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Research article

Does policy finance promote domestic industrial gradient relocation? Evidence from China

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Abstract: This study innovatively investigated whether policy finance can facilitate domestic industrial gradient relocation. Building on a theoretical framework and the formulation of research hypotheses, we utilized panel data from China's manufacturing industry across 30 provinces (2014–2023) to empirically examine both the direct effects and indirect mechanisms of policy finance on domestic industrial gradient relocation, while also conducting an analysis of industry heterogeneity. The results indicated that policy finance significantly promotes domestic industrial gradient relocation, a conclusion that holds robustly across multiple tests. Potential mechanisms through which policy finance exerts this effect include fostering industrial transformation, upgrading in high-gradient regions, and lowering business costs in low-gradient regions. Moreover, the impact of policy finance is markedly stronger in labor-intensive and capital-intensive industries compared with technology-intensive industries.

Keywords: policy finance; domestic industrial gradient relocation; baseline regression; action mechanism; industry heterogeneity analysis

JEL Codes: O18, R58, G28, L52

1. Introduction

The world today is undergoing a profound realignment of the international order, characterized by frequent geopolitical conflicts and rising trade protectionism. Developed economies, led by the United States, are implementing tariff increases to incentivize the repatriation of manufacturing industries, while emerging economies in Southeast Asia are leveraging their cost advantages to actively attract foreign investment. These dynamics have accelerated the restructuring of global industrial and supply chains, heightening concerns about their resilience and security to unprecedented levels (Gokkaya et al., 2025). In this complex external environment, countries worldwide are shifting their priorities from solely pursuing the economic benefits of industrial and supply chains to emphasizing their security. To mitigate the risk of industrial hollowing-out caused by excessive outward migration, nations with vast territories and distinct industrial gradients have introduced supportive policies to promote orderly domestic industrial gradient relocation. Such measures not only strengthen the anchoring of industries within home countries, prevent the risks associated with excessive industrial outflow and disrupted supply chains, and enhance the resilience and security of industrial and supply chains, but also contribute to narrowing domestic regional development disparities. Policy finance, a specialized form of financial intermediation conducted with government backing through preferential loans, guarantees, interest rate incentives, and other tailored instruments, operates strictly within the scope and objectives defined by national regulations, with the primary aim of achieving specific economic and social policy goals (Zhang, 2023). It plays a crucial role in facilitating domestic industrial gradient relocation. Therefore, exploring the effects and mechanisms of policy finance in promoting such relocation and clarifying their interrelationships holds significant research value.

Existing research has examined policy finance and industrial relocation largely in isolation. Studies on policy finance primarily focus on the impact of various policy finance models on specific socioeconomic issues, including technology finance, digital finance, inclusive finance, and green finance. Within technology finance, prior research has investigated its role in fostering corporate technological innovation and efficiency improvements. For example, Zhong and Jin (2024), Shao et al. (2025), and Sheng et al. (2021) have analyzed its effects on corporate high-quality development, digital technology innovation, and industrial innovation efficiency, respectively. Research on digital finance has explored its contributions to social equity and green, low-carbon development. Li et al. (2021), Yao and Ma (2022), Xu et al. (2024), and Li et al. (2020) have examined its impacts on rural income growth, income inequality, rural revitalization, and household consumption, respectively. Additionally, Cao et al. (2021), Li et al. (2022), and Zhang and Liu (2022) have investigated digital finance's role in enhancing energy and environmental performance, promoting corporate green innovation, and improving carbon emission efficiency. In the domain of inclusive finance, scholars such as Zhu and Guo (2024), Liu et al. (2021), Pan et al. (2025), Shahbaz et al. (2025), and Zhang and Jia (2025) have analyzed its effects on bank performance, farmers' income growth, poverty alleviation, carbon neutrality targets, and the development of new productive forces. Research on green finance has primarily focused on its role in promoting green and sustainable economic development, with studies by Lee and Lee (2022), Huang et al. (2022), Chen et al. (2024), Hu et al. (2023), and Zhao et al. (2024) examining its impacts on green total factor productivity, green innovation, energy transitions, low-carbon economic transformation, and carbon emission reduction.

On the other hand, existing research on industrial gradient relocation primarily addresses its connotation, measurement, influencing factors, and promotion pathways. Regarding its connotation,

industrial gradient relocation is defined as the process and phenomenon in which, under market economy conditions, marginal industries in high-gradient regions are driven by external forces to relocate to low-gradient regions through interregional investment activities, thereby facilitating cross-regional industrial gradient shifts. In terms of measurement, three main approaches are commonly employed. First, the survey method assesses the scale and direction of industrial relocation by examining the number and proportion of relocation cases within enterprises (Okubo and Tomiura, 2012; Sang and Anwar, 2016; Zhao and Lee, 2024). Second, regional industrial distribution indicators are constructed to capture the scale and direction of relocation, with frequently used metrics including location entropy, industrial gradient coefficient, foreign investment volume, Herfindahl coefficient, and Gini coefficient (Zhao and Yin, 2011; Wu et al., 2014; Chen et al., 2018; Wu et al., 2023). Third, input-output techniques measure the scale and direction of industrial relocation based on input-output table data and models (Fan and Liu, 2021; Wang et al., 2021; Zhang et al., 2023; Lin and Wang, 2024). Regarding the influencing factors, studies mainly analyze the effects of production factor costs (land, labor, capital), market conditions, access to production technology, and policy adjustments on industrial relocation (Shen et al., 2017; Huang et al., 2017; Li et al., 2023; Kinkel et al., 2023). In terms of implementation pathways, existing research highlights strategies such as promoting industrial upgrading in relocate-out regions, reducing business costs in relocate-in regions, and enhancing collaboration and interest sharing between relocate-out and relocate-in regions (Liu et al., 2022; Liu et al., 2023).

Research examining the impact of policy finance on industrial gradient relocation remains limited. Existing studies have primarily focused on the role of different policy finance models in promoting industrial upgrading and enhancing production efficiency. For example, Xu (2022), Ren et al. (2023), and Zhanbayev and Bu (2023) have investigated the effects of digital finance on industrial upgrading; Gu et al. (2021) and Zhang et al. (2023) have examined green finance's influence on manufacturing upgrading and industrial upgrading efficiency; and Jin and Zhong (2023) have studied the role of digital inclusive finance in improving agricultural total factor productivity.

As demonstrated above, existing research on policy finance and industrial gradient relocation has generated substantial findings that offer valuable references and insights for this study. However, although prior studies have extensively examined how various types of policy finance promote corporate technological innovation, enhance industrial efficiency, improve social equity, and facilitate green and low-carbon development, research specifically investigating the relationship between policy finance and industrial gradient relocation remains limited. To address this gap, the present study integrates policy finance and domestic industrial gradient relocation into a unified research framework. First, by elucidating the theoretical mechanisms through which policy finance promotes domestic industrial gradient relocation, we formulate our research hypotheses. Next, using empirical data from manufacturing sectors across 30 Chinese provinces, we construct fixed-effects regression models and action mechanism models to empirically examine both the impact and potential mechanisms of policy finance on domestic industrial gradient relocation, supplemented by an analysis of industry heterogeneity. Finally, based on our findings, we propose targeted policy recommendations to provide theoretical support and strategic guidance for countries with significant industrial gradients seeking to optimize their policy finance systems and facilitate domestic industrial gradient relocation.

Compared with existing research, this study makes three primary contributions. First, regarding the research subject, it investigates the impact of policy finance on domestic industrial gradient relocation, thereby extending the scope of research on the effects of policy finance. Second, by focusing on two pathways, promoting industrial transformation and upgrading in high-gradient regions,

and reducing business costs in low-gradient regions, the study clarifies the theoretical mechanisms through which policy finance facilitates domestic industrial gradient relocation, creating a synergistic effect that advances relocation from both the relocate-out and relocate-in regions. Third, it further explores the industry heterogeneity of policy finance in promoting domestic industrial gradient relocation. Manufacturing industries are categorized into labor-intensive, capital-intensive, and technology-intensive sectors, and the study compares the differential effects of policy finance across these categories, revealing industry-specific patterns in how policy finance drives domestic industrial gradient relocation.

The remainder of this paper is structured as follows: Section 2 presents the theoretical mechanisms through which policy finance promotes domestic industrial relocation and proposes the research hypotheses; Section 3 outlines the empirical analysis, including model construction, variable definitions, and data description; Section 4 presents the analysis of empirical results; and Section 5 concludes the study and offers policy recommendations.

2. Theoretical analysis and research hypotheses

This study elucidates the theoretical mechanisms through which policy finance facilitates domestic industrial gradient relocation by examining both its direct effects and underlying action mechanisms, while also proposing the corresponding research hypotheses.

2.1. Direct impact of policy finance on promoting domestic industrial gradient relocation

Countries with vast territories often experience regional development disparities due to geographical differences, uneven resource distribution, and varying historical foundations. At the industrial level, these nations exhibit distinct gradient characteristics (Zhang and Xiong, 2025). From the perspective of industrial relocation theory, industries in the high-gradient regions, after prolonged development, may lose their comparative advantage. In contrast, low-gradient regions implement preferential industrial policies and optimize business environments to attract relocating industries from high-gradient regions, aiming to stimulate local economic growth and narrow development gaps. As a result, high-gradient regions have inherent incentives to relocate industries to low-gradient regions for purposes such as market expansion, cost reduction, or the acquisition of policy benefits. However, the reality is more complex. On one hand, according to industrial economics theory, market information asymmetry and imperfect competition create significant barriers and rigidity in industrial gradient relocation. Enterprises in high-gradient regions often have limited knowledge of the business environment, preferential policies, market potential, and industrial chain support in receiving regions. Compounded by a complex external environment and intense internal competition, their profit margins are squeezed, and funding sources are severely constrained. Unable to meet the capital requirements of cross-regional investment, these enterprises are often reluctant or unwilling to relocate. Furthermore, industrial relocation primarily occurs through cross-regional investment, which necessitates that receiving regions possess abundant labor, natural resources, and other supporting production factors. However, factors such as capital and labor exhibit rigidity, preventing their free and costless movement across regions (Huang et al., 2011). Capital and labor from high-gradient regions tend to remain local, intensifying competition there rather than flowing to distant, unfamiliar low-gradient areas. On the other hand, from the perspective of government performance evaluation, rapid economic growth

remains a key metric for local authorities. While low-gradient regions implement favorable policies to attract relocating industries, high-gradient regional governments often reinforce policy measures to prevent excessive industrial outflow that could adversely affect their performance evaluations. Consequently, substantial obstacles exist in realizing domestic industrial gradient relocation in practice.

Policy finance, as a specialized government-backed financial instrument designed to achieve specific socioeconomic objectives, can effectively mitigate the barriers to domestic industrial gradient relocation described above. On the one hand, from a public finance perspective, policy finance functions as an extension of fiscal instruments with the capacity to generate substantial social impact. First, compared to direct fiscal subsidies and tax incentives, policy finance exerts stronger leverage, mobilizing broader social resources. Second, it mitigates distortions to market mechanisms by typically adopting market-oriented operational models that channel capital toward sectors aligned with policy objectives, thereby improving capital allocation efficiency and avoiding the pitfalls of direct fiscal support, such as fostering corporate dependency, misallocating resources, and reducing efficiency. Finally, industrial gradient relocation involves considerable uncertainty, which often discourages commercial finance from participating. Policy finance addresses this challenge by stabilizing expectations and boosting market confidence, sharing risks with enterprises and commercial banks through guarantees and interest subsidies. This, in turn, incentivizes commercial finance to follow suit and support industrial relocation projects. On the other hand, policy finance can be facilitated through cross-regional cooperation mechanisms, including the joint development of specialized loans, funds, or bonds, the establishment of risk-sharing frameworks, and the provision of one-stop services for cross-regional account management. These approaches generate shared benefits from industrial relocation. Although industries physically move from high-gradient regions, these regions continue to retain economic gains, such as favorable development indicators, returns on financial products, and retained tax revenues. This arrangement mitigates the potential negative impact on local government performance metrics while simultaneously promoting industrial relocation. Therefore, policy finance functions as an innovative bridge between industrial policy and public fiscal policy. It respects the inherent dynamics of industrial development while introducing novel approaches to implementing fiscal policy. By leveraging policy finance to facilitate domestic industrial gradient transfer, it can more effectively and sustainably drive the strategic adjustment of the national economic structure. Based on this analysis, we propose the following research hypothesis:

H1: Policy finance can promote domestic industrial gradient relocation.

2.2. Action mechanism of policy finance on promoting domestic industrial gradient relocation

Current industrial transformation and upgrading primarily emphasize the promotion of high-end, intelligent, and green industrial development (Wang and Fan, 2025). Policy finance encompasses various forms, including financial technology, digital finance, and green finance, each playing a critical role in facilitating industrial transformation and upgrading. Financial technology encourages financial institutions to innovate products and improve service models, enabling the integration of technological innovation with financial capital. This supports enterprises in enhancing independent research and experimental development (R&D) capabilities, overcoming core technological challenges, increasing product value-added, and moving up the industrial value chain toward high-end industrialization. Digital finance leverages big data, artificial intelligence (AI), blockchain, and other advanced digital technologies to reshape financial services, deepen integration with the real economy, enable real-time financial risk

monitoring, provide tailored financing solutions, optimize decision-making processes, and drive industrial intelligent transformation. Green finance directs capital toward environmentally sustainable sectors, including environmental protection, energy conservation, clean energy, green transportation, and green construction, thereby promoting industrial green development. According to traditional industrial relocation theories, such as the flying-geese theory, product life cycle theory, and marginal industrial relocation theory, when industrial transformation and upgrading in high-gradient regions reach a certain stage, they encounter constraints such as rising labor costs and resource and environmental bottlenecks (Gerőcs and Pinkasz, 2019). To take advantage of low-cost labor, resources, and favorable environmental conditions in low-gradient regions, while freeing up space for the development of high-tech industries, high-gradient regions relocate labor-intensive or polluting industries to low-gradient areas. This process facilitates industrial replacement and further advancement along the high end of the value chain. Based on this analysis, we propose the following research hypothesis:

H2a: Policy finance facilitates industrial transformation and upgrading in the high-gradient regions, thereby promoting domestic industrial gradient relocation.

From the perspective of low-gradient regions, reducing business costs is a critical factor in attracting industrial relocation from high-gradient regions. Business costs consist of two main components: production factor costs (e.g., labor, land, and resources) and transaction costs associated with industrial support environments, government efficiency, taxation, infrastructure, and legal frameworks. First, policy financial institutions can provide low-cost funding to support local governments in low-gradient regions to reduce social insurance rates and offer job retention subsidies, thereby lowering labor costs for enterprises. They can also issue specialized loans for comprehensive land utilization, facilitating flexible industrial land transfers and reducing land use costs. Additionally, policy financial institutions can collaborate with governments to offer loans covering resource taxes or exploration rights, thereby lowering resource utilization costs, such as mining expenses, for enterprises. Second, policy financial institutions can fund governments to strengthen infrastructure development in low-gradient regions, including transportation, logistics, and information technology, and to enhance productive services such as asset leasing, business consulting, legal advisory, and human resource management. They can also support the standardized construction of industrial parks and improve park-level services, effectively optimizing the business environment and reducing transaction costs. By implementing these measures, low-gradient regions can increase their attractiveness as destinations for industrial relocation. Based on this analysis, we propose the following research hypothesis:

H2b: Policy finance reduces business costs in the low-gradient regions, thereby promoting domestic industrial gradient relocation.

3. Materials and methods

3.1. Model construction

3.1.1. Baseline regression model

We construct a fixed-effects regression model to examine the direct impact of policy finance on domestic industrial gradient relocation, as presented below.

$$igt_{it} = \alpha_0 + \alpha_1 pfi_{it} + \sum_j \alpha_j control_{it} + \mu_t + \nu_i + \varepsilon_{it} \quad (1)$$

where igt_{it} is the domestic industrial gradient relocation index, pfi_{it} represents the policy financial level, $control_{jit}$ denotes the control variables, α_0 is the constant term, α_1 and α_j are the estimated coefficients of the independent and control variables, respectively, μ_t represents time fixed effects, ν_i represents regional fixed effects, and ε_{it} is the random disturbance term.

3.1.2. Action mechanism model

We construct an action mechanism model to examine the indirect pathways through which policy finance promotes domestic industrial gradient relocation, as presented below.

$$med_{it} = \beta_0 + \beta_1 pfi_{it} + \sum_j \beta_j control_{it} + \mu_t + \nu_i + \varepsilon_{it} \quad (2)$$

$$igt_{it} = \gamma_0 + \gamma_1 pfi_{it} + \gamma_2 med_{it} + \sum_j \gamma_j control_{it} + \mu_t + \nu_i + \varepsilon_{it} \quad (3)$$

where med_{it} represents the mechanism variables, including industrial transformation and upgrading (itu_{it}) and business costs (bei_{it}), and β and γ denote the corresponding estimated coefficients.

3.2. Variable setting

3.2.1. Dependent variable

The common industrial relocation index is selected to measure domestic industrial relocation (Sun et al., 2018; Li and Lai, 2021). This index is designed to quantify the relative scale of industrial relocation based on changes in industrial share. Specifically, it measures relocation by capturing the relative change in a region's industrial share before and after relocation. However, since changes in industrial share may reflect either actual relocation or variations in the region's overall industrial scale, we introduce an adjustment factor: the proportion of the region's industrial scale relative to the national total. This adjustment eliminates the influence of industrial scale fluctuations on the relocation measurement. The industrial relocation index is constructed as follows:

$$\Delta Q_{c,i,t} = Q_{c,i,t} - Q_{c,i,t_0} = \frac{q_{c,i,t}}{\sum_{i=1}^{n} q_{c,i,t}} \Big/ \frac{\sum_{c=1}^{m} q_{c,i,t}}{\sum_{c=1}^{m}\sum_{i=1}^{n} q_{c,i,t}} - \frac{q_{c,i,t_0}}{\sum_{i=1}^{n} q_{c,i,t_0}} \Big/ \frac{\sum_{c=1}^{m} q_{c,i,t_0}}{\sum_{c=1}^{m}\sum_{i=1}^{n} q_{c,i,t_0}} \quad (4)$$

where $\Delta Q_{c,i,t}$ is the relocation amount of industry c in province i in year t, $q_{c,i,t}$ is the output of industry c in province i in year t, $\sum_{i=1}^{n} q_{c,i,t}$ is the national output of industry c in year t, and $\sum_{c=1}^{m} q_{c,i,t}$ is the national output of all industries in year t. If $\Delta Q_{c,i,t} > 0$, it indicates an inflow into industry c in province i in year t; otherwise, it indicates an outflow from industry c in province i in year t.

To capture the gradient characteristics of industrial relocation while reflecting China's actual industrial gradient distribution, we adopt the geographical division established by China's National Bureau of Statistics. This division highlights a clear industrial gradient from the eastern region to the central, western, and northeastern regions. The industrial gradient relocation index should account for both industrial outflows from high-gradient regions (eastern) and inflows to low-gradient regions (central, western, northeastern); accordingly, we adjust the standard industrial relocation index. For low-gradient regions (central, western, northeastern), no adjustment is required, as their industrial flows naturally align with the gradient direction. For high-gradient regions (eastern), when industries relocate out (consistent with the gradient), we take the absolute value of their industrial relocation index, whereas when industries relocate in (against the gradient), we take the opposite value of the index. This approach accurately captures the directional characteristics of industrial gradient relocation from the eastern region to the central, western, and northeastern regions.

Furthermore, as industrial relocation primarily involves manufacturing industries, which are particularly sensitive to cost variations and geographical advantages, and given substantial interregional differences in industrial characteristics, relocation patterns in other sectors are less pronounced. Consequently, this study adopts a narrow definition of industrial relocation, focusing specifically on manufacturing industries. Our classification of manufacturing industries follows the 31 categories specified in China's National Economic Industry Classification (GB/T 4754-2017).

3.2.2. Independent variable

Consistent with conventional research practices, we measure the level of policy finance using the loan balances of policy financial institutions. In China, these financial institutions include the China Development Bank, the Agricultural Development Bank of China, and the China Export-Import Bank. We use the aggregate loan balances of these three policy banks as our primary measure of policy finance. The core operational model of policy finance involves these institutions implementing policies through loan disbursements, and their loan balances directly reflect the total scale of such financial activities, representing the most direct and substantial manifestation of policy intervention in the economy. Although using loan balances may underestimate the overall scale of policy finance, capturing only the "explicit" portion while overlooking "implicit" activities and failing to fully reflect its core functions and economic effects, it remains the most reasonable indicator available in the absence of alternative metrics. This method provides estimated provincial-level policy bank loan balances. Nevertheless, this approach has notable limitations and should be employed only as a last resort when provincial-level data are unavailable, as it may result in substantial deviations from actual values.

3.2.3. Mechanism variable

Based on the preceding theoretical analysis, the mechanism variables include industrial transformation and upgrading, as well as business costs. Since current Chinese statistical data do not provide direct indicators for measuring industrial transformation and upgrading, we adopt a multi-indicator comprehensive evaluation approach. Considering that transformation in the manufacturing industry primarily occurs along three dimensions (high-end, intelligent, and green development), we construct a corresponding measurement indicator system across these dimensions, as presented in Table 1.

Table 1. Indicator system for measuring industrial transformation and upgrading.

Dimension/ primary indicator	Secondary indicator	Indicator description	Indicator direction
High-end	High value-added	Output value of manufacturing enterprises above unit size	Positive
	High technical innovation level	R&D of industrial enterprises above the designated size investment as a percentage of marketing revenue	Positive
Intelligent	Digitization level	Number of computers per 100 employees in the enterprise	Positive
	Automation level	Average employment of manufacturing enterprises above unit size	Negative
Green	Energy consumption intensity	Energy consumption per unit of manufacturing output	Negative
	Carbon emission intensity	Carbon emissions per unit of manufacturing output	Negative

Building upon the constructed industrial transformation and upgrading measurement indicator system, we employ the entropy method to calculate the industrial transformation and upgrading index. The entropy weighting method determines indicator weights based on their variability, offering the advantages of objectivity, high reliability, and accuracy, which make it one of the most widely used approaches for constructing statistical evaluation indices.

Assuming that the study period spans t years $(t = 1, 2 \cdots, s)$, with n regions, m primary indicators, and each primary indicator comprising l secondary indicators, we first standardize and normalize the indicators, then measure their entropy and redundancy using the following formulas:

$$E_{ijk} = -\alpha_1 \sum_{i=1}^{n} \sum_{t=1}^{s} F_{ijk} \ln F_{ijk} \tag{5}$$

$$D_{ijk} = 1 - E_{ijk} \tag{6}$$

where F_{ijk} is the normalized value of the k secondary indicator of the j primary indicator for the i region. E_{ijk} represents the entropy of the k secondary indicator of the j primary indicator for the i region, let $\alpha_1 = 1/\ln(n \times s)$, and D_{ijk} denotes the redundancy of the k secondary indicator of the j primary indicator for the i region.

The weight of each secondary indicator is defined as its proportion of total redundancy among all indicators and is calculated as follows:

$$W_{ijk} = D_{ijk} / \sum_{k=1}^{l} D_{ijk} \tag{7}$$

where W_{ijk} is the weight of the k secondary indicator of the j primary indicator for the i region. By taking the mean of the secondary indicator entropies as the entropy of the primary indicator, we can determine the weight of the primary indicator W_{ij}.

The standardized indicator values are then weighted and summed according to their respective secondary and primary indicator weights to calculate each province's industrial transformation and upgrading index. The measurement formula is as follows:

$$M_{i,t} = \sum_{j=1}^{m} W_{ij} (\sum_{k=1}^{l} W_{ijk} P_{ijk,t}) \tag{8}$$

where $M_{i,t}$ represents the industrial transformation and upgrading index of the i region in year t, and $P_{ijk,t}$ denotes the standardized value of the k secondary indicator corresponding to the j primary indicator for the i region in year t.

Additionally, since China has officially published provincial-level data on manufacturing business costs, we directly use these statistics to measure business costs.

3.2.4. Control variable

Beyond policy finance levels, domestic industrial gradient relocation is influenced by various other factors. To control for these influences while preserving the explanatory power of the core variable and avoiding multicollinearity from excessive controls, we introduce five control variables: first, the level of economic development, measured by per capita GDP; second, the labor supply level, measured by the proportion of employment in the secondary industry relative to the national total; third, the infrastructure level, measured by freight turnover, reflecting the convenience of road transportation; fourth, fiscal expenditure intensity, measured by government general public budget expenditures; and fifth, the level of openness, measured by the total export value of foreign-invested enterprises.

The descriptive statistics for the above variables are shown in Table 2.

Table 2. Descriptive statistics of variables.

Variable	Abbreviation	Obs	Mean	Std. Dev.	Min	Max
Domestic industrial gradient relocation index	*igt*	300	0.578	0.193	0.049	1.000
Policy financial level	*pfi*	300	0.698	0.590	0.063	3.520
Industrial transformation and upgrading index	*itu*	300	0.553	0.133	0.230	0.855
Business costs	*bei*	300	2.950	3.138	0.106	15.179
Economic development level	*eco*	300	6.768	2.991	2.520	17.693
Supply level labor	*lar*	300	0.033	0.029	0.003	0.120
Infrastructure level	*fda*	300	0.650	0.667	0.040	3.407
Fiscal expenditure intensity	*gov*	300	0.033	0.016	0.007	0.088
Openness level	*ope*	300	0.220	0.420	0.000	1.969

3.3. Data description

This study utilizes panel data from 30 Chinese provinces (excluding Tibet, Hong Kong, Macao, and Taiwan due to data unavailability) spanning from 2014 to 2023. The primary data sources include

the China Statistical Yearbook, China Industrial Statistics Yearbook, China Financial Yearbook, China Labor Statistics Yearbook, and provincial statistical yearbooks. Data on loan balances of policy banks are obtained from the annual reports of the three policy banks. As output data for the 31 sub-sectors of the manufacturing industry are missing, marketing revenue data are used as a proxy. Since the industrial gradient relocation index includes both positive and negative values, it is standardized to enhance data stability. To eliminate the impact of inflation, indicators such as GDP and marketing revenue, which are affected by price changes, are adjusted to constant 2014 prices. Minor data gaps and isolated outliers are addressed using either the average interpolation method or the moving average method. We visualize all indicator data using scatter plots to identify outliers that were clearly distant from the main data clusters. Since the data in this study are panel data spanning from 2014 to 2023, replacing outliers using the moving average method is more appropriate for maintaining data stability and objectivity than methods requiring subjective cutoff determinations, such as winsorizing. To mitigate the impact of heteroskedasticity on the estimation results and enhance the stability of the variables, the natural logarithm is applied to all variables.

4. Empirical results and analysis

4.1. Baseline regression results

Table 3. Baseline regression results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
pfi	0.172**	0.393**	0.584***	0.636***	0.824***	0.914***
	(2.49)	(1.98)	(2.75)	(3.00)	(3.79)	(4.12)
eco		−0.360	−0.650**	−0.837**	−1.178***	−1.473***
		(−1.19)	(−2.00)	(−2.52)	(−3.42)	(−1.89)
lar			−0.505**	−0.552***	−0.459**	−0.532**
			(−2.36)	(−2.59)	(−2.16)	(−2.74)
fda				0.172**	0.228***	0.233***
				(2.35)	(3.07)	(3.14)
gov					−0.897***	−0.959***
					(−3.12)	(−3.33)
ope						0.138*
						(1.84)
_cons	−0.504***	0.301	−0.970	−0.623	−2.633**	−2.052*
	(10.29)	(0.44)	(−1.12)	(−0.72)	(−2.46)	(−1.85)
Time fixed effects	YES	YES	YES	YES	YES	YES
Regional fixed effects	YES	YES	YES	YES	YES	YES
R-squared	0.0170	0.0189	0.0281	0.0631	0.0082	0.0106
N	300	300	300	300	300	300

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Using the baseline regression model described above, we employ Stata software to estimate the direct impact of policy finance on domestic industrial gradient relocation, with the results presented in Table 3.

As shown in Table 3, columns 1–6 report the estimated results as control variables are gradually added. As shown in column 1, when control variables are not included, policy finance has a significant positive effect on domestic industrial gradient relocation at the 5% level, with an estimated coefficient of 0.172. In column 6, after including all control variables, the significant promotional effect of policy finance increases substantially, with the estimated coefficient rising to 0.914. This indicates that policy finance has a highly significant positive effect on domestic industrial gradient relocation, thereby validating research hypothesis H1. Regarding the impact of control variables, economic development level, labor supply level, and fiscal expenditure intensity exhibit significant inhibitory effects on domestic industrial gradient relocation. Regions with higher economic development typically have invested substantial fixed capital and possess well-developed industrial chains. Regions with higher labor supply have more abundant labor and lower wages, reducing business costs for enterprises. Similarly, regions with higher fiscal expenditure intensity offer more tax incentives and production subsidies, further lowering business costs. These factors increase industrial stickiness within regions, thereby inhibiting domestic industrial gradient relocation. Conversely, the infrastructure and openness levels have a promotional effect. Regions with well-developed infrastructure often host high-end industries where land rents and labor costs are higher, pushing low-end manufacturing to relocate to lower-gradient regions. Regions with higher openness are more integrated into the global value chain, face international competition, and are more likely to adopt advanced production models from abroad, resulting in the relocation of low-end industrial segments to lower-gradient regions. Thus, these factors contribute to promoting domestic industrial gradient relocation.

4.2. Robustness test results

To further verify the robustness of the baseline regression results, we employ four methods: replacing the dependent variable, replacing the independent variable, removing abnormal samples, and adopting an alternative estimation method. The corresponding results are presented in Table 4.

In Table 4, column 1 presents the estimation results when the domestic industrial gradient relocation index is replaced with the commonly used manufacturing location entropy change from existing studies. The results indicate that policy finance continues to significantly promote domestic industrial gradient relocation at the 1% level, with an estimated coefficient of 0.680. Column 2 shows the estimation results when the policy finance index is replaced with government debt issuance expenditures. Policy finance remains significant at the 5% level, with an estimated coefficient of 0.755. Although the significance is slightly weaker than in the baseline regression, this confirms the robustness of using policy financial institution loan balances to measure policy finance. Column 3 reports the results after excluding the impact of the COVID-19 pandemic, an uncertain public health event in 2020. Policy finance still exhibits a significant promotional effect at the 1% level, with an estimated coefficient of 0.93. Column 4 presents the results obtained by replacing the ordinary least squares estimation method with the generalized least squares method, showing that policy finance continues to have a significant positive effect at the 1% level, with an estimated coefficient of 0.437. In summary, after replacing the dependent variables, replacing the independent variables, removing abnormal samples, and adopting a different estimation method, policy finance consistently exhibits a significant promoting effect on domestic industrial gradient relocation, confirming the robustness of the baseline regression results.

Table 4. Robustness test results.

Variable	Replacing the dependent variable	Replacing the independent variable	Removing abnormal samples	Adopting a different estimation method
	(1)	(2)	(3)	(4)
pfi	0.680***	0.755**	0.930***	0.437***
	(4.18)	(2.25)	(3.97)	(4.38)
eco	−0.875	0.192*	−1.561***	−0.337
	(−3.15)	(1.80)	(−3.88)	(−3.17)
lar	−0.142	0.112	−0.601**	−0.249***
	(−0.90)	(0.74)	(−2.57)	(−3.45)
fda	0.132**	0.088	0.249***	0.083**
	(2.43)	(1.60)	(2.17)	(2.16)
gov	−0.777	−0.503**	−1.022***	−0.067
	(−3.67)	(−2.43)	(−3.35)	(−0.56)
ope	0.041	−0.011	0.167**	−0.025
	(0.74)	(−0.20)	(2.02)	(−1.55)
_cons	−1.468*	−2.124***	−2.257*	−0.910***
	(−1.80)	(−2.60)	(−1.91)	(−3.12)
Time fixed effects	YES	YES	YES	YES
Regional fixed effects	YES	YES	YES	YES
R-squared	0.0167	0.0011	0.0068	—
N	300	300	270	300

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.3. Endogenous test results

To address potential endogeneity concerns in the baseline regression results, we follow the methodology of Yan et al. (2024) and employ the instrumental variables approach. The findings from this analysis are presented in Table 5.

As shown in Table 5, to address endogeneity issues arising from reverse causality, we select the one-period lag of the independent variable as the instrumental variable and replace the original independent variable with this instrument to re-estimate the results. Column 1 indicates that the one-period lag of the policy financial level continues to exert a significant positive effect on domestic industrial gradient relocation at the 1% level, with an estimated coefficient of 0.738, suggesting that the model is not affected by endogeneity caused by reverse causality. To further mitigate potential biases in the model results due to endogeneity, an instrumental variable is constructed by interacting the ratio of deposit and loan balances to GDP in each province in 2008 with the number of financial institutions and employing 2SLS estimation. This instrument is highly correlated with the policy finance level, while only weakly correlated with domestic industrial gradient relocation, thereby satisfying the requirement that the instrumental variable is endogenous with respect to the independent variable but exogenous to the dependent variable. According to the 2SLS results, in the first stage shown in column 2, the instrumental variable has a significant positive effect on policy finance at the 1% level, with an estimated coefficient of 0.802. In the second stage, shown in column

3, policy finance, after being instrumented, continues to have a significant positive impact on domestic industrial gradient relocation at the 1% level, with an estimated coefficient of 0.354, ruling out potential model bias due to endogeneity. Moreover, the validity of the instrumental variable is confirmed through diagnostic tests: the Anderson canonical correlation LM test yields a result of 140.134 (p = 0.00), rejecting the null hypothesis of under-identification, and the Cragg-Donald Wald F test produces a value of 256.836, exceeding the critical value of 16.38 and rejecting the null hypothesis of a weak instrument. These results confirm that the instrumental variable is valid and that the 2SLS estimation results are reliable.

Table 5. Endogeneity test results.

Variable	Using the one-period lag of the independent variable as the instrumental variable	Two-stage least squares method	
		First stage	Second stage
	(1)	(2)	(3)
pfi		0.802***	0.354**
		(5.57)	(2.42)
$L_1.pfi$	0.738***		
	(3.40)		
eco	−1.545***	1.351***	−0.277**
	(−3.88)	(24.09)	(−2.10)
lar	−0.660***	0.360***	−0.227***
	(−3.09)	(6.82)	(−2.93)
fda	0.266***	−0.049**	0.082**
	(4.02)	(−2.54)	(2.13)
gov	−0.676**	0.389***	−0.011
	(−2.44)	(5.38)	(−0.08)
ope	0.095	−0.073***	−0.022
	(1.30)	(−3.76)	(−1.38)
Anderson canonical correlation LM test			140.134[0.00]
Cragg-Donald Wald F test			256.836[16.38]
_cons	−1.561	−1.630	−0.787**
	(−1.34)	(−5.54)	(−2.37)
Time fixed effects	YES	YES	YES
Regional fixed effects	YES	YES	YES
R-squared	0.0123	0.7323	0.0866
N	300	300	300

Note: Robust standard errors in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1.

4.4. Action mechanism test results

To examine the mechanism through which policy finance promotes domestic industrial gradient relocation, we employ the action mechanism model constructed in the previous section, with estimation results presented in Table 6.

Table 6. Action mechanism test results.

Variable	Industrial transformation and upgrading		Business costs	
	itu	*igt*	*bei*	*igt*
	(1)	(2)	(3)	(4)
pfi	0.325***	0.670***	−0.681***	0.670***
	(6.12)	(2.87)	(−5.40)	(2.93)
itu		0.750***		
		(2.96)		
bei				−0.358***
				(−3.37)
eco	−0.475***	−1.116***	1.422***	−0.964**
	(−5.24)	(−2.85)	(6.60)	(−2.40)
lar	0.015	−0.543**	0.412***	−0.384*
	(0.29)	(−2.56)	(3.37)	(−1.79)
fda	−0.026	0.252***	0.109***	0.272
	(−1.46)	(3.44)	(2.59)	(3.69)
gov	0.015	−0.970***	0.891***	−0.640
	(1.22)	(−3.42)	(5.43)	(−2.51)
ope	0.031*	0.115	0.071	0.164**
	(1.72)	(1.54)	(1.64)	(2.20)
_cons	0.656**	−2.544**	2.550***	−1.140
	(2.46)	(−2.29)	(4.03)	(−1.01)
Time fixed effects	YES	YES	YES	YES
Regional fixed effects	YES	YES	YES	YES
R-squared	0.2394	0.0026	0.8351	0.0107
N	300	300	300	300

Note: Robust standard errors in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1.

As shown in column 1 of Table 6, when industrial transformation and upgrading is treated as a mechanism variable, policy finance has a significant positive effect on industrial transformation and upgrading at the 1% level, with an estimated coefficient of 0.325. Column 2 shows that when both policy finance and industrial transformation and upgrading are included, they each exert a significant positive effect on domestic industrial gradient relocation at the 1% level, with estimated coefficients of 0.670 and 0.750, respectively. Comparing this with the baseline regression, where the mechanism variable is excluded, the estimated coefficient for the direct effect of policy finance on domestic industrial gradient relocation is 0.914, which is higher than 0.670. This suggests that industrial transformation and upgrading serves as a potential action transmission mechanism for policy finance in promoting domestic industrial gradient relocation, thereby supporting research hypothesis H2a. In column 3, when business costs are treated as a mechanism variable, policy finance has a significant negative effect on business costs at the 1% level, with an estimated coefficient of -0.681. Column 4 shows that when both policy finance and business costs are included, policy finance continues to significantly promote domestic industrial gradient relocation at the 1% level, with an estimated coefficient of 0.670, which is lower than 0.914, while business costs have a significant inhibitory effect on domestic industrial gradient relocation at the 1% level, with an estimated coefficient of −0.358.

This indicates that reducing business costs also serves as a potential action mechanism through which policy finance facilitates domestic industrial gradient relocation, thereby validating research hypothesis H2b.

4.5. Industry heterogeneity analysis results

Given variations in industry characteristics, technological barriers, and factor dependencies across manufacturing sectors, the impact of policy finance on domestic industrial gradient relocation may exhibit industry-specific heterogeneity. Following the classification methodology in existing research, we categorize the 31 manufacturing sub-sectors into three groups: labor-intensive, capital-intensive, and technology-intensive industries. Using the grouped estimation model, we conduct an analysis of industry heterogeneity, with the results presented in Table 7.

Table 7. Industry heterogeneity analysis results.

Variable	Labor-intensive industries	Capital-intensive industries	Technology-intensive industries
	(1)	(2)	(3)
pfi	0.575*	0.618*	0.472
	(1.87)	(1.80)	(1.43)
eco	−1.404***	−1.268**	−1.267*
	(−2.67)	(−2.17)	(−1.93)
lar	0.639**	−0.046	−0.684*
	(2.14)	(−0.14)	(−1.84)
fda	0.184*	0.352***	0.159
	(0.79)	(3.08)	(1.24)
gov	−0.782*	−1.523***	−1.189**
	(−1.95)	(−3.42)	(−2.39)
ope	0.268**	0.059	0.308**
	(2.56)	(0.51)	(2.36)
_cons	3.009*	−2.944*	−3.772*
	(1.95)	(−1.71)	(−1.96)
Time fixed effects	YES	YES	YES
Regional fixed effects	YES	YES	YES
R-squared	0.0024	0.0005	0.0025
N	300	300	300

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As shown in columns 1 and 2 of Table 7, policy finance has a significant positive effect on the domestic gradient relocation of labor-intensive and capital-intensive industries at the 10% level, with estimated coefficients of 0.575 and 0.618, respectively. However, as shown in column 3, policy finance does not have a significant effect on the domestic gradient relocation of technology-intensive industries. Labor-intensive industries, characterized by low technical barriers and high sensitivity to production factor costs, along with capital-intensive industries, which prioritize economies of scale and resource optimization and require robust infrastructure and supply chains, face relatively low relocation barriers.

Policy financial institutions support these enterprises by providing long-term, low-interest loans and interest subsidies. Moreover, they enhance the business environment in low-gradient regions and reduce investment costs for enterprises moving from high-gradient regions, thereby significantly promoting domestic industrial gradient relocation. In contrast, technology-intensive industries depend on patents, R&D talent, and accumulated knowledge, with core technologies often strictly protected and difficult to replicate through relocation. Additionally, governments tend to offer greater policy support to retain high-tech industries locally, creating higher relocation barriers. Consequently, policy finance has limited effectiveness in significantly promoting the domestic gradient relocation of technology-intensive industries. The industry heterogeneity findings align closely with the national objective of building domestic value chains, promoting smooth economic circulation, and achieving high-quality development. From the perspective of China's development strategy, the primary goal of domestic industrial gradient relocation is to guide the transfer of low-end industries, specifically labor-intensive and capital-intensive sectors, from eastern regions to central and western regions. Policy finance exerts a stronger promotional effect on the relocation of these low-end industries compared to technology-intensive industries, thereby facilitating their movement from the eastern regions to the central and western regions. The eastern regions, constrained by higher production factor costs and limited resources, cannot simultaneously support the development of both high- and low-end industries. By leveraging their strengths in advanced technology and high levels of openness, they can free up space to vigorously promote technology-intensive industries. To mitigate the risk of industrial hollowing out caused by excessive relocation overseas, labor-intensive and capital-intensive industries in the eastern regions should be redirected to the central and western regions. Meanwhile, as the central and western regions remain less developed in terms of economic output and living standards, their immediate priority is to capitalize on abundant, low-cost labor and resources to attract labor-intensive and capital-intensive industries, thereby driving rapid economic growth. This approach fosters a complementary and synergistic industrial landscape across the eastern, central, and western regions.

5. Conclusions and recommendations

5.1. Research conclusions

Through theoretical analysis and empirical investigation using panel data from China's manufacturing industry across 30 provinces (2014–2023), this study clarifies the specific impact of policy finance on domestic industrial gradient relocation. The main research findings are as follows:

First, baseline regression results indicate that policy finance significantly promotes domestic industrial gradient relocation. This finding remains robust across four alternative approaches: replacing the dependent variable, replacing the independent variable, removing abnormal samples, and employing different estimation methods. Furthermore, endogeneity tests confirm the absence of both reverse causality and estimation bias arising from endogenous factors.

Second, the action mechanism analysis shows that policy finance significantly promotes both industrial transformation and upgrading, as well as the reduction of business costs when these factors serve as mechanism variables. Both mechanism variables themselves also have significant positive effects on domestic industrial gradient relocation. Importantly, when both the independent variable and mechanism variables are included in the model, the effect of policy finance on relocation diminishes compared to the baseline regressions, confirming that industrial transformation and upgrading, along

with business cost reduction, serve as potential action mechanisms through which policy finance facilitates domestic industrial gradient relocation.

Third, industry heterogeneity analysis reveals that the effects of policy finance vary across industries. For labor-intensive and capital-intensive industries, which face relatively low relocation barriers, policy finance has significant positive effects on domestic gradient relocation. In contrast, technology-intensive industries face high relocation barriers, resulting in insignificant effects of policy finance on their domestic gradient relocation.

5.2. Policy recommendations

Based on the conclusions of the above research, the following targeted policy recommendations are proposed to enhance the effectiveness of policy finance and promote domestic industrial gradient relocation:

First, enhancing the precision of policy finance. As indicated by the baseline regression and industry heterogeneity analysis, policy finance significantly facilitates domestic industrial gradient relocation, with a stronger effect on labor-intensive and capital-intensive industries. Therefore, to address the strategic priority of advancing domestic industrial gradient relocation, policy financial institutions should innovate financing models, optimize the policy support system, provide stronger financial assistance to labor-intensive and capital-intensive industries, and more efficiently serve the real economy.

Second, accelerating industrial transformation and upgrading in the high-gradient regions. The action mechanism analysis indicates that industrial transformation and upgrading in high-gradient regions serve as a potential channel through which policy finance promotes domestic industrial gradient relocation. This upgrading should focus on high-end, intelligent, and green development. Accordingly, high-gradient regions should strengthen technological innovation, extend industrial chains into high-value-added segments such as R&D, design, and brand services, accelerate the adoption of smart manufacturing equipment, enhance the enabling effects of AI on production processes, and promote clean energy and circular utilization technologies. These measures will provide strong momentum for the relocation of industries to low-gradient regions.

Third, reducing business costs in the low-gradient regions. The action mechanism analysis also demonstrates that lowering business costs in low-gradient regions serves as a transmission mechanism through which policy finance facilitates domestic industrial gradient relocation. Therefore, low-gradient regions should implement preferential policies to reduce the costs of production factors such as labor, land, and resources. They should strengthen the development of standardized industrial parks and supporting infrastructure, actively promote productive services, enhance government administrative efficiency, optimize the business environment, and strive to lower transaction costs in local enterprises' production processes. These measures will attract enterprises from high-gradient regions to invest locally.

Fourth, strengthening regional industrial relocation collaboration and benefit sharing. Cross-regional cooperation and benefit sharing between relocate-out and relocate-in regions are essential for overcoming barriers to domestic industrial gradient relocation, building domestic value chains, and facilitating smooth economic circulation. Both regions should clearly define the distribution ratios of key economic indicators, such as tax revenue and GDP. They should jointly develop distinctive industrial chains and clusters that leverage regional synergies and complementary strengths, advance the co-construction of cross-regional industrial parks, strengthen production-sales linkages, harmonize market rules, promote mutual recognition of qualifications and standardized

regulatory frameworks, and ensure that industrial transfers are smoothly relocated, effectively received, and successfully developed.

Author contributions

Zeng Kang: Data curation, Investigation, Funding acquisition, Methodology, Project administration, Writing-original draft.

Luo Liangqing: Conceptualization, Formal analysis, Supervision, Funding acquisition, Writing-review and editing.

Li Hanqing: Investigation, Resources, Software, Validation, Visualization.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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