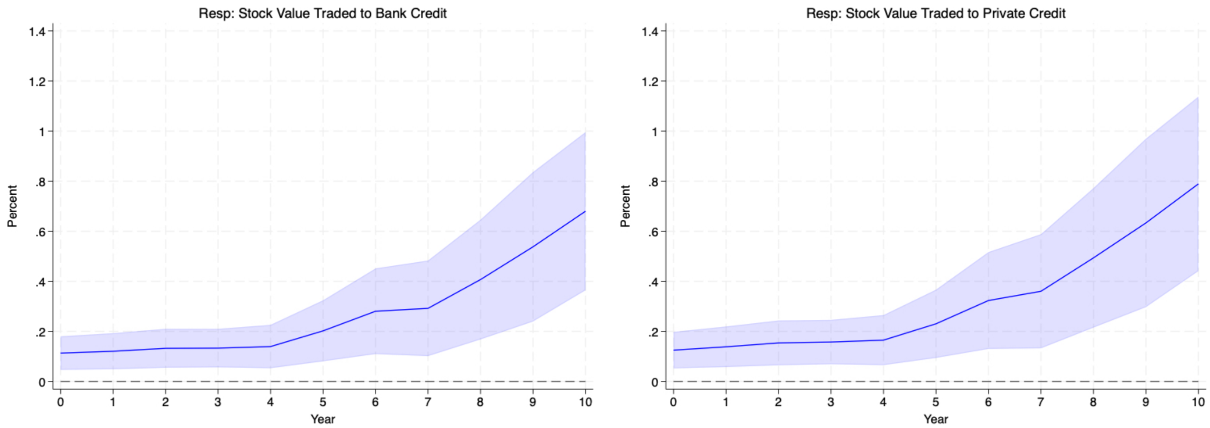

Figure 7: IRF, impulse on patents.

Note: Impulse-response functions (IRF) showing the response of the ratio of stock value traded to bank credit to a shock to patent applications. The blue solid line represents the response of the dependent variable to an increase in patents for the forecast horizon $h = 0, 1, 2, 3, 4, ..., 10$. Blue shadow band represents the 95% confidence interval calculated based on White's heteroskedasticity-robust standard error. The horizontal axis represents the year after an increase in patent applications. The dependent variable is stock value traded by private credit by banks or by all financial corporations. Instruments and control variables are the same as the baseline IV specification and include time fixed effects.

4.2 The dynamic effects of interacted institutional terms

While earlier sections establish that innovation influences financial structure on average, and that institutional quality conditions this relationship, it remains unclear how these effects unfold over time. Financial markets may not adjust instantaneously to innovation shocks, especially when institutional environments shape the speed and magnitude of financial system responses. For instance, a strong rule of law or effective regulation could either accelerate or delay the way innovation translates into market-based financing. Understanding these dynamic channels is crucial for policymakers seeking to promote innovation-driven stock market development under diverse institutional contexts.

To capture these dynamics, we estimate the following instrumental variable local projection model with interaction terms:

$$y_{i,t+h} = \beta_1^h \, x_{i,t} + \beta_2^h \, q_{i,t} + \beta_3^h \, (x_{i,t} \times q_{i,t}) + \gamma^h \, \mathbf{W}_{i,t} + \lambda_t^h + \varepsilon_{i,t+h}^h \tag{12}$$

where $y_{i,t+h}$ denotes the financial structure outcome for country i at horizon $t + h$. The variable $x_{i,t}$ measures innovation (e.g., patent applications), while $q_{i,t}$ represents one of five institutional-related indicators. The interaction term $x_{i,t} \times q_{i,t}$ allows the effect of innovation to vary depending on the level of institutional quality.

The coefficient β_3^h captures the dynamic heterogeneous effect of innovation conditional on institutions. A positive β_3^h implies that higher institutional quality amplifies the effect of innovation on financial structure at horizon h. Control variables $\mathbf{W}_{i,t}$, time fixed effects λ_t^h, and the error term $\varepsilon_{i,t+h}^h$ are included as in previous specifications. This framework enables us to trace how institutional settings shape the temporal path through which innovation affects financial systems, revealing whether the impact is immediate, delayed, or persistent over time.

Figure 8 presents the dynamic responses of the interaction between innovation and institutional quality on the activity dimension of financial structure across five institutional indicators. Across all panels, the impulse responses start positive and statistically significant in the early years, indicating that stronger institutional environments initially amplify the effect of innovation on shifting financial activity toward market-based channels relative to bank credit. However, a common pattern emerges in which the responses gradually decline over time, with several institutional indicators showing effects that converge toward zero or become statistically insignificant by year 8 to 10.

For corruption control and political stability, the initial impact of innovation is strongest, reaching levels above 1.2 percentage points, but the effect exhibits a sharp downward trend after year 4, suggesting diminishing marginal returns of such factors in sustaining innovation-driven financial structure shift over longer horizons. However, regulation quality shows a more modest and flatter profile, with stronger initial effects that gradually decline but remain positive for most of the period.

In addition, accountability and the rule of law also show significant early effects, but both have low initial values and decline steadily. The impact of the rule of law is even close to zero at the end of the timeline, which suggests that although citizen participation and the strength of the rule of law initially promote the redistribution of financial activities, this effect may weaken as the financial system adapts to innovation shocks.

Overall, these results imply that institutional quality not only conditions the immediate impact of innovation on financial markets but also influences the persistence and durability of that impact. While strong institutions can enhance the initial responsiveness of financial markets to innovation, their ability to sustain such effects appears to diminish over time.

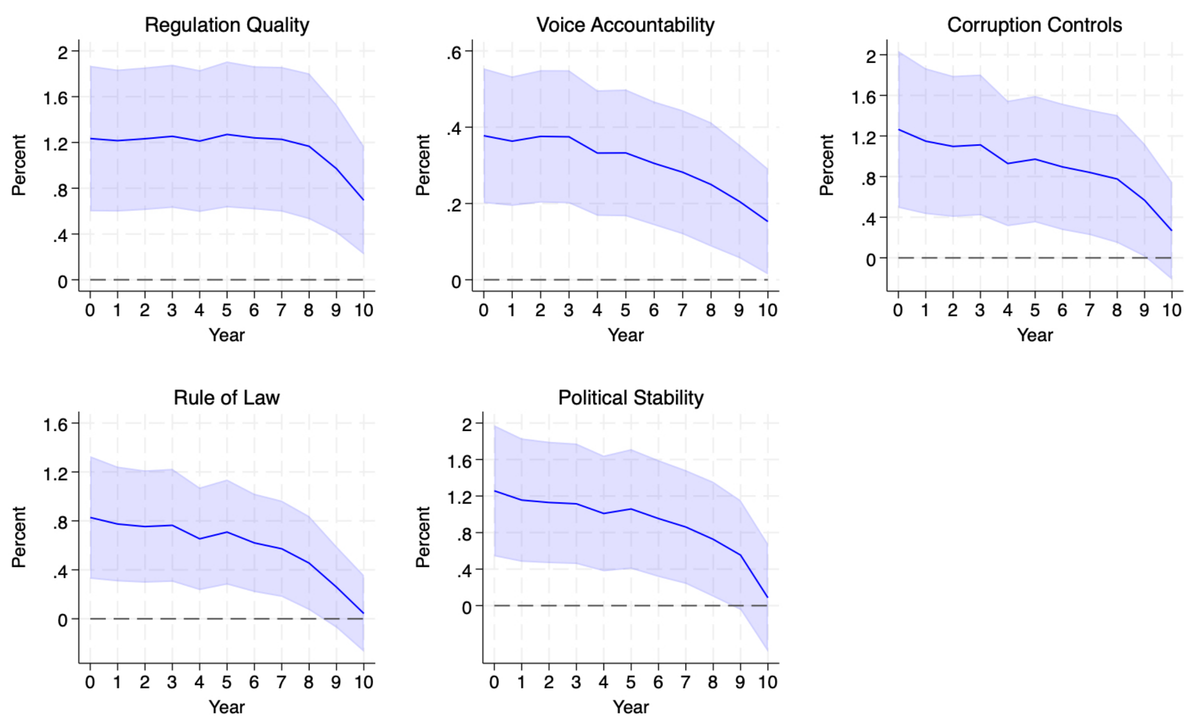

Figure 8: IRF, impulse on patents.

Note: Impulse-response functions (IRF) showing the response of the ratio of stock value traded to bank credit to a shock to patents interacted with five different institutional-related indicators. The blue solid line represents the response of the dependent variable to an increase in patents for the forecast horizon $h = 0, 1, 2, 3, 4, ..., 10$. Blue shadow band represents the 95% confidence interval calculated based on White's heteroskedasticity-robust standard error. The horizontal axis represents the year after an increase in patent applications. The dependent variable is stock value traded by private credit by banks or by all financial corporations. Instruments and control variables are the same as the baseline IV specification and include time fixed effects.

5 Conclusion

This paper revisits the relationship between innovation and financial systems by shifting the conventional perspective. Rather than viewing finance as the enabler of innovation, we conceptualize innovation as a catalyst that gradually reshapes financial structure. Drawing on a broad panel of 75 countries over 40 years, we provide empirical evidence that increases in innovation activity, measured through patent applications, intellectual property receipts, scientific publications, and high-tech exports, are associated with a structural shift from bank-based to market-based financing. By employing instrumental variables, local projections as well as various nonlinear specifications, we address endogeneity concerns and explore the robust heterogeneous and dynamic nature of this relationship.

Our results show that the effect of innovation on financial structure is conditional and varies depending on institutional and levels of development. We find an amplification effect whereby countries closer to the global technological frontier experience stronger market-based system to innovation activities. Moreover, our analysis highlights the importance of institutional quality in moderating the relationship between innovation and financial structure. We uncover non-linear effects across institutional indicators such as regulatory quality, voice and accountability, rule of law, political stability, and control of corruption. Moderate levels of institutional quality generally enhance the impact of innovation on market-based finance, while extremely high levels sometimes reduce its marginal benefits. This pattern suggests diminishing returns or crowding-out effects when institutional environments become highly rigid or overly regulated.

Our local projection estimates further indicate that the influence of innovation on financial structure is not only immediate but also accumulates over time. The dynamic effects tend to intensify around the fifth year after an innovation shock. Furthermore, stronger institutional environments enhance the initial impact of innovation on shifting financial structures toward market-based channels rather than banks. Yet this influence is not permanent. Over time, the positive effects tend to diminish, with several institutional indicators showing responses that taper off and lose statistical significance by roughly the eighth to tenth year. These findings suggest that while sound institutions play a critical role in translating innovation into financial structural change in the short to medium term, their capacity to sustain this transformation may weaken over longer horizons.

We craft policy implications for Japan, which stands close to the global technological frontier yet retains a financial system historically centered on bank-based finance. Our findings suggest clear policy avenues. To promote the development of its stock market and facilitate a shift toward market-based financing, Japan should focus on maintaining institutional quality at levels that are supportive but not excessively rigid. While strong legal protections and regulatory frameworks are essential, overly strict regulations may dampen the capacity of innovation to translate into vibrant capital markets. Policymakers should aim for balanced institutional reforms that enhance investor confidence and market transparency without imposing excessive burdens on market participants. In addition, fostering deeper connections between innovative firms and equity markets, for example, through incentives for public listings, improved disclosure standards, and measures to reduce listing costs and financial frictions between borrowers and investors, could help channel Japan's robust innovation capacity into a more dynamic and market-oriented financial structure.

In summary, these findings suggest that innovation does not reshape financial structures uniformly or instantaneously. Instead, it acts as a gradual catalyst whose effects depend on institutional context and productivity positioning. By emphasizing the long-term and state-dependent nature of this process, our study contributes to a deeper understanding of how innovation reshapes financial structures. Future research could explore how firm-level innovation influences capital structure decisions.

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