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Research Article

Econometric Analysis of the Impact of Financial Structure on Innovation Based on the Fixed Effects Panel Model

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This study addresses the impact of financial structure on innovation. The mechanism of the impact of financial structure on innovation at different levels of economic development is elucidated from the perspective of optimal financial structure decision theory and development economics, and empirical evidence is provided using manufacturing data from 59 countries or regions for the period 1996–2015. The study finds that financial structure has no significant effect on innovation at lower levels of economic development, but at higher levels of economic development, market-based financial structure significantly promotes innovation in the industry. The role of financial structure in innovation shifts in the interval where per capita income is greater than 9747 International dollar (hereinafter called I$9747) and less than I$17070. This paper verifies that the innovation approach of technological imitation requires the support of a bank-based financial structure, while the innovation approach of independent innovation requires the support of a market-based financial structure. The differences in innovation approaches at different stages of economic development lead to the evolution of the inherent demand for financial structures in the economy. Promoting the evolution of financial structures according to the stage of economic development is of great significance in building an innovative country and leading the sustainable and healthy development of the economy.

1. Introduction

1.1. International Context Analysis. From the humiliating modern history more than a hundred years ago to the trade war between the United States and China in recent years, history has warned us over and over again that science and technology are the lifeblood of the nation and that we will be beaten if we fall behind. Good institutions provide the necessary environment for national innovation, and the financial system is the most crucial part of the system. After the Second World War, economies that achieved national liberation and independence made efforts to seek prosperity and strength. Unfortunately, only a few countries, such as South Korea, have made the leap from developing to developed, while the developed countries have grown slowly and the developing countries have stagnated, and the division between the rich and the poor has intensified. The choice of how to achieve growth and what kind of growth to achieve has become a question that economists have been diligently pursuing. In this process, Williamson's "Washington Consensus," which is based on the practices of developed countries, has been applied to financial reforms in Latin American and East Asian economies [1–4]. Unfortunately, the liberalisation of the banking sector in some countries or regions has led to financial disruptions, and financial reforms have not been effective in achieving the desired goals (Huang, 1997; Chen, 1998; Chen and Fu, 2010) [1, 2, 5]. Marketisation (market fundamentalism) should not be the ultimate goal of reform, nor will it be a panacea for reform (Kolodko, 1999; Wang, 2008) [3, 6]. Marketisation and liberalisation have not solved the principal-agent problem of corporate governance. In its critique of "the Washington Consensus," "the Post-Washington Consensus" emphasises that institutions have important role, that good institutions are a guarantee that markets will work, that financial constraints can be used to ensure the efficiency of banks' financial services with rents, and that credit rationing can help control the moral hazard (Stiglitz and Weiss, 1981; Kolodko, 1999; Lan, 2002; Tian, 2005) [3, 4, 7, 8]. The US savings and loan crisis in the 1980s also highlighted the importance of institutions (Greenbaum et al., 2015) [9]. Lin (2003) [10] affirms Sachs et al.'s (2003) view of the importance of institutions [11] while suggesting the endogeneity and nonuniversality of institutions. In addition, Ramo proposes a "Beijing Consensus" [12] for countries in transition, emphasising that innovation and independence are the golden keys to development. This view is also in line with Solow (1956) [13] and Denison (1985) [14] stating that technological progress is the central driver of economic growth.

1.2. Analysis of the Current Situation in the Country. Since the reform and opening up, technological advances have transformed China from a manufacturing importer to a manufacturing exporter, and it is only right that we use innovation as a key tool to drive the economy. Based on the Beijing Consensus, Wang (2008) suggests that one of the lessons of China's rapid development is the establishment of a diversified system of financial institutions and a well-developed financial market [6]. Liu et al. (2011) found empirical evidence that the growth rate of high growth economies decelerated around a per capita income of 11000 international dollars (1990 prices) when analysing the timing of growth rate changes in countries or regions that experienced high growth, such as Japan, Korea, Chinese Taiwan Province, and Germany [15]. That is, economies are likely to achieve high growth when per capita income is less than I$11000 and resume or maintain normal growth when per capita income is above I$11000. Unfortunately, the financial sector in the dynamic stochastic general equilibrium model under the New Keynesian framework is currently limited to banking institutions, and the available studies cannot point to changes in the relative importance of banks and stock markets; meanwhile, the post-Keynesian school, represented by Minsky et al., focuses more on economic cycles than on stages of economic development (Mitchell et al. 2019) [16–20]. Therefore, two questions now lie ahead: What is the path of China's innovative development and independence? What are the financial institutional arrangements needed to provide an environment in which innovation can thrive at different stages of economic growth?

2. Review of the Literature

2.1. Analysis of the Two Financial Structures. An underdeveloped financial system cannot provide firms with funds to mitigate the adjustment costs of R&D, which will discourage innovation (Aghion et al., 2004) [21]. Distortions in the financial sector can reduce economic growth by reducing the rate of innovation (King and Levine, 1993) [22]. Reducing financial frictions can promote innovation and growth (Giordani, 2015) [23]. Subsidies to the financial sector may have greater growth effects than direct subsidies to research because of moral hazard (Morales, 2003) [24]. It is obviously necessary to have a good financial system in place so that firms can innovate "on their own." There are two opposing views in the literature on the relationship between financial structure and innovation: those that support a bank-based financial structure and those that support a market-based financial structure.

Arguments in favour of a bank-based financial structure for innovation discuss the reasons for this in terms of financial functions such as resource allocation, monitoring incentives, and risk management. Financial institutions assess prospective entrepreneurs and select the most promising R&D projects, mobilise resources to finance the most promising projects, spread the risks associated with innovative activities with uncertainty, and increase the level of return on high-tech investments relative to existing technologies (King and Levine, 1993) [22]. Multiple lenders investing in the same project have to bear the same monitoring costs separately, and when delegating monitoring to a financial institution as an agent, this monitoring cost is shared by multiple delegated monitoring lenders for the project. By reducing duplication of oversight, delegated oversight reduces the fixed costs of R&D, which can lead to clear expectations of positive operating profits for research firms and encourage new firms to enter the research sector (Blackburn and Hung, 1998) [25]. Intermediaries gather information and spread risk, facilitating the flow of resources to risky innovation activities (Fuente and Marín, 1996) [26]. By offering demand deposits and an appropriate mix of liquid and illiquid investments, banks can provide liquidity insurance to depositors while also promoting high-return, long-term investments (Diamond and Dybvig, 1983) [27]. Improving credit availability helps to promote innovation (Jia et al., 2017) [28].

Arguments in favour of market-based financial structures for innovation are articulated in terms of financial functions such as risk management, pooling of resources, and segmentation of shares. Capital markets can effectively provide risk management services (Saint-Paul, 1992; Lin et al., 2003) [29, 30]. The ability to hold a diversified portfolio of innovative projects reduces innovation risk and promotes investment in innovative activities (King and Levine, 1993) [22]. The liquidity of secondary securities markets provides an incentive to invest in technologies with longer maturities and higher returns (Bencivenga et al., 1995) [31]. In addition, banks will only provide liquidity if there is a sufficiently large barrier to trading in the securities market (Diamond, 1991) [32]. The industrial revolution in Britain would not have occurred if capital markets had not mitigated liquidity risk (Hicks, 1969) [33]. Good financial markets direct resources to industries where growth is driven by R&D (Ilyina and Samaniego, 2011) [34]. Stock markets promote innovation by easing financing constraints, and more developed stock markets significantly increase industry R&D expenditures (Zhong and Wang, 2017; Zhou and Lu, 2019) [35, 36]. Market-based financial structures are more conducive to innovation activities in China (Khan et al., 2018) [37]. Japan's economy, which once achieved high growth rates, has underperformed in the postindustrial period due to the ineffectiveness of the bank-based financial structure in providing financial support to high-tech industries (Lei and Wang, 2014) [38]. The inherent tendency of banks to be prudent may discourage innovation (Morck and Nakamura, 1999) [39]. Banks can use monopoly power to squeeze firms' profits through interest payments and inhibit firm innovation and growth through conservative investment policies (Weinstein and Yafeh, 1998) [40]. Faced with uncertainty related to new products and processes, banks cannot effectively collect and process information (Allen and Gale, 1999) [41].

Both arguments in favour of bank-based and market-based financial structures are valid, but what is the optimal financial structure that is embedded in the stage of economic growth? Studies have not verified the heterogeneity of the role of financial structures at different stages of economic growth; the mechanisms involved; and the conclusion that a purely pro-bank or pro-market financial structure does not explain the fact that "bank-based" Germany and Japan and "market-based" Britain and the United States all have experienced high growth rates, high levels of technology, and high per capita incomes.

2.2. Shortcomings of the Existing Literature. In addition to this, the existing literature is deficient in three aspects of the analysis. First, there is a large literature on the relationship between financial structure and innovation using firm data, but the problem is that micro rationality is not a sufficient condition for macro rationality, and using micro-firm data may lead to synthetic fallacies [34, 35, 37, 42]. To reduce the synthetic fallacy, this paper uses industry-level data. Second, existing empirical literature often uses a single indicator to measure banks and markets, and studies by Demirgüç-Kunt and Levine (1999) and Levine (2002) show that there can be large differences in rankings when different indicators are used to rank the financial structure of the same country [43, 44]. This paper uses composite indicators in both baseline regressions and robustness tests, which provide a more objective and fair assessment of the financial structure. Third, previous scholars have often used US patent office data in cross-country empirical analyses (Hsu et al., 2014; Zhou and Lu, 2019) [36, 45], which can underestimate the level of innovation in non-US economies, especially in countries or regions with less economic engagement with the US. This paper uses data aggregated by the World Intellectual Property Organization from patent offices around the world, which is more representative. In 2015, for example, WIPO shows that China (excluding Hong Kong SAR, Macao SAR, and Taiwan Province), South Korea, Russia, and Ireland had 279508, 109108, 24996, and 2331 patents, respectively, ranked as China (excluding Hong Kong SAR, Macao SAR, and Taiwan Province) > South Korea > Russia > Ireland, while the OECD database shows that the number of patents granted by the US Patent Office in China (excluding Hong Kong SAR, Macao SAR, and Taiwan Province), South Korea, Russia, and Ireland was 7558.8, 18105.3, 345.8, and 599.6, respectively, with the ranking changing to South Korea > China (excluding Hong Kong SAR, Macao SAR, and Taiwan Province) > Ireland > Russia.

2.3. Perspectives of This Paper. This paper argues that changes in the factors of production of innovation and technological progress are endogenous to a country's (or region's) technological level and urbanisation process. Based on the classification of economic growth stages by Liu et al. (2011), this paper looks for differences in the role of financial structure between the two economic stages from empirical data and then considers the economic growth stage, the risk of new technology, and optimal financial structure, taking into account Allen and Gale (1999) and development economics, in an attempt to explain the mechanism of evolution of optimal financial structure and provide empirical evidence. This paper finds that the role of market-based financial structures in innovation increases as the stage of economic growth changes. During the high growth phase, the bank-based financial structure played an important role in capital aggregation and in serving the financing needs of technology imitators, but after the normal growth phase, the innovation which is dominated by independent innovation puts forward higher requirements for the risk management function of the financial system, which is the relative advantage of the market-based financial structure.

The marginal contributions of this paper are as follows: (1) This paper examines the optimal financial structure for promoting innovation at different stages of economic growth from the human capital and R&D expenditure channels, while providing both theoretical analysis and empirical evidence. (2) The international empirical research on innovation is no longer limited to the US patent office data but uses aggregated data from patent offices around the world, thus obtaining more representative empirical new findings. (3) There are many studies on corporate innovation in the existing literature, but few pieces of research on innovation at the macro level. This paper is enrichment and reexpansion of the research on macro-level innovation, and such research can also overcome the problem of synthetic fallacies. (4) In the existing research on innovation and financial structure, a single perspective is used for financial structure indicators, which cannot comprehensively evaluate the financial structure. This paper uses composite indicators in the empirical tests, which are more objective and valid in the evaluation.

3. Theoretical Analysis

3.1. Research Ideas. We consider the relationship between economic growth stage, new technology risk, and optimal financial structure and then construct an analytical framework for the dynamic evolution of the optimal financial structure during the transition from economic growth stage in three steps, in an attempt to explain the differences and similarities between the optimal financial structure for innovation at lower and higher levels of economic development. In the first step, the logical relationship between the risk of new technology and the optimal financial structure under a single project is analysed based on Allen and Gale (1999) [41]. In the second step, the changes in the approach of technological progress in the process of economic development are analysed with reference to the development economics perspective. In the third step, Allen and Gale (1999) and development economics are combined to expand the single project into two projects; a logical framework covering the economic development process, new technology risk, and optimal financial structure is constructed; and two hypotheses are proposed based on human capital and R&D expenditure channels. In the following, they are analysed step by step.

3.2. New Technology Risks and Optimal Financial Structures. Allen and Gale (1999) based on a search matching model analysis concluded that the function

$$f(\alpha, \beta, H-L, c, I) = \alpha(1-\beta)(H-L) - \left(c - \frac{c}{I}\right), \quad (1)$$

determines the type of optimal financial structure, which is market-based when the function value is greater than 0 and bank-based when the function value is less than 0, and there is no difference between market-based and bank-based financial structures when the function value is equal to 0 [41]. Specifically, we can know from function (1) that the following factors determine whether market or intermediary finance prevails: (1) the degree of ex-ante optimism, α; (2) the diversity of views, 1 - β; (3) the risk of the project, H - L; and (4) the cost of information, c, and the number of investors, I. The economic implication of this analysis is a trade-off between the principal-agent problem and the cost of information. The severity of the principal-agent problem depends on the probability that the bank represents the wishes of the principal investor and the extent to which the bank's going against the wishes of the principal investor would result in losses to the investor. Unlike (bank) intermediated finance, market finance can mitigate the principal-agent problem. (Bank) intermediated finance can save information costs through delegated supervision, and the amount of information cost savings depends on the number of mandated investors accepted by the bank. Unlike (bank) intermediated finance, investors in market finance bear information costs independently, and investors bear higher information costs when participating in market finance.

3.3. Changes in the way Technology Progresses in the Course of Economic Development

3.3.1. The Technology Imitation-Driven Stage. At the beginning of economic development, the economy has only an agricultural sector. The technological imitation activities of enterprises lead to the creation of the nonagricultural sector, which provides jobs for the absolute surplus of labour in the agricultural sector and the migration of labour from the countryside to the towns (migrant workers to the cities), at which point urbanisation starts. The reason for the start of urbanisation is that simple labour can be competent for technological imitation activities and becomes the main human capital for the expansion and reproduction of enterprises. With fewer jobs in the nonfarm sector, more absolute surplus labour in the agricultural sector, and an excess supply of labour in the nonfarm sector, nonfarm sector firms have excess returns in the urbanisation process. In pursuit of higher excess returns, nonfarm enterprises achieve technological progress through technological imitation. After the complete migration of surplus rural labour to urban areas, located at point A in Figure 1, the oversupply of labour in the market is alleviated. Along with the expansion of the nonfarm sector, competition for the hiring of labour in the nonfarm sector causes workers' wages to rise until they reach the level of skilled farmers' income. Nonfarm firms, motivated by excess returns, continue to use technological imitation to achieve technological progress. The first stage of urbanisation is completed when wages rise to the level of skilled farmer's income, at point B in Figure 1. Technological progress at this stage is mainly driven by technological imitation, and the optimal financial structure to serve less risky technological imitation is a bank-based financial structure.

3.3.2. Technology Imitation Mature Stage. As the nonagricultural sector provides technical support to the agricultural sector, agricultural production methods shift from intensive human cultivation to mechanised scale and technology, and productivity in the agricultural sector increases. The second stage of urbanisation is initiated when it takes less labour to produce the same production, creating a relative surplus of labour. In other words, the relative surplus of labour is based on technological progress in agriculture (industry feeds agriculture). The nonfarm sector continues to pursue technological progress by imitating technology. This imitation approach to technological progress in the nonfarm sector will continue until the economy reaches the world's frontier level of mature technology, at point C in Figure 1, at which point there is no more technology to be introduced in the nonfarm sector. The urbanisation process will continue as there is still a relative surplus of labour in the agricultural sector. The surplus labour supply ensures excess returns for nonfarm enterprises, and the nonfarm sector digests and reabsorbs the introduced technology while expanding its production.

3.3.3. The Stage of Technology Independent Innovation. During the period of technological imitation in the nonfarm sector, there comes a point in the process of expansion and reproduction of enterprises, located at point D in Figure 1, at which the excess return on independent innovation equals the excess return on frontier mature technology. This signifies the end of the high growth phase driven by investment through technology imitation strategy and the beginning of the normalised growth phase driven by the innovation which is dominated by independent innovation. After point D in Figure 1, independent innovation arises and grows progressively with the expansion of excess returns, with independent innovation accounting for an increasing share of new technologies. High-tech talent plays a pivotal role in independent innovation activities, and its contribution to innovation increases as the share of independent innovation expands. In this process, technological imitation (mainly technological adaptation) coexists with independent innovation, and this situation

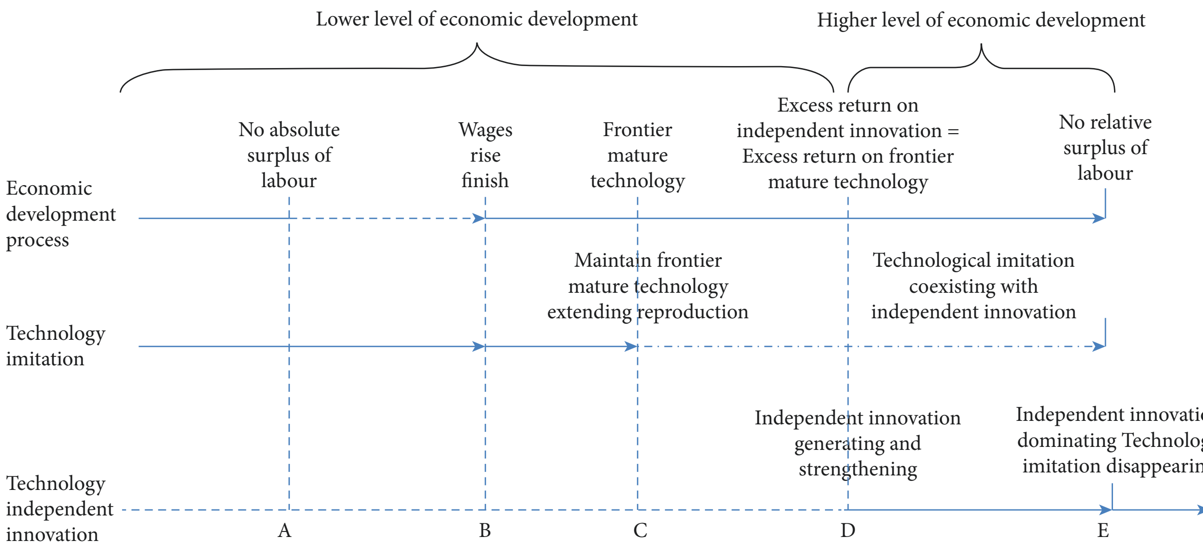

Figure 1: Changes of technological progress approach in the economic development process.

will continue until all the relatively surplus labour in the agricultural sector is transferred to the nonagricultural sector and the second stage of urbanisation is completed, at which point urbanisation ends, at point E of Figure 1. At this point, technological imitation tends to disappear and independent innovation becomes the dominant type of new technology.

3.3.4. Summary of Approaches of Technological Progress. There are two approaches of technological progress: technological imitation and independent innovation. The cost of technological progress is lower for technological imitation than for independent innovation. Before the economy reaches the level of frontier mature technology, technological progress is driven by technological imitation, followed by independent innovation, with earlier innovation being detailed improvements and localisation in the process of technological imitation and later innovation being technological exploration and transition of independent innovation. The reason why foreign firms sell more advanced technology than the domestic mature one is that mature technology exists in a large number of homogeneous firms, which can sell any number of goods at international market prices, no firm can change the price, and the entry of new firms does not change the price. Selling technology to domestic firms will not affect their sales in international markets, and even if the entry of new firms could affect prices, the benefits of selling technology to domestic firms would outweigh the reduction in sales profits, and foreign firms would still sell technology to domestic firms, and mature technology may become obsolete in the near future or has already become so.

4. Stage of Economic Growth and Optimal Financial Structure

4.1. Optimal Financial Structure. The typical facts observable in economic development are as follows: independent innovation is risky and suitable for equity market financing (e.g., Baidu, Facebook, Microsoft, and Google), and this view is also supported by the literature, e.g., Kapadia (2006), Gong et al. (2014), and Zhang et al. (2016); risk is lower for technology imitation but increases as the technology approaches the frontier, as there are fewer objects and fewer experiences to learn from [46–48]. As can be seen from the above, the difference between the expected project return of market investment and the expected project return of intermediary investment $f(H-L)$ can be expressed as

$$f(H-L) = \alpha(1-\beta)(H-L) - \left(c - \frac{c}{I}\right). \qquad (2)$$

It is easy to see from function (2) that the net return to market investment relative to intermediary investment $f(H-L)$ is a function of project risk $(H-L)$. To simplify the analysis, we assume that the domain of definition $\{H–L\}$ of $f(H-L)$ is a continuous interval and that $f(H-L)=0$ when the firm imitates the world's leading-edge mature technology. The existence of a break in the domain of definition $\{H–L\}$ does not change the conclusion.

Realistically, influenced by endowments and frictions, the level of technology in different industries and firms in the same country is not the same, project risk (H-L) shows a certain distribution, and hence $f(H-L)$ will also show a certain distribution. The value of $f(H-L)$ in this paper is ($E[f(H\text{-}L)]$), which is the mean value of $f(H-L)$. When technological progress occurs below the world frontier mature technology, technological progress arises in technological imitation (firms choose based on cost), $f(H-L)<0$, and intermediary financing prevails. When technological progress occurs in the world frontier mature technology level, technological progress arises between technological imitation and independent innovation, and intermediary financing is not different from market financing (a condition that guarantees continuous derivability of $f(H-L)$). When technological progress occurs above the level of mature technology at the world frontier, technological progress can only arise in independent innovation, and market finance prevails. When only projects with $f(H\text{-}L)<0$ exist, the optimal financial structure is intermediary-led, and when there are two types of projects with $f(H\text{-}L) \le 0$ and $f(H\text{-}L) > 0$, the optimal financial structure is determined by the ratio of the two types of projects. As the proportion of items with $f(H\text{-}L) > 0$ rises after the high-income wall (located at point D in Figure 1), the relative share of market finance in the optimal financial structure rises, reaching a maximum at point E in Figure 1.

4.2. Two Hypotheses

Hypothesis 1. At lower levels of economic development, market-based financial structures do not significantly promote innovation, and at higher levels of economic development, market-based financial systems significantly promote innovation. The relationship between financial structure and innovation is shown in Figure 2.

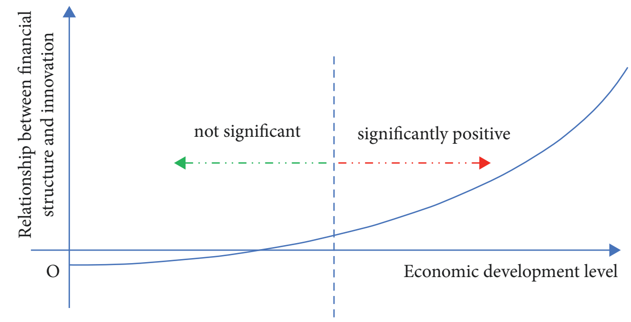

Figure 2: Relationship between financial structure and innovation at different levels of economic development.

As the level of economic development increases, a shift in innovation approaches takes place in the economy, which is a direct result of the evolution of the role of the financial structure in innovation. At lower levels of economic development, the innovation approach in an economy is dominated by technological imitation, while at higher levels of economic development, the innovation approach in an economy is dominated by independent innovation. The characteristics of human capital committed to innovation change with the way in which it is innovated, as do the characteristics of R&D costs.

Throughout the process of economic development, the reduction of excess returns to technological imitation is the reason for generating point D in Figure 1, prior to which excess returns led to a rapid expansion of the nonfarm sector and high economic growth, with the miracle of economic growth arising in this interval. The low level of economic development was dominated by the simple labour force, which acted as the backbone of technological imitation activities and was committed to the socialisation of mass production after the introduction of technology, providing the necessary preconditions and incentive compatible conditions for technology introduction and technological transformation. The accumulation of human capital for simple labour is completed by debt financing, as the surplus rural labour force is transformed into the simple labour required for the nonagricultural sector in towns and cities through the purchase of houses for settlement; i.e., real estate investment accumulates simple labour for towns and cities.

After point D in Figure 1, the economy begins to move to a higher level of economic development, and for economies that have achieved high growth rates, the economy has since steadily shifted to normalised growth. Point D in Figure 1 is what Liu et al. (2011) refer to as the wall of high income [15], where the economy is close to full employment. In other words, point D in Figure 1 is the watershed between the lower stage of economic development and the higher stage of economic development. Constrained by the knowledge threshold for independent innovation, high-tech talent becomes the core human capital for independent innovation. At higher levels of economic development, the financialisation of the human capital of high-tech talent relies on the equity financing and the realisation of human capital value through innovative enterprises. This is because high-tech talent is a high-risk human capital, and the risk to the enterprise once the technical talent leaves is high; debt financing is not sufficient to manage such risk, and equity financing is needed to promote the accumulation of high-tech human capital, which in turn promotes independent innovation in this period. At point E in Figure 1, the economy ends urbanisation, firms without independent innovation have no excess returns as in the agricultural sector, and innovation consists of independent innovation.

Before point D in Figure 1, bank lending favours technological imitation, and the optimal financial structure is bank-based. After point D in Figure 1, however, the financial market services required for independent innovation also increase, the importance of the market in finance rises, and the proportion of market finance in the optimal financial structure rises, reaching a maximum at point E in Figure 1, where the optimal financial structure morphs into a market-dominated financial structure. Technology imitation at point D in Figure 1 is mainly related to detail upgrading, while at point E in Figure 1, economies are already using modern mature technology in most of their resources.

We can explain the impact of innovation approaches on the role of financial structures not only in terms of human capital characteristics but also by further dissecting them in terms of R&D cost characteristics. At lower stages of economic development, when economies are far from the technological frontier and technological progress is driven by technology introduction and technological adaptation, product development costs are low and risks are low, and banks and financial markets are willing to finance innovative activities. Even long-term banking relationships ensure that firms' technology development and diffusion activities run smoothly and are not disturbed by financing constraints. At higher levels of economic development, where economies are close to the technological frontier and technological progress is driven by independent innovation, product development is costly and risky, and innovation requires more risk management functions from financial markets. Based on the human capital perspective and the R&D cost perspective, we elucidate how the innovation approach affects the relationship between financial structure and innovation, and to this end, we propose hypothesis 2.

Hypothesis 2. The bank-based financial structure promotes innovation when the economy's innovation approach is dominated by technological imitation; the market-based financial structure significantly contributes to innovation growth when the economy's innovation approach is dominated by independent innovation. The specific structure is shown in Figure 3.

5. Data Sources and Model Design

5.1. Data Sources. The patent data in this study are from the World Intellectual Property Organization (WIPO) and are based on the location of the applicant for the patent for the invention. Data on financial structure are from the World Bank's Financial Development Database (GFDD). Per capita income data used to classify economic growth stages are from the Maddison Database. Value added by industry is from the OECD database. R&D personnel, the share of employed population in industry and services, and R&D expenditure (ratio to GDP) are from the World Bank database. The data sample period is 1996–2015 and covers manufacturing industry data for 59 countries or regions.

5.2. Model Design. To test hypothesis 1, this paper draws on Hsu et al. (2014) and Zhou and Lu (2019) to construct a baseline regression model as follows [36, 45].

$$INN_{i,j,t} = \alpha + \beta_1 D_{i,t} + \beta_2 D_{i,t} \times FS_{i,t} + \beta_3 FS_{i,t} + \beta_4 Z_{i,j,t} + \mu_{i,j} + \tau_t + \varepsilon_{i,j,t}, \quad (3)$$

$$INN_{i,j,t} = \alpha + \beta_1 D_{i,t} + \beta_2 D_{i,t} \times FS_{i,t} + \beta_3 FS_{i,t} + \beta_4 Z_{i,j,t} + \mu_i + \mu_j + \tau_t + \varepsilon_{i,j,t}. \quad (4)$$

In model (3) and model (4), i, j, t stands for country, industry, and year. $INN_{\mathrm{i,j,t}}$ stands for the size of patents granted in country or region i and industry j in year t. $D_{i,t}$ stands for the level of per capita income, based on the Maddison Database 1990 price international dollar per capita income, and $D_{i,t}$ is 1 when per capita income is greater than or equal to \$11000 and 0 otherwise. $FS_{i,t}$ stands for financial structure and is based on the Demirgüç-Kunt and Levine's (1999) approach to constructing a composite index of financial structure, which measures financial structure in terms of three dimensions: size, activity, and efficiency [43]. The control variables consist of two indicators, $FD_{\mathrm{i,t}}$ and $VA_{i,j,t}$. $FD_{i,t}$ represents the financial development index, and the data are from the IMF's working paper Svirydzenka (2016) [49]. Levine (2002) [44] refers to financial development rather than financial structure as contributing to economic growth; therefore, to study the role of financial structure, one needs to control for the financial development. $VA_{i,j,tt}$ represents the value added in year t of industry j in country or region i as a proportion of value added in manufacturing in year t in country or region i. This control variable is consistent with the models of Hsu et al. (2014) and Zhou and Lu (2019) [36, 45]. $\varepsilon_{i,j,t}$ represents the disturbance term. Fixed effects are set in two ways to allow for comparison and to increase model credibility. Conventionally, the fixed effects in model (3) control for both individual fixed effects $\mu_{i,j}$ (country-industry fixed effects) and time fixed effects. Following Zhou and Lu (2019) [45], the fixed effects in model (4) control for three high-dimensional fixed effects: country effects μ_i, industry effects μ_j, and time effects τ_t.

To test hypothesis 2, the following model was constructed.

$$INN_{i,j,t} = \alpha + \beta_1 TER_{i,t} + \beta_2 TER_{i,t} \times FS_{i,t} + \beta_3 FS_{i,t} + \beta_4 Z_{i,j,t} + \mu_{i,j} + \tau_t + \varepsilon_{i,j,t}. \quad (5)$$

In model (5), $TER_{\mathrm{i,t}}$ represents the innovation approach in country i in year t. The innovation approach is measured in terms of both human capital characteristics and R&D cost characteristics, using two indicators of R&D personnel/nonfarm population ($LA_{i,t}$) and R&D cost ($CO_{i,t}$). $\mu_{i,j}$ represents country-industry effects, τ_t represents time effects, and the remaining variables are the same as in the baseline regression.

5.3. Description of Variables. The specific meanings of the variables in the above model setting and the method of construction are as follows.

Size of patent grants ($INN_{i,j,t}$): This indicator is equal to the natural logarithm of the number of patents granted according to the applicant's place of origin plus one. This indicator is used to measure industry innovation and is derived from data from the World Intellectual Property Organization (WIPO), which counts the official patent offices of over 100 economies covering the vast majority of the world's population and economy. This data solves the problem of the underestimation of the number of patents granted in each country in the literature using only USPTO data and provides a more accurate and desirable measure of industry innovation activity in each country of the world. This paper defines national innovation as the innovation

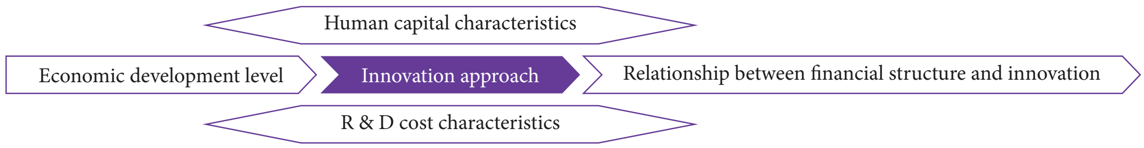

Figure 3: Impact mechanisms of financial structure on innovation.

output of a country (economic agent in general or) in a particular field, using the national novelty criterion for innovation outcomes (Hu and Mathavs, 2007) [50]. For this purpose, this indicator is selected as a proxy variable for national innovation in this paper by referring to Hsu et al. (2014) and Zhou and Lu (2019) [36, 45].

Per capita income level ($D_{i,t}$): The income per capita ($D_{i,t}$) is a dummy variable used to distinguish between lower stages of economic development and higher stages of economic development. Based on data from the Maddison Database measured at 1990 prices, per capita income level ($D_{i,t}$) is 1 when per capita income is greater than or equal to 11000 international dollars and 0 otherwise.

Financial structure ($FS_{i,t}$): Following the approach of Demirgüç-Kunt and Levine (1999) [43], we define the financial structure ($FS_{i,t}$) as the ratio of stock market development (tested by size, activity, and efficiency) relative to banking sector development (also tested by size, activity, and efficiency). Indicator of the size of the financial structure = value of domestic equities/total domestic assets of deposit money banks. Indicator of the activity of the financial structure = value of the trades of domestic equities on domestic exchanges/deposit money bank credits to (and other claims on) the private sector. Indicator of financial structure efficiency = (value of the trades of domestic equities on domestic exchanges/GDP) × (bank overhead costs/total assets of the banks). The equally weighted average of the three-dimensional indicators in this paper is used as the financial structure ($FS_{i,t}$). This indicator measures the comparative role of banks and markets in the economy [43], with larger values indicating a more market-based financial structure. Data are obtained from the World Bank Financial Development Database.

R&D personnel/nonfarm population ($LA_{i,t}$): This indicator is the ratio of the R&D personnel indicator to the nonfarm population indicator. Data are obtained from the World Bank database. The R&D personnel indicator is researchers in R&D (per million people). The nonfarm population indicator is the sum of employment in industry (% of total employment) and employment in services (% of total employment).

R&D costs ($CO_{i,t}$): This indicator is the ratio of R&D expenditure to the number of patents, in millions of dollars per patent. R&D expenditure is the current and capital expenditure on systematic innovation efforts, including basic research, applied research, and experimental development. Data on R&D expenditure as a proportion of GDP and GDP (2010 constant prices) are obtained from the World Bank database. The number of patents refers to the number of resident patent applications, and data are obtained from the World Bank database. The high cost of R&D is a characteristic that distinguishes independent innovation from technological imitation.

Financial development index ($FD_{i,t}$): The IMF working paper Svirydzenka (2016) constructs a composite index that evaluates the depth (market size and liquidity), accessibility (the ability of individuals and firms to access financial services), and efficiency (ability of institutions to provide financial services at low cost and with sustainable income, and the level of activity in capital markets) of financial institutions and financial markets [49]. The financial institutions covered by the index include banks, insurance companies, mutual funds, and pension funds, and the financial markets covered by the index include stock and bond markets. The index normalises the true value and does not measure the growth rate of the relevant value. Data are obtained from Svirydzenka (2016) [49].

Value added by industry ($VA_{i,j,t}$): Value added by industry ($VA_{i,j,t}$) is equal to the ratio of value added by industry to value added by manufacturing in the country. Data is from OECD database. The descriptive statistics of the main variables in the empirical test of this paper are shown in Table 1 and Figures 4–6.

6. Analysis of Empirical Results

6.1. Baseline Regression Results

6.1.1. Preliminary Regression Results. See Table 2 for specific regressions.

At lower levels of economic development, market-based financial structures do not significantly promote innovation, and at higher levels of economic development, market-based financial systems significantly promote innovation. This is due to changes in the intrinsic demand for finance in the economy as the stage of economic development evolves, which gives rise to changes in the relationship between financial structure and innovation. Table 2 records the results of the baseline regression model, which focuses on the role of financial structure at different stages of per capita income. The coefficient on financial structure in column (1) is −0.0042, which is not significant; the coefficient on the interaction term between financial structure and per capita income level is 0.2261 and is significant. Column (2) has a nonsignificant coefficient of −0.0042 on financial structure and a significant coefficient of 0.2261 on the interaction term between financial structure and per capita income level. Columns (3) and (4) use country-industry clustering standard errors instead of country clustering standard errors. The coefficient on financial structure in column (3) is −0.0042, which is not significant; the coefficient on the interaction term between financial structure and per capita income level is 0.2261 and is significant. Column (4) has a nonsignificant coefficient of -0.0042 on financial structure

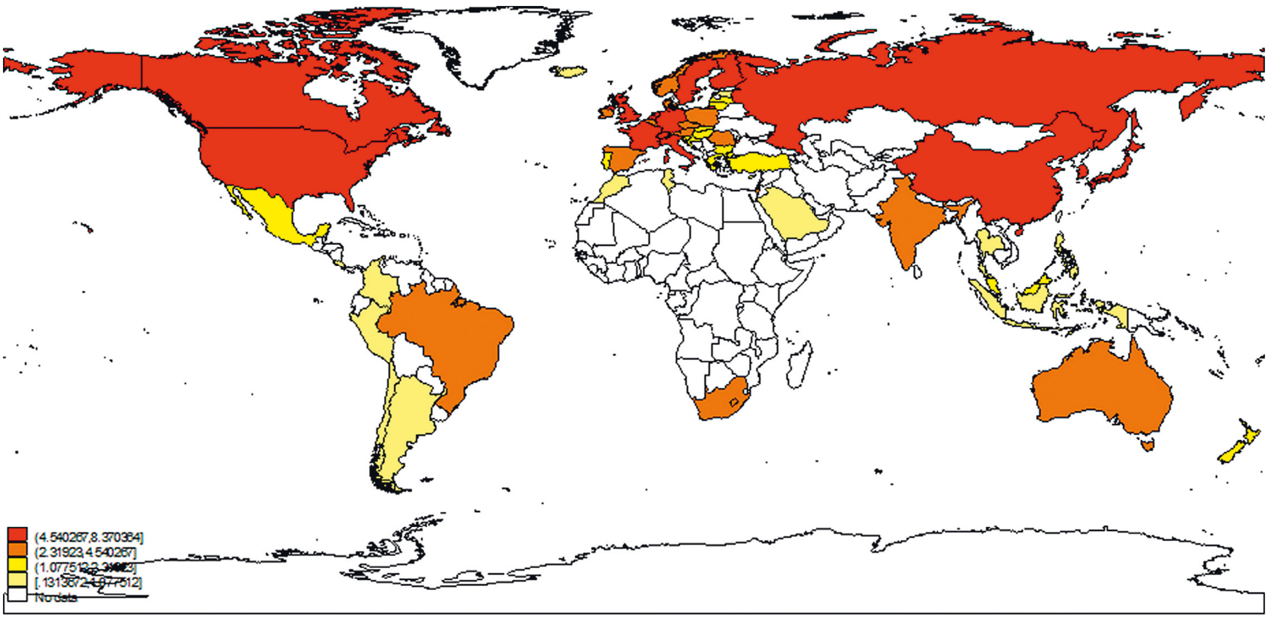

Figure 4: A map of the size of patent grants of economies. The size of patent grants is the mean value of size of patent grants (INN) during the sample period, and calculation method can be seen above in the paper. The data of China in the map does not include Hong Kong SAR (China), Macao SAR (China), and Taiwan (China). The map shows data of 58 economies, excluding Hong Kong SAR (China), because of the lack of geographical location data of Hong Kong SAR (China). Data source: WIPO and Boston College website.

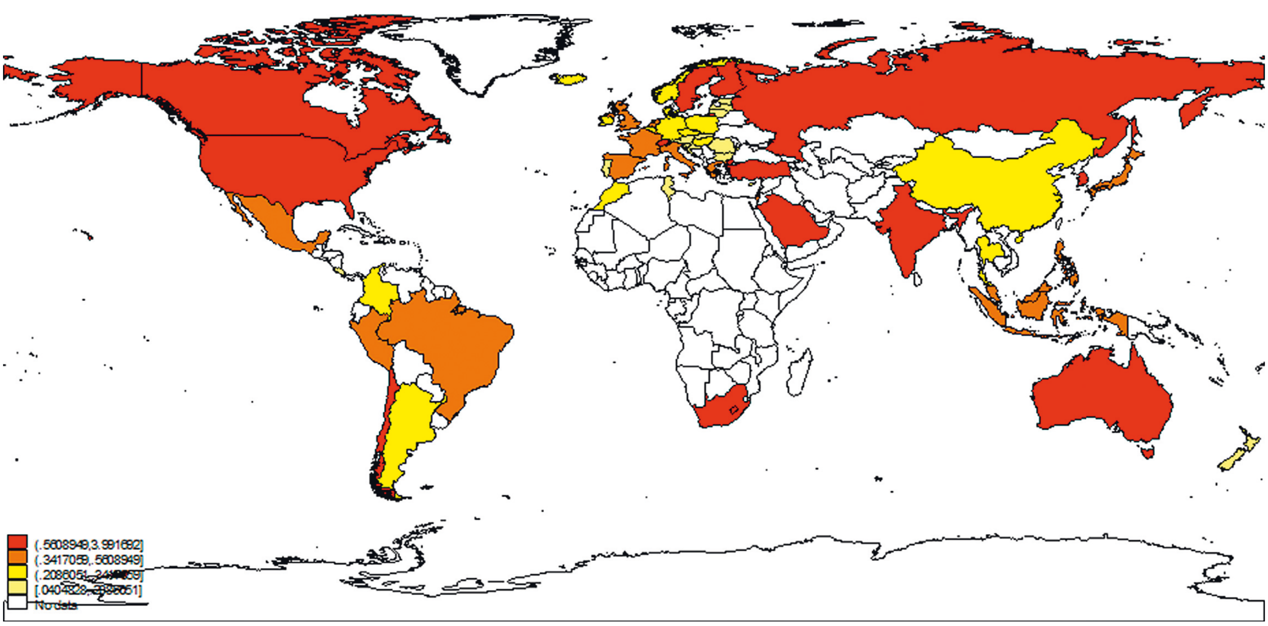

Figure 5: A map of the financial structure of economies. The financial structure is the mean value of financial structure (FS) during the sample period, and calculation method can be seen above in the paper. The data of China in the map does not include Hong Kong SAR (China), Macao SAR (China), and Taiwan (China). The map shows data of 58 economies, excluding Hong Kong SAR (China), because of the lack of geographical location data of Hong Kong SAR (China). Data source: World Bank Financial Development Database and Boston College website.

and a significant coefficient of 0.2261 on the interaction term between financial structure and per capita income level. This suggests that at lower levels of economic development, bank-based financial structures favour innovation, while at higher levels of economic development, market-based financial structures favour innovation. This confirms hypothesis 1 that the market-based financial structure does not play a significant role in promoting innovation until the higher levels of economic development. Columns (5) and (6) replace the level of per capita income (dummy variable) in the first two columns with GDP per capita and are used to test the plausibility of I$11000 as the turning point of the per

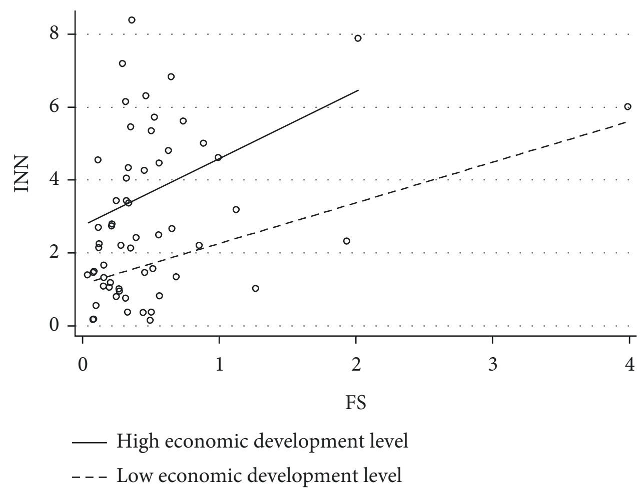

Figure 6: Scatter chart of financial structure and the size of patent grants. The financial structure and the size of patent grants are the mean values during the sample period, and calculation method can be seen above in the paper. If the mean value of per capita GDP at 1990 prices is greater than or equal to 11000 international dollars, we consider sample economies as high economic development level ones. Otherwise, we consider sample economies as low economic development level ones. The figure shows data of 59 economies. Data source: World Bank Financial Development Database, WIPO, and Maddison Database.

Table 1: Descriptive statistics for key variables.

Variables	Definition	Observations	Average value	Standard deviation	Minimum value	Maximum value
Country-industry						
INN	Size of patent grants	23600	2.9018	2.4230	0	11.1982
VA	Value added by industry	23600	0.0500	0.0440	−0.0066	0.5300
Country						
D	Per capita income level	1180	0.5780	0.4941	0	1
FS	Financial structure	1100	0.5277	0.8856	0.0018	15.3582
LA	R&D personnel/nonfarm population	897	27.8169	18.1539	0.5278	85.4619
CO	R&D costs	965	4.4395	5.0371	0.1888	57.0127
FD	Financial development index	1180	0.5399	0.2055	0.1072	1.0000

Note. FDs are in %.

capita income stage. By substituting the GDP per capita observations, the confidence interval for GDP per capita (for the turnaround in the role of financial structure) is found for the corresponding country year at the 5% significance level (eliminating the interval obtained by the observation values that do not participate in regression). The original hypothesis is that I$11000 falls within this interval. The *p*-values of the original hypothesis in columns (5) and (6) are 0.59 and 0.71, respectively, both of which are greater than 0.05, and the original hypothesis cannot be rejected. Therefore, we can think that I$11000 is reasonable as a stage turning point. Hsu et al. (2014) found that market-based financial structure is positively correlated with innovation, and this paper builds on their findings that this positive correlation is bound to the interval of higher per capita income [45].

6.1.2. For the Endogeneity Treatment. The results of the baseline regression endogeneity treatment-panel instrumental variables method are shown in Table 3.

We use the panel instrumental variables method for endogeneity tests. Columns (1), (2), and (3) in Table 3 use the corruption control index as an instrumental variable; see Demirgüç-Kunt and Levine (1999) [43] for the effect of corruption on the financial structure. Columns (1) and (2) are first-stage regressions, and column (3) is a second-stage regression. The coefficient of the interaction term between corruption control and per capita income level in column (1) is 0.3014, which is significant. The coefficient of the corruption control in column (2) is −0.0707, which is significant. Column (3) has a significant coefficient of 0.9643 for the interaction term between financial structure and per capita income level. Columns (4), (5), and (6) refer to Jing et al. (2017) [51] using financial structure (and its interaction term with per capita income level) lagged by one period and financial structure (and its interaction term with per capita income level) lagged by two periods as instrumental variables. Columns (4) and (5) are first-stage regressions, and column (6) is a second-stage regression. The one-period lagged coefficient of the interaction term between financial structure and per capita income level in column (4) is 1.1608, which is significant; the two-period lagged coefficient of the interaction term between financial structure and per capita income level is -0.4388, which is significant; and both are cumulatively positive. The one-period lagged coefficient of

Table 2: Baseline regression results.

$INN_{i,j,t}$	(1)	(2)	(3)	(4)	(5)	(6)
Di,t	−0.1175	−0.1175	-0.1175^{***}	-0.1175^{***}	—	—
	(0.1018)	(0.1019)	(0.0351)	(0.0280)	—	—
$D_{i,t} \times FS_{i,t}$	0.2261^{***}	0.2261^{***}	0.2261^{***}	0.2261^{***}	—	—
	(0.0502)	(0.0502)	(0.0248)	(0.0240)	—	—
$FS_{i,t}$	−0.0042	−0.0042	−0.0042	−0.0042	-0.0444^{***}	-0.0444^{***}
	(0.0098)	(0.0098)	(0.0052)	(0.0078)	(0.0143)	(0.0145)
Per $GDP_{i,t}$	—	—	—	—	$\leq 0.0001^{***}$	$\leq 0.0001^{***}$
	—	—	—	—	(≤0.0001)	(≤0.0001)
Per $GDP_{i,t} \times FS_{i,t}$	—	—	—	—	$\leq 0.0001^{***}$	$\leq 0.0001^{***}$
	—	—	—	—	(≤0.0001)	(≤0.0001)
$FD_{i,t}$	0.9756^{*}	0.9756^{*}	0.9756^{***}	0.9756^{***}	1.0151^{***}	1.0151^{***}
	(0.5334)	(0.5336)	(0.1525)	(0.1002)	(0.1481)	(0.1000)
$VA_{i,j,t}$	0.7547^{***}	3.5318^{***}	0.7547^{*}	3.5318^{***}	0.7547^{*}	3.5318^{***}
	(0.2387)	(0.4080)	(0.4474)	(0.1275)	(0.4432)	(0.1274)
Constant term	2.1619^{***}	2.1980^{***}	2.1619^{***}	2.1980^{***}	1.7231^{***}	1.6569^{***}
	(0.2562)	(0.2673)	(0.0750)	(0.0562)	(0.1182)	(0.0794)
Time effect	Control	Control	Control	Control	Control	Control
Country-industry effects	Control	—	Control	—	Control	—
Other fixed effects	—	Country/industry	—	Country/industry	—	Country/industry
Clustering	Country	Country	Country-industry	—	Country-industry	—
Observations	22000	22000	22000	22000	22000	22000
$R2$ value	0.2285	0.9243	0.2285	0.9243	0.2324	0.9245
Number of individuals	1180	—	1180	—	1180	—

***stands for $p < 0.01$, ** stands for $p < 0.05$, * stands for $p < 0.1$. The following tables are the same. Per GDP stands for GDP per capita. Column (1), column (2), column (3), and column (5) are clustered robust standard errors in parentheses; columns (4) and (6) are reported in parentheses with reference to Zhou and Lu (2019) ordinary standard errors [36]. Controlling for time effects (annual effects) and individual effects (country-industry effects) and reporting individual (country-industry) clustering standard errors are a regular practice in the literature for fixed effects panel models; controlling for country, industry, and time three-dimensional fixed effects and reporting ordinary standard errors (or unadjusted t-values) are the practice in the paper by Zhou and Lu (2019) for comparison [36].

financial structure in column (5) is 1.3629, and the two-period lagged coefficient of financial structure is -0.6007, which is significant and positive cumulatively. The coefficient of the interaction term between financial structure and per capita income level in column (6) is 0.2171, which is significant. The second-stage regressions in columns (3) and (6) show that the market-based financial structure is more significant in promoting innovation at higher levels of economic development.

Instrumental variables can deal with measurement errors, omitted explanatory variables, and mutual causation at the same time. Once the disturbance term is related to the explanatory variable, the explanatory variable coefficient cannot be correctly estimated. At this time, an instrumental variable needs to be found, which is closely related to the explanatory variable but has no relationship with the explained variable. The endogeneity test validates the results of the baseline regressions, indicating that market-based financial structures significantly promote innovation only at higher levels of economic development.

6.1.3. Replacement of Sensitive Variables or Sectoral Classifications. Replacement of sensitive variables or sectoral classifications is specified in Table 4.

The ratio of the financial market development index to the financial institutions development index in the IMF financial development index series is used as the IMF financial structure (IMFFS) in columns (1) and (2) of Table 4, and the new index takes into account the development of the bond market compared to the financial structure index in the baseline regression. The coefficient on the interaction term between financial structure and per capita income level is significantly positive in both columns (1) and (2), and the coefficient on financial structure is insignificant in both cases. Since the coefficients on financial structure in columns (1) and (2) are not significantly positive, the ratio of the number of patents granted to industry value added (INA) under the SIC classification is used to replace the size of patents granted (INN) as the explained variable in columns (3) and (4) of Table 4. The coefficient on the interaction term between financial structure and per capita income level is significantly positive in both columns (3) and (4), and the coefficient on financial structure is significantly negative in both columns. This suggests that bank-based financial structure favours innovation at lower levels of economic development and market-based financial structure significantly promotes innovation at higher levels of economic development. We then ran the regressions on the Eora database sectoral classification criteria, with the sectoral classification of patents granted (*INA*) representing the size of patents granted by Eora database sectoral classification and the remaining variables matched from the USSIC classification to the Eora sectoral classification. Although there are more USSIC classifications than Eora sectoral classifications, the

Table 3: Baseline regression endogeneity treatment-panel instrumental variables approach.

Staging	(1) Stage 1	(2) Stage 1	(3) Stage 2	(4) Stage 1	(5) Stage 1	(6) Stage 2
Variables	$D_{i,t} \times FS_{i,t}$	$FS_{i,t}$	$INN_{i,j,t}$	$D_{i,t} \times FS_{i,t}$	$FS_{i,t}$	$INN_{i,j,t}$
$D_{i,t}$	0.0895***	−0.1823***	−0.3105**	0.0906***	−0.0188***	−0.0884**
	(0.0223)	(0.0249)	(0.1371)	(0.0069)	(0.0052)	(0.0364)
$D_{i,t} \times CC_{i,t}$	0.3014***	0.1779***	—	—	—	—
	(0.0256)	(0.0340)	—	—	—	—
$CC_{i,t}$	0.0239	−0.0707*	—	—	—	—
	(0.0190)	(0.0382)	—	—	—	—
$D_{i,t-1} \times FS_{i,t-1}$	—	—	—	1.1608***	−0.0984***	—
	—	—	—	(0.0130)	(0.0093)	—
$D_{i,t-2} \times FS_{i,t-2}$	—	—	—	−0.4388***	0.0776***	—
	—	—	—	(0.0111)	(0.0124)	—
$FS_{i,t-1}$	—	—	—	0.0006	1.3629***	—
	—	—	—	(0.0012)	(0.0016)	—
$FS_{i,t-2}$	—	—	—	0.0024**	−0.6007***	—
	—	—	—	(0.0011)	(0.0031)	—
$FD_{i,t}$	0.3911***	2.1639***	1.3531	0.0688**	0.6142***	0.9296***
	(0.0500)	(0.2890)	(1.2556)	(0.0271)	(0.0922)	(0.1828)
$VA_{i,j,t}$	≤0.0001	≥−0.0001	0.5654	≤0.0001	≥-0.0001	0.5121
	(0.1937)	(0.3767)	(0.4047)	(0.0665)	(0.0915)	(0.4041)
$D_{i,t} \times FS_{i,t}$	—	—	0.9643***	—	—	0.2171***
	—	—	(0.3001)	—	—	(0.0247)
$FS_{i,t}$	—	—	−0.3296	—	—	0.0070
	—	—	(0.6356)	—	—	(0.0048)
Constant term	−0.2666***	−0.8761***	2.0895***	−0.0128	−0.2125***	2.1511***
	(0.0258)	(0.1705)	(0.3141)	(0.0169)	(0.0511)	(0.0990)
Stage I Sanderson–Windmeijer multivariate F-test	0.0152	0.0038	—	0.0000	0.0000	—
Kleibergen–Paap rk LM test	—	—	0.0144	—	—	0.0000
Sargan–Hansen test	—	—	0.0000	—	—	0.0000
Time effect	Control	Control	Control	Control	Control	Control
Country-industry effects	Control	Control	Control	Control	Control	Control
Observations	18620	18620	18620	19280	19280	19280
R^2 value	0.1750	0.0886	0.0389	0.7636	0.8333	0.2307
Number of individuals	1180	1180	1180	1180	1180	1180

Note. 1. Country-industry clustering robust standard errors are in parentheses. 2. Columns (1) to (3) instrumental variables are World Governance Index corruption controls, and columns (4) to (6) instrumental variables are endogenous variables lagged by one and two periods. 3. *CC* stands for corruption controls. Corruption control data are derived from the World Governance Index published by the World Bank.

Eora database provides a larger number of individual countries (or regions) in the input-output table than the OECD database does. In columns (7) and (8), we expand the range of matched countries (or regions) to 97 and observe whether the results are (generally) robust after the sample expansion. The coefficient on the interaction term between financial structure and per capita income level is significantly positive in columns (5), (6), (7), and (8), and the coefficient on financial structure is negative in all cases. Again, this suggests that a bank-based financial system is conducive to innovation at lower levels of economic development and a market-based financial system is good for innovation at higher levels of economic development. Both the substitution-sensitive variables and the sectoral classification results are consistent with the baseline regression results.

6.1.4. Mutation Point Value Intervals. The financial structure and innovation within the different GDP per capita quantile intervals are shown in Table 5.

As GDP per capita rises, the role of market-based financial structures in promoting innovation shifts from insignificant to significant. This is because as the economy grows, the innovation approach changes, and the intrinsic demand for finance in the economy changes as well. As can be seen through Table 5, the effect of financial structure on innovation is statistically insignificant when GDP per capita (in the 0%–20% quantile range) is less than I$6425. When GDP per capita (in the 20%–40% quantile range) is greater than I$6425 and less than I$9747, the effect of financial structure on innovation is economically insignificant at 0.0263. When GDP per capita (in the 40%–60% quantile range) is greater than I$9747 and less than I$17070, financial structure has a significant contribution to innovation. When GDP per capita (in the 60%–80% quantile range and the 80%–100% quantile range) is greater than I$17070 and less than I$22584 and greater than I$22584, the financial structure still contributes significantly to innovation growth. Accordingly, we infer that when GDP per capita (in the 40%–60% quantile range) is greater than I$9747 and less than I$17070, there is a structural shift in the role of financial

Table 4: Replacement of sensitive variables or sectoral classifications.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$INN_{i,j,t}$		$INA_{i,j,t}$		$IND_{i,j,t}$			
$D_{i,t}$	−0.2394***	−0.2394***	−0.0853***	−0.0853***	−0.1305**	−0.1305***	−0.0700	−0.0700*
	(0.0469)	(0.0334)	(0.0231)	(0.0127)	(0.0578)	(0.0401)	(0.0489)	(0.0374)
$D_{i,t}$ × $IMFFS_{i,t}$	0.3042***	0.3042***	—	—	—	—	—	—
	(0.0747)	(0.0520)	—	—	—	—	—	—
$IMFFS_{i,t}$	0.0273	0.0273	—	—	—	—	—	—
	(0.0627)	(0.0278)	—	—	—	—	—	—
$D_{i,t}$ × $FS_{i,t}$	—	—	0.2074***	0.2074***	0.2196***	0.2196***	0.1437***	0.1437***
	—	—	(0.0763)	(0.0109)	(0.0341)	(0.0343)	(0.0336)	(0.0350)
$FS_{i,t}$	—	—	−0.0221***	−0.0221***	−0.0094	−0.0094	−0.0117	−0.0117
	—	—	(0.0080)	(0.0035)	(0.0083)	(0.0111)	(0.0082)	(0.0118)
$FD_{i,t}$	0.7617***	0.7617***	−0.1142	−0.1142**	1.0917***	1.0917***	1.1795***	1.1795***
	(0.2167)	(0.1134)	(0.0837)	(0.0455)	(0.2343)	(0.1436)	(0.2036)	(0.1321)
$VA_{i,j,t}$	0.7562*	3.5757***	−1.1814***	−1.0619***	2.5096*	1.8500***	2.5494*	1.1681***
	(0.4066)	(0.1186)	(0.2766)	(0.0579)	(1.5151)	(0.1092)	(1.3437)	(0.0983)
Constant term	2.2412***	2.2547***	0.2032***	0.2106***	2.6084***	2.9053***	1.5851***	1.9246***
	(0.0876)	(0.0561)	(0.0350)	(0.0255)	(0.1974)	(0.0808)	(0.1664)	(0.0603)
Time effect	Control	Control	Control	Control	Control	Control	Control	Control
Country-industry effects	Control	—	Control	—	Control	—	Control	—
Other fixed effects	—	Country/ industry	—	Country/ industry	—	Country/ industry	—	Country/ industry
Clustering	Country-industry	—	Country-industry	—	Country-industry	—	Country-industry	—
Observations	24000	24000	22000	22000	9900	9900	15147	15147
R^2 value	0.1950	0.9222	0.0391	0.2144	0.2705	0.9394	0.1903	0.9322
Number of individuals	1200	—	1180	—	531	—	873	—

Note. 1. Columns (1), (3), (5), and (7) are clustered robust standard errors in parentheses, and columns (2), (4), (6), and (8) are ordinary standard errors in parentheses. 2. IMF financial structure (IMFFS) is the ratio of the financial market development index to the financial institutions development index using the series of financial development indices constructed by Svirydzenka (2016) [49]. 3. The ratio of the number of granted patents to industry value added (INA) represents the ratio of the number of granted patents to industry value added under the SIC classification 4. The sectoral classification of granted patents (IND) represents the size of granted patents by sectoral classification in the Eora database, i.e., the natural logarithm of the number of granted patents plus one. 5. The Eora database provides data on the Eora sectoral classification, and the OECD database provides data on the USSIC industry classification. The number of sectors in the Eora database is less than the number of industries in the USSIC, but the number of countries in the Eora database is more than the number of countries in the OECD database.

Table 5: Financial structure and innovation in different GDP per capita quartiles.

GDP per capita quantile	0%–20%	20%–40%	40%–60%	60%–80%	80%–100%
$INN_{i,j,t}$	(1)	(2)	(3)	(4)	(5)
Per $GDP_{i,t}$	0.0004***	≤0.0001	≥−0.0001	0.0001***	≤0.0001***
	(0.0001)	(≤0.0001)	(≤0.0001)	(≤0.0001)	(≤0.0001)
$FS_{i,t}$	−0.0344	0.0263***	0.1789**	0.0834**	0.1028***
	(0.0551)	(0.0060)	(0.0769)	(0.0342)	(0.0239)
$FD_{i,t}$	−1.5468***	1.2613***	0.8033***	−0.3049*	−0.1120
	(0.3654)	(0.3362)	(0.2689)	(0.1657)	(0.1547)
$VA_{i,j,t}$	−1.0771	1.6121	1.3641**	1.2470	−0.0023
	(1.2671)	(1.1073)	(0.6595)	(0.8086)	(0.4831)
Constant term	0.5074	0.7573***	1.0485***	3.1272***	3.4141***
	(0.3294)	(0.1980)	(0.1629)	(0.2066)	(0.2192)
Time effect	Control	Control	Control	Control	Control
Country-industry effects	Control	Control	Control	Control	Control
Observations	4400	4400	4400	4400	4400
R^2 value	0.1266	0.1949	0.2560	0.1871	0.2985
Number of individuals	440	440	480	520	380

Note. Country-industry clustering robustness criteria errors are in brackets. The same applies to Table 6.

structure on innovation, with the effect of market-based financial structure on innovation shifting from insignificant to significant. In other words, when GDP per capita is less than I$9747, financial structure has no significant effect on innovation; when GDP per capita is greater than I$9747 and less than I$17070, the level of significance of the effect of financial structure on innovation shifts; when GDP per capita is greater than I$17070, market-based financial structure strongly promotes innovation. Allen and Gale (1999) suggest that the optimal financial structure may shift from bank-based to market-based as the risk of new technology increases [41]. This provides a theoretical basis for the empirical findings of this paper, giving possible reasons for the shift in the role of financial structure on innovation at different stages of economic development in terms of the type of new technology risk. The empirical validation of this theoretical explanation is given in the next part of the paper.

6.2. Mechanistic Analysis of Financial Structures and Innovation. There are differences in the labour force characteristics and R&D cost characteristics between the innovation approach of technology imitation and that of independent innovation. Specifically, technology imitation is mainly driven by simple labour, the need for high-tech talent is less than that of independent innovation, and the existence of mature technology for reference reduces R&D costs to a certain extent; independent innovation relies mainly on high-tech talent, the market-based financial structure helps to mitigate the higher risk of human capital loss, and the lack of mature technology to support frontier exploration pushes up the trial-and-error costs of R&D, with its R&D costs being higher than those of technology imitation. As the stage of economic development changes, firms will choose the innovation approach that can maximise profits according to the amount of surplus labour in society, and the environment corresponding to different innovation approaches will have an impact on the relationship between financial structure and innovation.

6.2.1. Mechanistic Tests. The mechanism test for financial structure and innovation is shown in Table 6.

Firms at a particular level of economic development choose the appropriate innovation approach, and the relationship between financial structure and innovation varies between different innovation approaches. At lower levels of economic development, the technological level of the economy is low, there are many more advanced mature technologies abroad for firms to learn and imitate, and firms can make excess profits from surplus labour (demographic dividend), so choosing to imitate technologies with lower R&D costs can help maximise profits, and banks and markets are willing to provide financing for technological imitation. At a high level of economic development, the technological level of the economy is high and there is a lack of more advanced and mature foreign technologies for enterprises to learn and imitate, so enterprises can only achieve technological progress through independent innovation. Just at this moment, the proportion of high-tech talents that independent innovation relies on in social human resources is gradually increasing, and it is difficult for enterprises to obtain excess profits from the surplus labour force, so choosing independent innovation that can obtain monopoly profits is conducive to maximising profits. Independent innovation, which is characterised by high risk, requires the support of a market-driven financial structure.

We choose human capital characteristics and R&D cost characteristics to study the impact of innovation approaches on the relationship between financial structure and innovation and thus give the mechanism of the evolution of the relationship between financial structure and innovation in the process of economic development. The coefficients of the human capital type (R&D personnel/nonfarm population) and financial structure interaction terms in columns (1) and (2) are 0.0033 and 0.0047, respectively, which are significantly positive. This suggests that an increase in the share of high-tech talent enhances the innovation-promoting effect of market-based financial structure, which in turn suggests that independent innovation led by high-tech talent enhances the innovation-promoting effect of market-based financial structure. The coefficients of the interaction term between (economy) R&D cost characteristics and financial structure in columns (3) and (4) are 0.0074 and 0.0131, respectively, which are significantly positive. This indicates that market-based financial structure can play a greater role in promoting innovation for high R&D cost innovations, which in turn indicates that high-cost independent innovation enhances the promotion effect of market-based financial structure on innovation. Afterwards, we change the two-way fixed effect to a triple fixed effect of country, industry, and year, and the empirical results are consistent. Next, we replace the measures of sensitive variables. Columns (5) and (6) replace the human capital type (*LA*) with the ratio of R&D personnel to urbanisation rate (*LAA*), as the population living in urban areas is more likely to participate in economic activities in nonfarm industries, and also replace the financial structure with the IMF financial structure (IMFFS). The interaction terms for the ratio of R&D to urbanisation rate and IMF financial structure in columns (5) and (6) remain significantly positive. Columns (7) and (8) replace the economy R&D cost characteristics with the country-industry level R&D cost characteristics (*COO*), where the use of country-industry level R&D cost characteristics helps to obtain more accurate results if industry technology spillovers are not taken into account; the financial structure is also replaced with the IMF financial structure (IMFFS). The interaction term between R&D cost characteristics and IMF financial structure in columns (7) and (8) is still significantly positive.

The results of the combined analysis of columns (1) and (2), (5), and (6) confirm that the role of market-based financial structures in innovation gradually increases as the innovation approach shifts from technological imitation to independent innovation in economic development. Thus, at higher levels of economic development, market-based financial structures promote innovation more significantly. Similarly, the same conclusion can be drawn for columns (3), (4), (7), and (8). We can think that the empirical results

Table 6: Mechanistic tests of financial structure and innovation.

$INN_{i,j,t}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$FS_{i,t}$	−0.0979	−0.1423**	−0.0021	−0.0035	—	—	—	—
	(0.0691)	(0.0652)	(0.0053)	(0.0054)	—	—	—	—
$FS_{i,t} \times LA_{i,t}$	0.0033*	0.0047**	—	—	—	—	—	—
	(0.0020)	(0.0018)	—	—	—	—	—	—
$LA_{i,t}$	0.0136***	0.0152***	—	—	—	—	—	—
	(0.0017)	(0.0017)	—	—	—	—	—	—
$FS_{i,t} \times CO_{i,t}$	—	—	0.0074***	0.0131***	—	—	—	—
	—	—	(0.0026)	(0.0027)	—	—	—	—
$CO_{i,t}$	—	—	−0.0173***	−0.0188***	—	—	—	—
	—	—	(0.0028)	(0.0029)	—	—	—	—
$\text{IMFFS}_{i,t}$	—	—	—	—	−0.3996***	−0.4132***	0.0091	−0.0171
	—	—	—	—	(0.0985)	(0.0950)	(0.1250)	(0.1222)
$\text{IMFFS}_{i,t} \times LAA_{i,t}$	—	—	—	—	0.0192***	0.0184***	—	—
	—	—	—	—	(0.0020)	(0.0019)	—	—
$LAA_{i,t}$	—	—	—	—	−0.0047***	−0.0018	—	—
	—	—	—	—	(0.0017)	(0.0016)	—	—
$\text{IMFFS}_{i,t} \times \text{COO}_{i,j,t}$	—	—	—	—	—	—	0.0073*	0.0069*
	—	—	—	—	—	—	(0.0039)	(0.0037)
$COO_{i,j,t}$	—	—	—	—	—	—	−0.0104**	−0.0103**
	—	—	—	—	—	—	(0.0044)	(0.0043)
Per $GDP_{i,t}$	≤0.0001***	—	≤0.0001***	—	≤0.0001***	—	0.0001***	—
	(≤0.0001)	—	(≤0.0001)	—	(≤0.0001)	—	(≤0.0001)	—
$FD_{i,t}$	1.4759***	1.5186***	1.0920***	1.1263***	0.6656***	0.8005***	0.7143**	0.8810***
	(0.1615)	(0.1664)	(0.1633)	(0.1693)	(0.1938)	(0.1978)	(0.2853)	(0.2887)
$VA_{i,j,t}$	0.8424*	0.8424*	0.7571	0.7571	0.9061**	0.9061**	1.3482***	1.3286***
	(0.4850)	(0.4927)	(0.4603)	(0.4752)	(0.4344)	(0.4520)	(0.4755)	(0.5064)
Constant term	1.6688***	1.9455***	1.8755***	2.3754***	2.2109***	2.5631***	2.1062***	3.1381***
	(0.1450)	(0.0979)	(0.1291)	(0.0888)	(0.1369)	(0.1044)	(0.1455)	(0.1060)
Time effect	Control	Control	Control	Control	Control	Control	Control	Control
Country-industry effects	Control	Control	Control	Control	Control	Control	Control	Control
Observations	16480	16480	17880	17880	17940	17940	11543	11543
R^2 value	0.2542	0.2511	0.2398	0.2307	0.2385	0.2315	0.2696	0.2371
Number of individuals	1120	1120	1180	1180	1140	1140	813	813

Note. *LAA* is the ratio of R&D personnel to urbanisation rate. R&D to patents (*COO*) is the ratio of R&D expenditure (at the national-industry level) to the number of patents granted.

in Table 6 support hypothesis 2. Acemoglu et al. (2006) show mathematically that as the economy develops, technology will move to the frontier, with banks being more favourable than markets to firms' imitation strategies at the time when technology is further away from the frontier, and with markets being more favourable than banks to firms' innovation strategies at the time when technology is closer to the frontier [52]. Both this literature and this paper highlight the role of market-based financial structures in facilitating innovation as the economy develops and technology moves to the frontier level. However, this paper fails to conclude that bank-based financial structures promote imitation, possibly because banks' savings on information costs are not economically significant, or because of the sample's truncated effect, missing data, or poor data quality in countries with very low levels of economic development.

6.2.2. Endogeneity Test. To endogenise the financial structure and innovation mechanism test, this paper uses a two-stage instrumental variable approach. The paper uses corruption controls from the World Bank Governance Index as an instrumental variable for financial structure, where clean government is an important guarantee of well-functioning financial markets. This paper uses the number of national (or regional) journal publications as an instrumental variable for R&D personnel/nonfarm population (LA) and R&D costs (CO). The rationale for the number of journal publications as an instrumental variable is that countries (or regions) with a higher number of publications tend to have a higher share of R&D personnel; publications represent to a certain extent (school) research capacity, and the more publications a country (or region) has, the more companies are willing to increase their R&D investment (in school-enterprise cooperation) and deepen their innovation activities. The empirical results are consistent with Table 6 and strongly support the hypothesis.

7. Robustness Tests

7.1. Explanatory Variables Lagged by One Period. To ensure the robustness of the baseline regression results, we carry out relevant tests. We lag the explanatory variables by one period following Hsu et al. (2014) and Zhou and Lu (2019), and the empirical results are consistent with the results of the baseline regression [36, 45]. Explanatory variables lagged by one period solve the mutual causality problem, because the current explained variable cannot affect the past explanatory variable, while the past explanatory variable can affect the present explanatory variable and then affect the explained variable. A one-period lag of the explanatory variables verifies that there is indeed a causal relationship between financial structure and innovation. In addition to this, we also use panel vector autoregression and Heckman's two-step method to test for endogeneity, and the results are also consistent with the results of the baseline regression.

7.2. Changing to Country Fixed Effects. We then use country fixed effects to replace the country-industry fixed effects and country and industry dual fixed effects in the baseline regression, and the empirical results are consistent with the results of the baseline regression.

7.3. Replacement of Innovation Indicators. We then use the size of patent publication under SIC classification (INP) to replace the size of granted patents (*INN*) as the explained variable, and the empirical results are consistent with the baseline regression results.

7.4. Innovation Variables at the Technology Classification Level. All previous regressions in this paper have been based on the US Standard Industrial Classification (USSIC) classifying industries, and given that WIPO patents are classified by technology, it is reasonable to use the size of patents granted by technology (*INF*). At the same time, we matched the other variables in the regression to the technology classification criteria and then conducted robustness tests, and the empirical results were consistent with the results of the baseline regression.

7.5. Placebo Test. The paper also performs a 1000-time placebo test on the baseline regression. The paper uses a Bootstrap method to regress the baseline model after random sampling of the explanatory variables, and the empirical results show that there are no omitted variables that affect the estimation results.

7.6. Get Rid of the OPEC Countries. Oil-rich countries have different development patterns from other countries, which may influence the regression results. OPEC has 13 members, according to its official website. Among the sample countries of the benchmark regression, Saudi Arabia is an OPEC country. The regression results are consistent with the benchmark regression model after removing Saudi Arabia.

8. Conclusions and Recommendations

8.1. Conclusions of the Study. This paper investigates the relationship between financial structure and national innovation at different levels of economic development through a panel model using data on manufacturing industries in 59 countries or regions from 1996 to 2015. The empirical test confirms that market-based financial structures significantly promote innovation at higher levels of economic development rather than at lower levels of economic development. This is mainly due to the fact that as per capita income rises, independent innovation replaces technological imitation as the dominant approach of innovation, and the risk of innovation increases, making the risk management function of market-based financial structures more important at higher levels of economic development.

After the high growth economies reach the high-income wall (I$11000 in 1990 prices), economic growth returns to normality. Applying the general international rule of different periods of per capita income levels based on high-income wall to high-growth or former high-growth economies, we conclude that the optimal financial structure begins to change to a market-based structure when the economy moves from a high growth phase to a normal growth phase. The reason for this is that during the high growth stage, technological imitation (dominated by simple labour and characterised by low R&D costs) is the main approach of innovation, and the bank-based financial structure is not less conducive to technological imitation than the market-based financial structure, but during the normal growth stage, the market-based financial structure promotes national innovation through (dominated by high-tech talent and characterised by high R&D costs) independent innovation for national innovation. These findings provide insights for policy formulation in the process of changing economic growth stages in China.

8.2. Policy Recommendations. With per capita income reaching 9885 international dollars in 2016, China is about to cross the wall of high income and enter a stage of normalised growth. Based on the empirical analysis in this paper, in the upcoming new stage, independent innovation has become a new source of productivity, and innovation has put forward two intrinsic requirements for the development of the financial structure, namely, the mobilisation of high-tech talent and the optimisation of the allocation of R&D expenditure. It is necessary for us to vigorously develop the securities market, further expand the issuance of securities, and lower the barriers to entry for SMEs under the condition of ensuring strict and effective regulation of market operations and exit regulation. At the lower stage of economic development, the government should pay attention to the housing and children's schooling problems of migrant workers moving to cities, set up a special fund to provide commercial financial institutions with loan insurance for migrant workers' first home purchase, allow migrant workers' children to attend school in the school district near their workplace, and solve the worries of migrant workers through financial means and administrative arrangements. The state sets within enterprises in the same industry to jointly introduce advanced foreign technology with appropriate financial subsidies, or implements a national purchase policy for mature foreign technology that is in line with the national strategic plan, and popularises the technology free of charge to enterprises in the relevant industry. At higher stages of economic development, governments and enterprises should give scientists greater autonomy and more adequate funding, while establishing a sound system of accountability and military orders. National laboratories and high-level research universities should play a leading role in promoting university-enterprise cooperation and technology diffusion. We should strengthen international exchanges of talents, increase the introduction of urgently needed and scarce international talents, tolerate failure, and encourage leading scientists and technicians to hang on to their leadership. The government should have a top-level design to increase technological research and development in strategic emerging industries, increase investment in R&D, strengthen technical support to enterprises, give full play to the role of the financial market in supporting independent innovation, and vigorously develop the Star Market and the Beijing Stock Exchange to effectively solve the financing problems of science and technology-based enterprises. At the provincial level, due to the differences in the level of economic development of each province, the financial system in backward regions should not be rushed into "de-banking," and banks should be guided to lend to support local technology-based enterprises, set up loan insurance for technology-based enterprises, reduce the risk of financing constraints on technology-based enterprises, and encourage technology-based SMEs to sign long-term cooperation agreements with banks. The government in developed areas should improve the multilevel capital market, guide enterprises to enter the Regional Equity Market and the basic tier of the National Equities Exchange and Quotations (NEEQ) in an orderly manner, and provide quality enterprises for the innovative and selective tiers of the National Equities Exchange and Quotations (NEEQ) and the main board through tier leapfrogging and board conversion; strengthen information disclosure, business operation regulation, and exit regulation of the national equities exchange and quotations (NEEQ) and regional equities exchange and quotations; increase penalties for enterprises that violate the law; and mitigate the lemon market effect. In addition, the financial ecology affects the efficiency of capital allocation, and the functioning of financial institutions and markets is constrained by the external financial ecology (Li and Han, 2011) [53]. Corruption can undermine market development to varying degrees, as better enforcement of shareholder rights is a necessary condition for the market-based financial structures (Demirgüç-Kunt and Levine, 1999) [43]. The incident of Xiaoshi Wang's sale of the list of Public Offering Review Committee shows that corruption can be a great threat to the development of financial markets in China. At the institutional level, it is necessary for the government to establish a clean and efficient public workforce and implement a standing anticorruption policy not only to eradicate the trading of power and money but also to eradicate the interference of connections and favours in administrative work [54–56]. Those who are capable should be promoted and those who are mediocre should be dismissed, eliminating malfeasance and overstepping of authority by public officials. A credible and enforced public workforce can adequately reduce the drain on social resources from insider trading and rent-seeking, adequately reduce transaction costs, and provide the necessary preconditions for the rapid development of the capital market.

Data Availability

The data used to support the findings of this study are included within the article.

Disclosure

Zhi-Gang Huang and Cheng-Ben Wang are co-first authors.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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