

Rethinking Regional Growth Drivers: Innovation, Finance, and Real Economy in Henan, China

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Abstract

This study investigates the relationships technological innovation (TI), financial development (FD), and the real economy (RE) in Henan Province, China, using annual data from 1999 to 2023. A Vector Autoregressive (VAR) framework with Granger causality tests, impulse response analysis, and variance decomposition is employed to examine both short term dynamics and long-term linkages. Robustness is confirmed using a Bayesian VAR with Minnesota priors. The findings indicate a two-way causal relationship between financial development and the real economy, where finance initially stimulates real sector growth but its influence weakens over time. In contrast, the real economy exerts a more sustained effect on finance, suggesting a crowding out mechanism caused by capital misallocation. Technological innovation shows a limited contribution to real economic performance, explaining less than two percent of its variance. These results highlight inefficiencies in credit allocation, weak diffusion of innovation, and low absorptive capacity within Henan's industrial structure. Policy measures should focus on channeling financial resources toward productive sectors such as high technology manufacturing, enhancing innovation financing mechanisms, and strengthening R&D industry collaboration.

Keywords: Technological Innovation, Financial Development, Real Economy, Vector Autoregressive

1. Introduction

The 20th National Congress of the Communist Party of China (2022) articulated a strategic vision positioning technological innovation (TI) as the "primary productive force", financial development (FD) as the "lifeblood of the modern economy," and the real economy (RE) as the "foundation of national rejuvenation" (Xi, 2022). This tripartite framework underscores their synergistic role in advancing high-quality development, a paradigm that emphasizes innovation-driven growth, financial efficiency, and real economic resilience. However, despite national policies promoting the integration of TI, FD, and RE, significant regional disparities persist in policy implementation and outcomes.

As an inland province with the third-largest population and a strategic geographic location, Henan plays a central role in China's national development agenda, particularly under initiatives

such as the "Central Plains Economic Zone" and the "Rise of Central China" strategy (State Council, 2022). Although Henan ranked sixth nationwide in terms of total GDP in 2024 (National Bureau of Statistics of China, 2024a), it continued to face notable structural challenges.

Henan Province's economic development is hindered by multiple structural constraints that collectively impede its growth. The region exhibits substantially lower economic output and household income levels compared to national benchmarks, with a per capita GDP of only 64,888 yuan in 2023, markedly below China's average of 95,749 yuan. This income gap reflects slower regional growth trajectories and a weaker consumption capacity in 2023 (National Bureau of Statistics of China, 2024a). Parallel financial sector challenges emerge from Henan's underdeveloped capital markets. Henan's incremental social financing to GDP ratio of 22.5 percent in 2023 significantly underperformed the national benchmark of 28.2 percent, reflecting a substantial financing gap compared to more developed regions (People's Bank of China, 2024; People's Bank of China Zhengzhou Central Branch, 2024). These financial constraints intersect with industrial structure limitations, where traditional sectors dominate economic activity, and high-tech manufacturing contributes merely 14.7% of industrial output, compared to the 15.7% national share in 2023 (Henan Provincial Bureau of Statistics, 2024; National Bureau of Statistics of China, 2024b). These interconnected challenges in income generation, financial intermediation, and industrial composition create persistent barriers to real economic modernisation and convergence with China's more developed regions, making Henan a representative case for studying how regions attempt to transition from factor-driven to innovation-led growth within institutional and market constraints.

In recent years, Henan has introduced a series of targeted policies aimed at advancing technological and financial integration to stimulate its real economy. In 2022, the provincial government issued the Work Programme on Financial Support for the Stable and Healthy Economic and Social Development of Henan Province, which emphasised expanding financial access for small and micro enterprises, lowering effective lending costs, and enhancing the operational efficiency of capital market financing channels (Department of Finance of Henan Province, 2023). In 2024, the *High-Quality Development Plan for the Low-Altitude Economy (2024–2027)* was launched to promote industrial transformation through the coordinated development of low-altitude consumption services, aircraft manufacturing, and operational support systems (State Council of the People's Republic of China, 2024). These initiatives reflect Henan's strategic efforts to strengthen the alignment between technological progress, financial instruments, and industrial policy.

Despite these efforts, Henan's economic performance remains underwhelming. Based on calculations, the average annual growth rate of the real economy in Henan between 2019 and 2023 was 3.4 percent, which is substantially lower than the national average of 8.9 percent during the same period (National Bureau of Statistics of China, 2024a). This significant gap suggests that the expected benefits of technological innovation and financial development may not be effectively transmitted to the real economy in the long run. This raises important questions

about the efficacy of current policy frameworks and the presence of institutional or structural barriers that hinder the synergy between Technological Innovation and Financial Development. Therefore, gaining a clear understanding of the existing conditions of technological innovation and financial development in Henan Province is of critical importance, and systematically exploring their interaction with real economic performance is necessary. Such an investigation is not only timely but also theoretically meaningful because it contributes to a deeper understanding of how innovation–finance linkages function under varying regional conditions. The findings of this study are expected to offer valuable implications for other inland and emerging regions in China and similar economies worldwide that are undergoing structural transitions toward innovation-led growth.

This study examines the dynamic interplay among innovation, financial, and real economic growth in Henan Province, an inland region that typifies the structural and institutional characteristics of China's less developed areas. Drawing on annual time-series data from 1999 to 2023, the analysis employs a VAR model to explore both the long-term equilibrium relationships and short-term adjustment dynamics among the three variables.

By focusing on an inland economy, this study addresses a notable gap in the existing literature, which has largely concentrated on coastal regions and static frameworks. It also introduces a time-sensitive and regionally grounded approach that captures the evolving and context-dependent nature of innovation, finance, and growth interactions in transitional settings. This framework offers new insights into the mechanisms through which financial and technological factors jointly influence real economic outcomes in structurally constrained environments.

2. Literature Review

2.1 Technological innovation and the real economy

Technological innovation plays a crucial role in driving genuine economic growth. Empirical evidence suggests that increases in patents and technological outputs are positively correlated with local economic development, underscoring the importance of innovation for economic expansion (Raghupathi & Raghupathi, 2017). Such innovations enhance the efficiency, coordination, and sustainability of economic activities, underscoring the need for government policies that promote technological transformation within enterprises (Cheng et al., 2023). Driven by innovations such as the Internet of Things and blockchain, recent advances in digital technologies have played a pivotal role in reshaping the real economy by facilitating the emergence of new industries and transforming traditional sectors (Raja, 2021). In the context of China, integrating digital and traditional economic sectors through innovation is strategic for maintaining sustained growth and strengthening global competitiveness (Shi & Wei, 2025). Technological innovation is a critical catalyst for the development of the real economy.

2.2 Financial development and the real economy

In emerging market economies, financial development and real sector investment have long been recognised as critical drivers of sustained economic growth, and economic resilience has been closely tied to the ability of financial systems to channel capital effectively into the real sector, thereby supporting industrial expansion and employment generation (Raghutla & Chittedi, 2021). In China, financial development has played a crucial role in facilitating market expansion and industrial upgrading, thereby forming a mutually reinforcing relationship with real economic growth (Jiang et al., 2020). The development of credit markets, banking institutions, and capital access mechanisms has, in many cases, provided the financial infrastructure necessary for firms to undertake long-term investments and innovation activities.

However, recent studies have raised concerns about the asymmetric effects of financial development on sectoral dynamics within the real economy (Ibrahim & Alagidede, 2020). In particular, some studies argue that financial deepening may contribute to structural imbalances, especially when capital is disproportionately directed toward speculative sectors, such as real estate (Bhattarai, 2015). Evidence shows that excessive financialization has rapid growth in the property market while crowding out investment in the secondary sector, including manufacturing and high-tech industries, which are more directly linked to sustainable productivity gains (Li et al., 2022). This misallocation of financial resources may weaken the transmission mechanism through which financial development supports the real economy.

These contrasting perspectives highlight critical research gaps. Although financial development is broadly associated with economic expansion, its sectoral allocation and interaction with industrial policy can either reinforce or undermine real economic growth. Understanding the conditions under which financial development promotes or distorts real sector performance is particularly important in transitional economies such as China, where institutional constraints and regional disparities may significantly influence financial flows. Therefore, a more nuanced and regionally grounded analysis is needed to clarify how financial systems interact with real economic activity, especially in inland provinces undergoing structural transformation, such as Guizhou.

2.3 Joint roles of technological innovation and financial development in the real economy

The sustained expansion of the real economy depends significantly on access to financial resources and the effective application of technological advances. Financial development and technological innovation are closely linked, functioning as a mutually reinforcing system that supports investment, enhances efficiency, and drives productivity growth in the real sector (Raimi et al., 2025). The extent to which the real economy relies on financial and technological inputs has direct implications for enterprise profitability, investment decisions, and long-term competitiveness (Sun et al., 2025). A range of mechanisms, including capital allocation, risk pricing, and innovation financing, links financial and technological progress to firm-level performance and macroeconomic outcomes (Zhao et al., 2025). However, these interactions are not without challenges. The push for innovation introduces risks related to technological failure, cybersecurity, and data privacy, which require robust regulatory frameworks and institutional safeguards.

Despite the recognised importance of both financial development and technological innovation, most existing studies tend to analyse their effects on the real economy in isolation. Research that jointly considers these two factors and their combined impact on the real economic performance is limited. Moreover, most studies are situated at the national level, often overlooking regional disparities and institutional heterogeneity. There is a lack of empirical studies that examine the tripartite relationship among financial development, technological innovation, and the real economy at the subnational level, particularly in provinces with distinct structural characteristics. This gap highlights the need to examine how the interplay between financial and technological systems influences real economic outcomes in specific regional contexts.

2.4 Theoretical framework

The theoretical framework of this study is informed by two foundational perspectives: Endogenous Growth Theory and Financial Intermediation Theory, which together provide a comprehensive lens for examining the interplay among innovation, finance, and the real economy.

The relationship between technological innovation and real economic growth is grounded in Endogenous Growth Theory. This theory emphasises that long-term economic expansion is primarily driven by internal factors, such as human capital accumulation, knowledge spillovers, and sustained investment in innovation (Shwayder, 2025). Technological progress contributes to productivity improvement, industrial upgrading, and the creation of new markets. However, the effectiveness of innovation in promoting real economic outcomes depends heavily on the institutional and structural environment, suggesting that without supportive systems such as R&D infrastructure, skilled labour, and innovation financing mechanisms, the transmission of innovation into real economic results may be constrained (Liu et al., 2025).

The interaction between financial development and the real economy is best understood using the framework of financial intermediation theory. This theory highlights the role of financial institutions in mobilising savings, improving capital allocation, and supporting investment activities that enhance productive capacity (Li et al., 2025). Financial development facilitates the expansion of the real economy by providing access to credit and reducing transaction costs. Conversely, as the real economy grows, it generates greater demand for diversified financial services, stimulating the development of financial markets. Nevertheless, in regions such as Henan, the long-term effect of financial development on real economic growth appears to diminish over time because of inefficiencies in capital allocation. Empirical evidence suggests that financial resources are often channelled into speculative sectors, particularly real estate, rather than supporting industrial production or innovation (Li & Beck, 2025). This misallocation disrupts the expected reinforcing cycle between financial and real economic activities.

The pathway from technological innovation to financial development is also aligned with Endogenous Growth Theory, particularly in its recognition of innovation as a driver of institutional and market transformation. Technological progress, especially in the field of

financial technology, enhances financial accessibility, operational efficiency, and service diversity (Yang & Gong, 2025). Innovations such as digital payments, block chain applications, and mobile finance platforms can strengthen financial inclusion and reduce service delivery costs (Ghosh & Bhatia, 2025). However, the sustainability of this effect is conditional on regulatory capacity and digital infrastructure. This framework (Figure 1) contributes to theoretical literature by integrating structural and temporal considerations into the established growth models. This emphasises that the interactions among technological innovation, financial development, and the real economy are shaped not only by internal dynamics but also by the broader regional context. This regionally grounded approach provides a more accurate understanding of economic transformation in transitional economies, such as Henan Province.

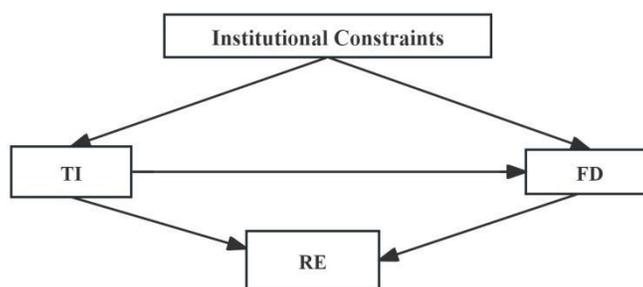


Figure 1. Theoretical Framework

By incorporating regional and temporal considerations into established growth theories, this framework enhances the explanatory power of endogenous growth models and provides a tailored analytical approach suitable for transitional economies, such as Henan. Thus, it provides a more accurate and policy-relevant understanding of how innovation and finance jointly influence real-sector outcomes in structurally constrained environments.

3. Methodology

3.1 Measurement of Key Variables

Financial Development (FD) is measured using the natural logarithm of the value added by the financial sector. Logarithmic transformation is applied to reduce heteroscedasticity and facilitate the interpretation of growth rates. This metric captures the direct economic contribution of financial intermediation activities, including banking, insurance, and other financial services (Heffernan & Fu, 2010). Alternative measures, such as the ratio of total deposits and loans to GDP, were considered but ultimately excluded to maintain consistency with the availability of provincial-level data in Henan.

Technological Innovation (TI) is measured using the growth rate of granted invention patents in Henan Province. This indicator reflects both R&D output and technological commercialisation capacity (Jemala, 2021). The patent-based measure was selected over technology market

turnover rates because of its superior reliability in tracking innovation activities at the provincial level.

The real Economy (RE) is measured as the natural logarithm of the total GDP net value added by the financial and real estate sectors. This transformation not only captures the scale of real sector activity but also mitigates heteroscedasticity, supporting log-linear modeling in the VAR framework. This adjusted measure provides a more accurate representation of productive economic activities in manufacturing, agriculture, and tangible services while excluding potentially distortive financial and speculative components (Nong, 2024).

3.2 Time-series modelling strategy

The time-series analysis follows a streamlined three-step procedure. First, the annual series for financial development (FD), technological innovation (TI) and the real economy (RE) are transformed into logarithms where appropriate and their integration properties are examined using Augmented Dickey-Fuller (ADF) tests (Ben-Ahmed et al., 2025). The results in Table 1 show that all three variables are stationary in levels at the 5% significance level, that is, they are integrated of order zero, I(0). This reduces the risk of spurious regression and implies that the variables can be modelled directly in levels without further differencing.

Table 1. ADF Test Results

Variables	T-Statistic	5% Critical value	P-value	Decision
FD	-4.0822	-3.0124	0.0053	I(0)
TI	-4.6018	-3.6122	0.0064	I(0)
RE	-3.8990	-3.7379	0.0069	I(0)

The test results indicate that the p-values for all three variables are below the 5% significance level, leading to the rejection of the null hypothesis of a unit root. This confirms that all variables are stationary in their level forms. Therefore, the model can be estimated directly, without the need for differencing.

Second, given the I(0) properties, a Vector Autoregressive (VAR) framework is adopted to capture the dynamic interrelationships among FD, TI and RE. In this system, each variable is treated as endogenous and is modelled as a function of its own lagged values and the lagged values of the other variables. The general VAR(p) specification is given in equation (1), where the coefficient matrices A_i summarise the effect of past shocks and ϵ_t denotes a white-noise error vector with constant variance-covariance matrix. The appropriate lag length is determined using the Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC) and Hannan-Quinn Criterion (HQC). All three criteria favour a parsimonious VAR(1) specification, which is reported in equation (1). In the context of this study, the VAR model was employed to explore

the short-term dynamics among these three variables. The matrix form of the VAR model of order p, denoted as VAR(p) is specified as equation 2.

$$\begin{bmatrix} FD_t \\ TI_t \\ RE_t \end{bmatrix} = C + \sum_{i=1}^p A_i \begin{bmatrix} FD_{t-i} \\ TI_{t-i} \\ RE_{t-i} \end{bmatrix} + \varepsilon_t \quad (1)$$

Where:

- FD_t , TI_t , and RE_t are the values of financial development, technological innovation, and the real economy at time t, respectively.
- C is a vector of constants (intercepts).
- A_i represents the coefficient matrices of lag i for $i=1,2,\dots,p$, which captures the influence of past values.
- ε_t is the vector of white noise error terms, assumed to be serially uncorrelated with a zero mean and constant variance-covariance matrix.

$$\begin{bmatrix} FD_t \\ TI_t \\ RE_t \end{bmatrix} = \begin{bmatrix} -3.5278 \\ 0.7604 \\ -0.4260 \end{bmatrix} + \begin{bmatrix} 0.5580 & 0.1017 & 0.6594 \\ 0.0050 & 0.2102 & -0.0590 \\ -0.1276 & 0.0212 & 1.1373 \end{bmatrix} \begin{bmatrix} FD_{t-1} \\ TI_{t-1} \\ RE_{t-1} \end{bmatrix} + \varepsilon_t \quad (2)$$

Third, standard diagnostic tests are applied to the VAR(1) residuals to ensure that the model provides a reliable basis for structural analysis. Tests for serial correlation, heteroskedasticity, normality and overall stability indicate that the residuals are well-behaved and that all roots lie inside the unit circle, confirming that the system is dynamically stable. Conditional on these diagnostics, the VAR(1) model is used to derive Granger causality tests, impulse response functions and forecast-error variance decompositions. These tools allow the direction, timing and relative importance of shocks transmitted among FD, TI and RE to be analysed in a coherent multivariate framework (Wiesen & Beaumont, 2024).

3.3 Sample size considerations

The use of annual data from 1999 to 2023 implies that the effective sample size is limited to 25 observations. For a tri-variate VAR(1) system in which each variable depends on its own lag and the lags of the other two variables, this already entails 18 slope coefficients and three intercepts. This relatively parameter-intensive specification, combined with a short sample, reduces the degrees of freedom and increases sampling uncertainty, making coefficient estimates and impulse responses potentially sensitive to specification choices and outliers. To mitigate these risks, the analysis adopts the most parsimonious lag length supported by the information criteria (VAR(1)) and complements the classical VAR with a Bayesian VAR (Section 4.7), where Minnesota-type shrinkage helps to contain over-fitting. Nevertheless, given the short time span, the dynamic results are interpreted as indicative patterns rather than precise quantitative effects, and all conclusions should be viewed with appropriate caution.

4. Findings and Discussion

4.1 Model stability test

Following the estimation of the VAR(1) model, it is necessary to assess its stability, a fundamental requirement for reliable forecasting and structural analysis. Stability implies that the effects of shocks to the system dissipate over time rather than accumulating, which ensures the meaningful interpretation of impulse response functions. The stability of a VAR model is typically evaluated by examining the inverse roots of its characteristic polynomial. According to the stability condition, all roots must lie strictly within the unit circle in the complex plane (Elias & Ali, 2025). As illustrated in Figure 2, all inverse roots of the estimated VAR(1) model fall within the unit circle. This confirms that the model satisfies the stability condition and is therefore suitable for subsequent dynamic analyses.

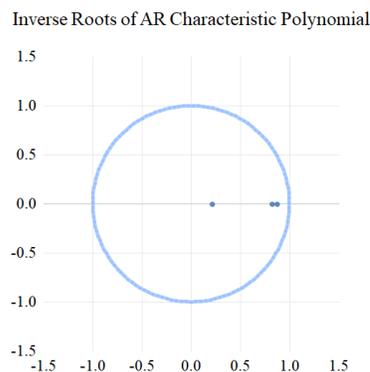


Figure 2. VAR(1) model stability test

4.2 Residual normality test

To evaluate whether the residuals of the estimated VAR(1) model conform to the assumption of multivariate normality, the Jarque–Bera residual normality test was applied. The test includes assessments of both skewness and kurtosis for each equation, as well as joint statistics for the full system. As shown in Table 2, the p-values for all individual components under the skewness test are well above the 5 percent significance threshold (0.9737, 0.6615, and 0.9671, respectively), with a joint probability of 0.9785. Similarly, the kurtosis test also returned non-significant p-values (0.6459, 0.6768, and 0.1348 for the three components), and the joint test yielded a probability of 0.4538. The Jarque–Bera test confirms that the residuals do not significantly deviate from normality, suggesting that the null hypothesis of multivariate normality cannot be rejected at conventional significance levels. Therefore, the residuals of the VAR model satisfy the normality assumption, supporting the robustness of the model for further structural analyses.

Table 2. Residual Normality Test

Component	Skewness	Prob.	Kurtosis	Prob.	Jarque-Bera	Prob.
1	-0.0165	0.9737	2.5406	0.6459	0.2121	0.8994
2	-0.2189	0.6615	2.5831	0.6768	0.3655	0.8330
3	-0.0206	0.9671	4.4955	0.1348	2.2381	0.3266
Joint		0.9785		0.4538		0.8316

4.3 VAR Residual Serial Correlation LM Test

Ensuring that model residuals exhibit white noise characteristics is fundamental to the reliability of statistical inference in VAR modelling, as serial correlation may reflect model misspecification and violate the assumption of independently distributed errors (Ariens et al., 2023). In this study, the LM test is employed to detect autocorrelation in the residuals of the VAR(1) model. As shown in Table 3, the test statistics at lag 1 (LRE* = 9.8085, p = 0.3662) and lag 2 (LRE* = 10.5264, p = 0.3096) are not significant. These findings fail to reject the null hypothesis of no serial correlation, indicating that the residuals behave like white noise and that the VAR(1) model is appropriately specified for further analysis.

Table 3. Residual Serial Correlation LM Test

Lag	LRE* stat	Prob.	Rao F-stat	Prob.
1	9.8085	0.3662	1.1269	0.3693
2	10.5264	0.3096	1.2207	0.3126

Note: Null hypothesis: No serial correlation at lag h

4.4 Granger causality test

The Vector Autoregression (VAR) based Granger causality test is a widely applied statistical technique for examining whether one time series can provide predictive information about another. This method is particularly valuable in economic and financial research because it helps uncover potential directional relationships among variables (Morshed & Hossain, 2022). In this study, Granger causality analysis was employed to explore the dynamic interactions among technological innovation, financial development, and the real economy. The empirical results derived from the VAR-based Granger causality tests are presented in Table 4. The results indicate that there is bidirectional Granger causality between financial development and the real economy in Henan Province, suggesting that the two variables are mutually predictive. Technological innovation is also a Granger cause of financial development, but the prediction path is unidirectional. In addition, technological innovation is not a Granger cause of the real

economy, which suggests that the influence of relationships may be indirect or require a longer time horizon to be reflected.

Table 4. VAR Granger Causality Test

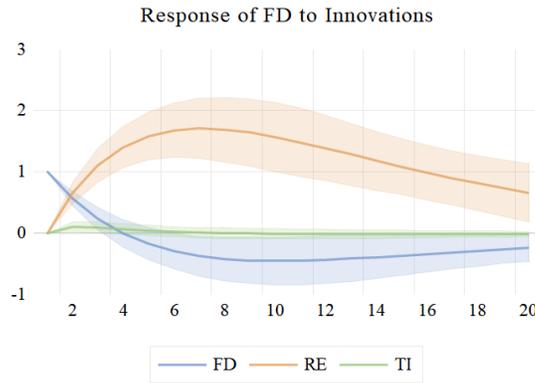
Dependent Variable: FD		Dependent Variable: RE		Dependent Variable: TI	
Excluded	Prob.	Excluded	Prob.	Excluded	Prob.
RE	0.0000	FD	0.0000	FD	0.9870
TI	0.0082	TI	0.2732	RE	0.8959
All	0.0000	All	0.0001	All	0.8606

4.5 Impulse Response Function

The impulse response analysis (Figure 3) provides valuable insights into the dynamic relationships among these three variables. The results show that technological innovation initially exerts a positive effect on the real economy, with the impact peaking before gradually declining and stabilising at a relatively modest level. This trajectory reflects the complex role of technological progress; while it contributes to productivity gains and industrial upgrading, it may also introduce short-term disruptions, including labour displacement in traditional sectors and adjustment costs associated with new technologies (Wadley, 2021). Financial development similarly exhibits a short-run positive impact on the real economy, which later becomes unstable and diminishes. This weakening effect suggests that although financial expansion can stimulate economic activity in the early stages, unchecked growth may lead to inefficiencies, including resource misallocation and speculative behavior, potentially diverting capital away from productive sectors (Hung, 2023).

In terms of reverse effects, the analysis indicates that technological innovation has a positive but temporary influence on financial development, which gradually fades and disappears in the eighth period. This may reflect the initial gains from digital financial tools, such as mobile banking and Fintech applications, which can enhance access and efficiency but whose effectiveness may erode over time due to unequal access or technological saturation. In contrast, the real economy exerts a more stable and persistent positive effect on financial development, peaking around the eighth period, highlighting its foundational role in driving financial sector growth through the demand for capital and financial services. These findings underscore the need for policymakers to adopt a balanced approach that aligns short-term economic incentives with long-term goals. Promoting inclusive technological advancement and maintaining a well-regulated financial system are essential to maximize the benefits of innovation and financial deepening while minimizing risks, such as labor market volatility and financial instability.

Response to Nonfactorized One Unit Innovations
95% CI using Monte Carlo S.E.s with 100 replications



Response to Nonfactorized One Unit Innovations
95% CI using Monte Carlo S.E.s with 100 replications

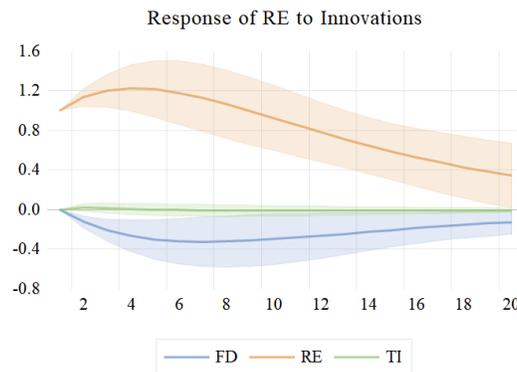


Figure 3. Impulse response functions

4.6 Variance Decomposition

Variance decomposition analysis offers further evidence of the evolving interrelationships and explanatory power among financial development (FD), the real economy (RE), and technological innovation (TI) over time. The results reveal distinct trajectories for the relative importance of each variable across different forecast horizons.

In the case of financial development (Figure 4), the variance decomposition results show that FD is initially almost entirely explained by its own innovations, accounting for 100% of the forecast error variance in period 1. However, this self-explanatory power declines steadily, reaching 23.72% by period 19. Meanwhile, the influence of the real economy increases significantly, from 0% to 68.83%, eventually becoming the dominant source of variation in the financial development. Technological innovation exhibits a different dynamic: its contribution to FD rises

to a peak of 18.75% in period 4, before gradually declining to 7.45% in the long run. These patterns suggest that while financial development may be largely endogenous in the short term, its evolution becomes increasingly dependent on real economic fundamentals, with technological innovation exerting a modest but persistent influence on it.

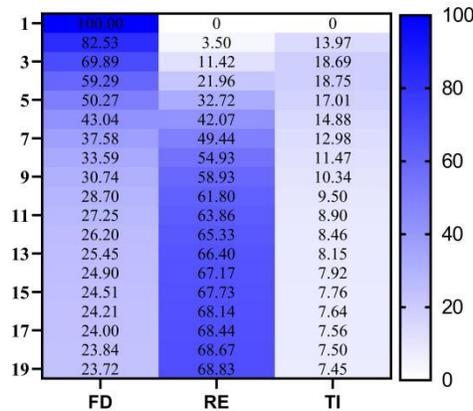


Figure 4. RE Variance Decomposition

In contrast, the variance decomposition of the real economy (Figure 5) indicates a high degree of self-dependence. RE explains 88.75% of its own variance in the initial period, and this contribution remains consistently high, reaching 90.43% by period 19. The explanatory power of FD is relatively limited, declining from 11.25% in the early stages to a low of 3.19% in period 5, before gradually rising again to 7.76% in the long term. Technological innovation contributes marginally to RE, with its share never exceeding 2.09% during the observed periods. This suggests that the real economy operates largely autonomously, with financial development exerting a limited and nonlinear influence and technological innovation having minimal direct explanatory power.

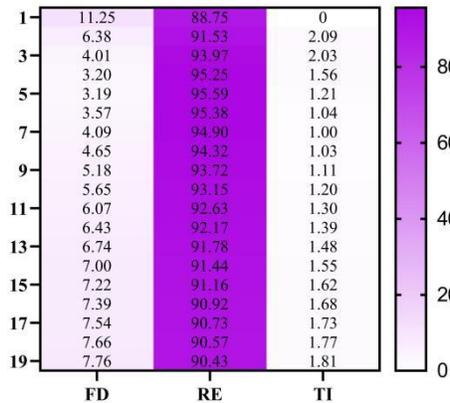


Figure 5. FD Variance Decomposition

4.7 Robustness Tests: Classical VAR versus Bayesian VAR

To ensure that our substantive conclusions are not an artifact of small-sample bias or over parameterization, the research re-estimates the tri-variate system (FD, RE, TI) within a Bayesian VAR (BVAR) framework and contrasts its dynamics with the baseline frequentist VAR. All computations were performed using EViews 13.

Table 5 shows the annual sample provides only $n = 25$ usable observations. A conventional VAR(1) already requires 18 slope coefficients and three intercepts. Under such a "large-p / small-n" setting, coefficient uncertainty inflates rapidly, and impulse responses become imprecise. The BVAR addresses these issues by employing the standard Minnesota prior, an economically sensible shrinkage that pulls distant lags and cross-equation effects toward zero, unless the data provide strong evidence to the contrary (Litterman, 1986).

Table 5. Prior settings and sensitivity window

Hyper-parameter	Economic Interpretation	Baseline Value
λ_1	Overall tightness (global shrinkage)	0.10
λ_2	Cross-equation weight (tightness across variables)	0.99
λ_3	Lag-decay (penalty on higher lags)	1.00

Figure 6 overlays the highest-posterior-density (HPD) bands from the BVAR (upper two panels) with the 95 % confidence bands of the classical VAR (lower two panels). All panels are plotted on identical vertical axes, allowing the slopes and magnitudes to be directly compared.

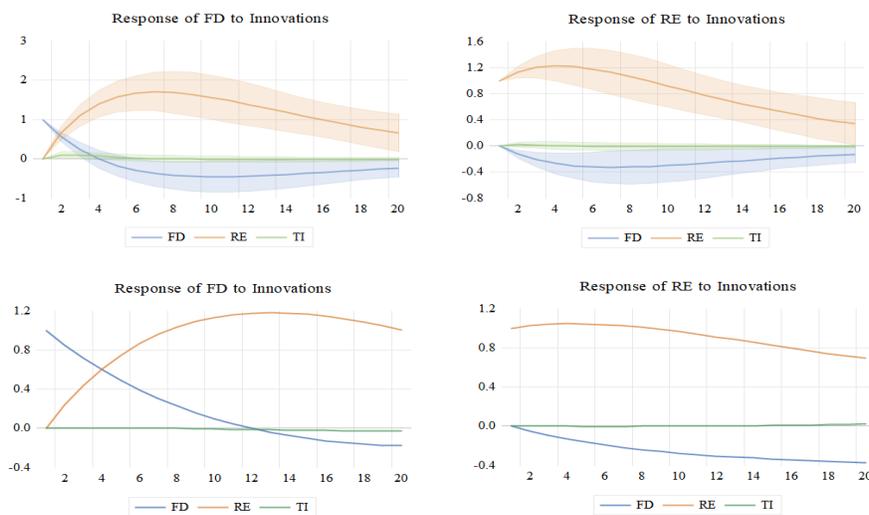


Figure 6. Impulse Response Functions of FD, RE, and TI

The impulse-response results derived from both the classical VAR and Bayesian VAR models exhibit consistent qualitative patterns. Financial self-shocks gradually diminish, confirming the presence of financial inertia. Shocks to the real economy triggered by financial development produce a hump-shaped response in both models, with the BVAR yielding a higher peak, suggesting that the classical VAR may underestimate the short-run stimulative effect of finance. Conversely, real-sector shocks exert a negative and persistent influence on financial development, supporting the crowding-out interpretation. Innovation-driven shocks remain statistically and economically insignificant across specifications, highlighting the limited macroeconomic transmission of patent-based technological changes. The direction, timing, and persistence of all responses remained robust across the estimation frameworks, reinforcing the credibility of the study's core empirical conclusions.

5. Conclusion and Discussion

This study investigates the dynamic interplay among innovation, finance and the real economy in Henan Province from 1999 to 2023, a region that exemplifies China's transitional inland economies. Despite substantial policy efforts to expand innovation capacity and financial access, Henan's real economic growth remains below the national average. In line with existing scholarship, technological innovation and financial development are widely recognised as key drivers of real sector performance (Jiang et al., 2020; Raghupathi & Raghupathi, 2017), but their effectiveness is often conditioned by regional structural factors and policy implementation efficiency (Liang & Teng, 2006; Shi & Wei, 2025). Against this background, a VAR framework with Granger causality tests, impulse response functions and variance decomposition is used to trace how shocks in innovation, finance and the real economy propagate over time.

The empirical analysis yields three main findings. First, a bidirectional causal relationship exists between financial development and the real economy, confirming a mutually reinforcing but asymmetric linkage. Financial development initially stimulates real economic activity, consistent with intermediation theory (Li et al., 2025), but its effect weakens over time, which may reflect capital misallocation and financialisation pressures (Bhattarai, 2015; Ibrahim & Alagidede, 2020). Second, the real economy consistently exerts a stronger and more persistent influence on financial development, suggesting that real sector demand remains the primary driver of financial system evolution, in line with evidence from other emerging economies (Raghutla & Chittedi, 2021). Third, the influence of technological innovation on the real economy is limited and largely indirect. Innovation provides short-term boosts to financial development through FinTech adoption (Yang & Gong, 2025), yet its direct contribution to long-run real sector expansion is small, accounting for less than 2% of RE variance. This pattern echoes concerns that institutional bottlenecks and weak diffusion channels hinder the translation of innovation inputs into real economic outcomes (Li et al., 2025).

These findings carry several practical implications for Henan's high-quality development strategy. To counter the weakening long-term impact of finance on the real economy, financial resources should be directed more efficiently toward productive sectors such as advanced manufacturing and infrastructure, in line with the *Work Programme on Financial Support*

(2023), which stresses improved credit access and public–private investment to support real-sector growth (Department of Finance of Henan Province, 2023). The limited and short-lived influence of technological innovation points to the need for deeper integration of digital finance with industrial policy. Consistent with the *Low-Altitude Economy Development Plan (2024–2027)*, Henan should promote financial technologies that enhance access and efficiency in underserved areas and emerging sectors, while improving mechanisms for technology commercialisation. This includes stronger support for R&D–industry collaboration, innovation-oriented financing instruments and institutional infrastructure such as incubators and transfer centres (State Council of the People's Republic of China, 2024). At the same time, bridging digital divides, promoting financial equity and extending support to rural and small-scale enterprises are essential to ensure that innovation and finance translate into broad-based, sustainable growth.

Several limitations should be acknowledged to contextualise these findings. The annual data from 1999 to 2023 provide only 25 observations, which constrains degrees of freedom and implies that the dynamic results should be interpreted as indicative patterns rather than precise quantitative effects. In addition, patent counts are used as a proxy for technological innovation, which may not fully reflect the depth, quality or market applicability of innovative activities; and financial development is measured at an aggregate level, which may obscure important distinctions between productive and speculative financial flows. Finally, although the VAR framework is well suited to exploring dynamic relationships, it does not allow for full identification of structural causality or the transmission mechanisms of specific policy instruments. Future research could extend the time span, incorporate sectoral or firm-level data and combine VAR with structural or panel approaches or micro-level case studies to provide a more nuanced understanding of how innovation, finance and the real economy co-evolve in Henan and comparable regions.

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