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Ural Branch of the Russian Academy of Sciences, Russia

*CORRESPONDENCE
Xindong Zhao
xzhao@hqu.edu.cn

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Can you have both fish and bear's paw? The impact of national innovative city pilot policy on the urban–rural income gap

Jiaqing Zhang, Xindong Zhao* and Dejin Zhao

Institute of Quantitative Economics and Statistics, Huaqiao University, Xiamen, China

In advancing China's high-quality development, the National Innovative City Pilot Policy has exerted a profound influence on the urban–rural income gap. Based on panel data from 280 prefecture-level and above cities in China for 2006–2018, this study employs a multi-period difference-in-differences (DID) framework to assess the policy's impact on urban–rural income gap and its heterogeneous effects, and further investigates the underlying mechanisms through industrial-structure optimization. The findings indicate that (1) the Pilot Policy significantly widens the urban–rural income gap at the prefecture level and above; (2) It intensifies this disparity via two channels—facilitating industrial upgrading while impeding structural rationalization—with partial mediation contributions of 31.71% and 35.13% of the total effect, respectively. This study concludes with policy recommendations for designing a scientifically grounded innovation system, narrowing income gap, and promoting coordinated urban–rural development.

KEYWORDS

the national innovative city pilot policy, the urban–rural income gap, industrial structure advancement, industrial structure rationalization, multi-period difference-in-differences

1 Introduction

In the process of continuously promoting Chinese-style modernization, China has emphasized the important role that innovation plays in driving development to "make the pie bigger" and in coordinating development to "divide the pie well." Specifically, the report of the 20th National Congress of the Communist Party of China clearly pointed out that China should implement the new development concept of "innovation, coordination, greenness, openness and sharing" and strive to promote high-quality development; the 14th Five-Year Plan (2021–2025) for National Economic and Social Development of the People's Republic of China also emphasized that an income distribution mechanism should be established that fully reflects the value of innovation factors such as knowledge and technology. This shows that technological innovation has not only become an engine of economic growth, but also has a profound impact on the income distribution model of various regions in the country (Lei et al., 2014; Zeng et al., 2022; Li and Yan, 2016).

At present, China's urban–rural income gap is at a high level, and it is still a difficult task to fundamentally narrow the gap between urban and rural areas (Zhao and Cui, 2023). From a vertical perspective, the ratio of per capita disposable income of urban and rural residents in China in 2023 was 2.39, 28.49% higher than the 1.86 ratio in 1986; although the relative gap has narrowed in recent years, the absolute gap is still widening, and the difference in per capita disposable income between urban and rural residents has reached 30,130 yuan (data source: "Resident Income and Consumption Expenditure in 2023," National Bureau of Statistics).

From a horizontal perspective, China's current urban–rural income gap is far higher than that of developed the countries, and even compared with India and Vietnam, which are also developing countries, it is still at a high level (Guo et al., 2022). Therefore, it is particularly important and urgent to conduct in-depth research on the policy effects of innovative development strategies on urban–rural income gaps.

As an important measure of the innovation-driven development strategy, the national innovative city PILOT POLICY has not only achieved significant results in continuously promoting the construction of a new national innovation system and improving the level of scientific and technological innovation, but also has exerted a significant influence on China's urban–rural income gap through industrial structure upgrading. On the one hand, with the transformation and optimization of the industrial structure, the increase in labor demand and employment opportunities in cities has led to the continuous transfer and gathering of rural surplus labor from rural areas to cities. The skill bias across industries and production sectors has led to divergent skill demands in urban versus rural areas. According to Guo (2019), shifts in the labor income share have significantly influenced the income gap between urban and rural residents; on the other hand, the adjustment and upgrading of the industrial structure is bringing about the flow of labor, talent, knowledge, education and other factors and innovation resources At the same time as the agglomeration phenomenon has occurred, it has also spawned new industrial formats such as digital services, e-commerce, and inclusive finance, which have effectively had a significant policy impact on the urban and rural income distribution pattern (Yang and Li, 2023; Li et al., 2021; Zhou et al., 2020; Song, 2017). This study attempts to deeply explore how innovative city pilot policies affect the urban–rural income gap from the perspective of industrial structure optimization, and provides a new research perspective for exploring the important issue of the impact mechanism between the two. The answer to this question is not only an important topic worthy of study in the process of promoting high-quality development, but also the starting point of this study.

This paper takes the national innovative city PILOT POLICY as a quasi-natural experiment, selects panel data from 280 prefecture-level cities from 2006 to 2018, and constructs a multi-period point double difference model to study the policy effect of the national innovative city PILOT POLICY on the urban–rural income gap. Furthermore, from the perspective of industrial structure, this paper explores and tests its impact mechanism, hoping to provide policy inspiration for exploring an effective and compatible model for the construction of national innovative city pilots and the coordinated development of urban and rural income distribution. The marginal contribution of this study is as follows: (1) In terms of research content, most of the current research on the effects of the national innovative city PILOT POLICY focuses on quantitative measurement and qualitative evaluation of its impact on urban and enterprise innovation. Few scholars pay attention to the impact of the national innovative city PILOT POLICY on the urban–rural income gap. This study not only expands the research content of the pilot policy effect analysis to a certain extent, but also further enriches the research on China's urban–rural income gap from the policy level. (2) In terms of research perspective, this paper systematically examines the impact mechanism of the national innovative city PILOT POLICY on the urban–rural income gap from the perspective of industrial structure upgrading and rationalization, which can enrich theoretical research on the evaluation of pilot policy effects and the urban–rural income gap. (3) In terms of research significance, this paper theoretically analyzes and quantitatively evaluates the impact of the national innovative city PILOT POLICY on the urban–rural income gap, and finds that the policy treatment effect has heterogeneous characteristics at the prefecture-level city level with different administrative levels and in different regions. Which provides useful reference and policy inspiration for better implementation and optimization of the pilot policy and accelerating the realization of innovation-driven development.

2 Literature review

2.1 Research on the National Innovation City Pilot Policy

The National Innovation City Pilot Policy is the "the highlight" for China to implement its innovation-driven development strategy, and it is also a hot topic widely studied by all sectors of society. In recent years, domestic scholars have actively explored this pilot policy. Quantitative evaluation of the implementation effect of the National Innovation City Pilot Policy, for example, Zou (2012), Zhou and Shen (2013) respectively used cluster analysis and factor analysis to quantitatively evaluate the structure and performance of China's innovative city construction; Wang et al. (2018) constructed a two-stage DEA model to evaluate the innovation efficiency of innovative pilot cities in the Yangtze River Delta region. On the other hand, scholars use the quasi-natural experiment of the National Innovation City Pilot Policy to focus on the dynamic effects of the policy on urban innovation and entrepreneurship, economic resilience, green development and other fields. Representative studies include: Nie and Liu (2019) who found that the construction of national innovative cities can improve the quality of FDI through the "loop effect"; Xu and Jiang (2020) who found that the national innovative city PILOT POLICY can significantly improve urban innovation, but the policy effect has weakened year by year; Li and Yang (2019) whose research conclusions show that the effectiveness of the innovative city pilot policy on improving the innovation level shows a change characteristic of first strengthening and then weakening; Nie et al. (2021) who found that the construction of innovative cities can significantly improve green total factor productivity; Chen C. et al. (2022), who found that the innovative city pilot policy can improve the level of urban green innovation and has a certain spatial spillover effect; Cao et al. (2022) who based on the framework of the heterogeneous enterprise monopolistic competition model, found that the construction of national innovative pilot cities has significantly improved the level of enterprise technological innovation, including R&D investment, quantity and quality of innovation output, etc.

2.2 Industrial structure optimization and urban–rural income gap

As a key factor affecting the urban–rural income gap, research on the impact of industrial structure optimization on the urban–rural income gap and its path of action has accumulated rich empirical results. However, existing research has not yet reached a consensus. Scholars have found that changes in industrial structure will widen the income gap between urban and rural residents. For example, Gao

(2011) found that there is a long-term stable positive equilibrium relationship between changes in China's industrial structure and the urban–rural income gap; Lin and Chen (2013) pointed out that the evolution of industrial structure is the core variable for understanding China's income distribution structure and income gap. The heavy industry priority development strategy will reduce labor demand, thereby reducing equilibrium wages and workers' income, leading to a widening income gap; Jing and Chen (2017) pointed out that when studying how FDI affects the urban–rural income gap through industrial structure upgrading, production factors such as talents and resources return or gather to the secondary and tertiary industries in cities, thereby forming a "low-end lock" on rural areas. The "center-periphery" phenomenon will widen the income gap. The research conclusions of some scholars show that industrial structure upgrading can narrow the urban–rural income gap. Among them, Liu and Lv (2011) found that the increase in the proportion of the primary and secondary industries can increase employment opportunities for rural residents, improve rural residents' income, and thus narrow the income gap; Yang et al. (2018) pointed out that with the upgrading of the industrial structure, the prices of production factors such as land and labor in cities have risen, which has promoted the migration of industries to low-cost rural areas, increased employment opportunities and income for rural residents, and helped to slow down the widening of the urban–rural income gap. In addition, Mu and Wu (2016) found that the adjustment of industrial structure and the urban–rural income gap show an inverted "U" relationship, and pointed out that the relationship between the two depends on the relative size of the marginal output elasticity of capital and land. Coincidentally, Gong et al. (2017) and Zhou and Chen (2021) each used a threshold regression model to draw the conclusion that there is a nonlinear relationship between industrial structure upgrading and the urban–rural income gap.

With a deeper understanding of the industrial structure, scholars have begun to conduct research from the perspective of advanced and rationalized industrial structure (Deng et al., 2020; Zhang, 2016; Qian et al., 2011). Research on the impact of industrial structure and urban–rural income gap has also been further enriched and expanded. Representatively, Chen (2014) fully considered the rationalization and upgrading characteristics of the industrial structure. The empirical test results show that the rationalization of the industrial structure is conducive to the narrowing of the urban–rural income gap, and the upgrading of the industrial structure. The income gap between urban and rural areas has significantly widened. When Wu et al. (2018) explored the impact of industrial structure changes on income inequality in the Chinese context, the study found that the rationalization of industrial structure can positively promote income distribution; however, when time trends and regional effects are not controlled, the industrial structure Gentrification has a negative impact on income inequality.

2.3 Literature review

In the innumerable volumes of existing documents, most of the research on the impact of the national innovative city PILOT POLICY focuses on quantitative evaluation and the dynamic effect analysis of the policy on the innovation level of cities and enterprises. Few literatures pay attention to and systematically examine the impact of this policy shock on the urban–rural income gap. This study is the first to explore whether there is a causal effect between the pilot policy and the urban–rural income gap. As a key factor affecting the urban–rural income gap and a core variable of the national innovative city PILOT POLICY, the industrial structure is naturally an important bridge, what roles do the advanced and rational industrial structure play in this impact mechanism? In summary, based on the research perspective of industrial structure optimization, this paper deeply explores the impact and internal mechanism of the national innovative pilot policy on the urban–rural income gap, and at the same time provides a new research perspective for existing research in this field.

3 Theoretical analysis and research hypothesis

3.1 Pilot policies and urban–rural income gap

The creation of national innovative city pilots is a major measure for China to implement the innovation-driven development strategy. This pilot policy impact has not only achieved technological innovation effects and results, but also had an impact on the urban–rural income gap that cannot be ignored. Zeng et al. (2022) found that in developing countries, the improvement of regional innovation levels will lead to the widening of the urban–rural income gap through two mechanisms: the "output effect" of innovation activities and the "erosion effect" on unskilled labor. In the process of creating national innovative pilot cities, the most direct result is to improve innovation efficiency and output and promote technological progress. However, the bias of technological progress will have a profound impact on the demand structure of the labor market and the polarization of the labor employment structure (Zeng et al., 2022; Acemoglu et al., 2012). Currently, it is a well-established fact that skilled labor is predominantly concentrated in urban areas, whereas rural regions are largely composed of unskilled workers (Li and Yan, 2016). Skill-biased technological progress not only increases the demand for skilled urban labor, but also triggers a skill premium (Dong and Wang, 2011; Wilfred, 2005). On the one hand, technological innovation will endogenously favor urban labor with higher skill levels (Acemoglu et al., 2012), which will reduce the employment opportunities and income levels of rural unskilled labor, and the wage gap between urban high-skilled labor and rural migrant workers with lower skill levels will widen accordingly; on the other hand, under China's "urban–rural dual structure" of innovation, the remuneration growth of urban high-skilled labor engaged in innovation activities is faster than that of rural low-skilled labor engaged in traditional industries (Glaeser, 1998), and the wage gap between urban and rural labor will gradually widen (Shin, 2016). Based on the above analysis, this paper proposes the following research hypothesis:

> *H1*: The national innovative city pilot policy has exacerbated the urban-rural income gap.

3.2 Pilot policies, industrial structure optimization and urban–rural income gap

According to the latest the national innovative city PILOT POLICY has effectively promoted the industrial upgrading of cities and the optimization of regional industrial structure. The pilot policy has led to the concentration and aggregation of innovation resources including science, technology, education, and talent, which is not only conducive to the learning and diffusion of technology and knowledge, and the improvement of industrial production and innovation efficiency, but also the aggregation of innovation factors has reduced market uncertainty to a certain extent, which can stimulate the enthusiasm for independent innovation and achieve the transfer to high-efficiency production departments, thereby promoting the upgrading of industrial structure (Yang and Fu, 2017). The impact of innovative city construction on the optimization and upgrading of industrial structure is mainly reflected in the two channels of industrial structure upgrading and rationalization (Wang et al., 2020; Zhao and Jia, 2019). Among them, industrial structure upgrading refers to the gradual shift of the focus of the industrial structure from the primary industry to the secondary and tertiary industries, which is reflected in the increase of industrial output value and the ratio of industrial employment; Industrial structure rationalization refers to the process of adjusting the unreasonable industrial structure based on scientific and technological level, consumption structure and resources to achieve the rational allocation and coordinated development of production factors, reflecting the degree of coordination between industries and the degree of coupling between factor input structure and output structure (Gan et al., 2011).

3.2.1 Advanced industrial structure

In the process of creating a national innovative pilot city, a number of technology-intensive, high value-added, and highly processed industries have been cultivated. The pilot policy has driven a marked rise in the relative shares of both high-tech and modern service industries, precipitating a gradual shift in the urban industrial structure toward tertiary-sector predominance. This structural transformation—from a secondary-sector focus to one dominated by the tertiary sector—demonstrates a clear advancement in industrial sophistication. Furthermore, the technology-selection framework established under the pilot policy has yielded strong innovation outcomes, notably by boosting investment in R&D inputs and enhancing the overall innovation environment. These improvements, in turn, have reinforced and accelerated the development of an advanced industrial structure (Hu et al., 2020). The national innovative city PILOT POLICY will select innovative elements in a targeted manner to achieve biased technological progress, which will help improve labor productivity and promote the upgrading of the industrial structure to a high level (Ngai and Pissarides, 2007; Krüger, 2008). In addition, the service support system of the pilot policy in finance, management and other aspects not only creates a good innovation and development environment for enterprises, but also accelerates the accumulation of innovation elements into enterprises, improves the "technical potential" of enterprises, and has a high impact on the industrial structure of cities and regions (Han et al., 2017). However, under the pilot policy, technological innovation and industrial structure adjustment are mostly concentrated and tilted toward cities, which will lead to unbalanced development of industrial sectors between urban and rural areas. The urban labor force enjoys the employment opportunities and income growth brought by the service industry, while the rural labor force with low levels of human capital and labor skills is difficult to quickly improve its labor productivity and does not enjoy the benefits brought by the development of knowledge-intensive industries. The advancement of industrial structure tends to exacerbate urban–rural disparities, leading to a widening income gap. Based on this observation, this article formulates the following research hypotheses:

> *H2*: The national innovative city pilot policy indirectly widens the urban-rural income gap by promoting the upgrading of the industrial structure.

3.2.2 Rationalization of industrial structure

In the construction of national innovative cities, the rationalization of industrial structure has also had an important impact. On the one hand, the design and selection of industrial policies before the implementation of policies will affect the coordination ability and correlation between industries that will develop in the future. For example, the planning of target industries can guide the allocation of resources and factors among industries, and can effectively avoid friction, resource mismatch, industrial structure convergence, etc. caused by unreasonable fluctuations in industrial structure, thereby promoting the rationalization of industrial structure. On the other hand, with the improvement of independent innovation capabilities, the efficiency of domestic factor utilization has also been greatly improved. Leading advantageous industries and emerging technology industries will further strengthen the correlation and cooperation and division of labor between upstream and downstream industries, making the industrial structure tend to be rational and coordinated. Combined with existing research, it can be concluded that the rationalization of industrial structure is conducive to reducing the urban–rural income gap (Wu et al., 2018; Chen, 2014). The improvement of the rationalization of industrial structure means that the industrial structure and employment structure are constantly moving toward equilibrium. The rational allocation of resources among industries and sufficient labor mobility make the labor productivity of various industries tend to be consistent. In addition, the rationalization of industrial structure can also indirectly affect the urban–rural income gap through the employment structure (Xiao et al., 2022; Donald, 2012). China's current three major industrial structures account for 7.7%, 37.8%, and 54.5%, respectively. The improvement of the rationalization of industrial structure means that the development speed of the first and second industries will increase, which can absorb more surplus rural labor, which is conducive to improving the income level of rural residents and narrowing the urban–rural income gap. In summary, this paper proposes the research hypothesis:

> *H3*: The national innovative city pilot policy can indirectly affect the urban-rural income gap through the rationalization of industrial structure.

4 Policy background, research design and data description

4.1 Policy background

In order to fully implement the innovation-driven development strategy, China has formulated a general plan for building national innovative cities and adopted the implementation method of "pilot first, gradually expanding in batches." In 2008, the National Development and Reform Commission approved Shenzhen as the first pilot city in the country to create a national innovative city, in order to use the "government licensing" method to create a city with strong independent innovation capabilities and outstanding scientific and technological support and leadership. In 2010, the scope of the pilot was further expanded. In the same year, a total of 44 cities (districts) were approved to enter the list of national innovative cities, reaching the largest scale of the entire gradual reform process. By 2018, 78 cities (districts) had carried out national innovative city pilots and developed into a number of strategic fulcrums for scientific and technological self-reliance. According to the latest "National Innovation City Innovation Capacity Evaluation Report 2022," by the end of 2022, the Ministry of Science and Technology has supported 103 cities (districts) to build national innovative cities.

In establishing national innovative cities, municipalities and districts employ independent innovation as their primary driving force. While promoting the upgrading of leading industries, they also cultivate strategic emerging industries such as new energy, new materials, and biomedicine, develop high-tech industries and modern service industries, accelerate the process of high-tech transformation of traditional industries, and optimize the industrial structure. It can be seen that the national innovative city PILOT POLICY has significantly promoted the transformation and upgrading of the industrial structure. At the same time, the impact of the evolution of the industrial structure on the urban income distribution structure is also worthy of our attention and concern (Lin and Chen, 2013). This research investigates whether the National Innovative City pilot policy exerts a causal impact on industrial structure at the prefecture-level and on the urban–rural income gap. Drawing on the relevant literature and policy context, it then undertakes detailed empirical analysis and mechanism testing.

4.2 Model construction and description

4.2.1 Multi-time point DID benchmark regression model

This paper takes the national innovative city PILOT POLICY as a quasi-natural experiment and uses the difference-in-difference method (DID) to evaluate its impact on the urban–rural income gap. Since the pilot policy is implemented in batches and gradually, this paper constructs a multi-time point DID regression model, the specific form is as follows:

$$Gap_{it} = \alpha + \beta Treat * Post_{it} + \gamma Control_{it} + \mu_i + \lambda_t + \epsilon_{it} \tag{1}$$

Among them, Gap_{it} represents the urban–rural income gap; $Treat * Post_{it}$ is the innovative city pilot policy treatment effect, represented by the interaction term of the city type dummy variable and the policy implementation time dummy variable; $Control_{it}$ is the control variable; μ_i and λ_t represent region fixed effects and time fixed effects, respectively. By strictly controlling for both city and year can largely eliminate the influence of other contemporaneous factors (Huo et al., 2020); ϵ_{it} is the random error term. The estimated coefficient measures the change in the urban–rural income gap of the experimental group compared with the control group before and after the pilot policy impact. The significant difference between the two reflects the policy effect: if $\beta > 0$, it means that the creation of national innovative pilot cities will exacerbate the urban–rural income gap; otherwise. This suggests that policy implementation has a mitigating effect on the urban–rural income gap.

4.2.2 Mediation effect test model

Based on the theoretical mechanism analysis in the previous article, this study refers to the approach of scholars Ma and Huang (2022) to construct a mediation effect model to test whether the national innovative city PILOT POLICY can affect the urban–rural income gap through the mechanism of industrial structure optimization. The model setting is as follows.

$$MED_{it} = \alpha + \theta Treat * Post_{it} + \gamma Control_{it} + \mu_i + \lambda_t + \epsilon_{it} \tag{2}$$

$$Gap_{it} = \alpha + \varphi Treat * Post_{it} + \delta MED_{it} + \gamma Control_{it} + \mu_i + \lambda_t + \epsilon_{it} \tag{3}$$

The interpretation of each parameter is the same as in Model 1; among them, MED is the intermediary variable, that is, the mechanism variable through which the pilot policy affects the urban–rural income gap, which mainly includes the upgrading of industrial structure (Ais) and the rationalization of industrial structure (Ris). Since the influence of the mediating variable on the explained variable is based on theoretical and literature support, this paper uses a two-step regression to determine whether the coefficient is significant and test it. This approach can effectively avoid the endogeneity bias that may exist when the mediating effect model is applied in the field of economics, the defect of unclear identification of some channels (Jiang, 2022).

The testing principle is as follows: if either coefficient θ or φ is not significant, a sobel test is required. A significant sobel test result indicates the presence of a mediating effect for MED, while an insignificant result suggests no mediation effect. If both coefficients θ or φ are significant, it confirms the existence of the mediating effect. Further testing of φ can distinguish between full mediation and partial mediation. If the coefficient φ is not significant, this indicates full mediation. If φ is significant and its sign is consistent with $\theta*\delta$, the contribution rate of the partial mediation effect of MED to the total effect can be calculated as:

$$\eta = \frac{\theta * \delta}{\theta * \delta + \varphi} \tag{4}$$

4.3 Variable selection

1. Explained variable: urban–rural income gap (*Theil*). Because the Theil Index takes into account both population structure and income distribution, and is sensitive to changes in income at both ends (Chen D. et al., 2022), this study uses this indicator to measure the urban–rural income gap. The calculation formula is shown below. Among them,I_{1t} and I_{2t} represent the total income of urban and rural residents respectively, and I_t is the total income; P_{1t} and P_{2t} represent the number of urban and rural populations respectively, and P_t is the total population.

$$Theil_t = \sum_{i=1}^{2} \left(\frac{I_{it}}{I_t}\right) \ln \left(\frac{\frac{I_{it}}{P_{it}}}{\frac{I_t}{P_t}}\right) \tag{5}$$

2. Explanatory variables: policy treatment effect ($Treat * Post$). *Treat* is a dummy variable for the treatment group, national

innovative pilot cities $Treat = 1$; non-national innovative pilot cities $Treat = 0$; $Post$ is a dummy variable for the policy implementation time, $Post = 0$ before the pilot policy is implemented; $Post = 1$ after the pilot policy is implemented. In summary, depending on whether $Treat * Post$ is 0, they are divided into an experimental group and a control group. In addition, since the national innovative pilot cities were established in batches, the time when the pilot cities received policy shocks was not the same. This study needs to set a relative time value dummy variable for each pilot city.

3. Intermediary variable: industrial structure optimization. This study defines the upgrading of industrial structure (ais) as the weighted value of the product of the ratio of the primary, secondary and tertiary industries and their labor productivity (Liu et al., 2008), as shown in Formula 6. Regarding the measurement of the rationalization of the industrial structure of each prefecture-level city, this paper uses Formula 7 to calculate, which better reflects the degree of coupling between the factor input structure and the output structure (Gan et al., 2011).
4. This paper draws on the approach of scholars Yuan and Zhu (2018) to calculate the industrial structure upgrading (ais_{it}) and industrial structure rationalization (ris_{it}). The specific calculation formula is as follows:

$$ais_{it} = \sum_{m=1}^{3} y_{imt} \frac{Y_{imt}}{L_{imt}} \tag{6}$$

$$ris_{it} = \sum_{m=1}^{3} y_{imt} \ln\left(\frac{y_{imt}}{l_{imt}}\right) \tag{7}$$

Among them, in Formula 6, y_{imt} represents the proportion of the region's first industry in the regional GDP during the period;Y_{imt} is the industry's added value; L_{imt} is the number of employees; in Formula 7, l_{imt} represents the proportion of the number of employees in the m industry in the region i during the period to the total number of employees, and the other parameters are the same as above.

5. Control variables: other factors that affect the urban–rural income gap. Based on existing literature (Zhou and Chen, 2021; Li and Yan, 2016; Fukiharu, 2013), the control variables selected in this paper mainly include: (1) Economic development level (*lnagdp*): measured by real per capita GDP after price deflation, logarithmized to reduce the possible heteroscedasticity, and its square term included in the control variable; (2) Openness level (*open*): the proportion of actual foreign investment in the year to GDP is used as a measurement indicator; (3) Government macroeconomic regulation degree (*gov*): expressed by the ratio of general public budget expenditure to GDP; (4) Human capital level (*talents*): This paper uses the proportion of "number of employees in scientific research, technical services and geological survey industry + number of employees in information transmission, computer services and software industry" to the total number of employees in the city to represent the level and content of human capital at the city level (Du and Yu, 2019); (5) Internet penetration rate (*ainternet*): represented by the number of Internet broadband access users per 10,000 people; (6) Urbanization (*urban*): The urbanization rate is calculated by dividing the urban population by the total population (both calculated based on the permanent population).

4.4 Data source and description

This study selected unbalanced panel data from 280 prefecture-level cities from 2006 to 2018 for empirical research. The data came from the "China City Statistical Yearbook" and "Statistical Communiqué on National Economic and Social Development" of various regions over the years. Among them, this paper did not include the urban areas of the four municipalities directly under the central government in the investigation, because the municipalities directly under the central government only took a certain district as a pilot (i.e., Haidian District, Beijing, Binhai New Area, Tianjin, Yangpu District, Shanghai, and Shapingba District, Chongqing). If it was used as a pilot city, the impact of the pilot policy would be underestimated. In addition, in view of data availability, this paper excluded a total of 14 prefecture-level cities with serious data missing and administrative division adjustments, and two county-level cities (Changji and Shihezi), to avoid interference in the empirical results arising from differences in cities' administrative levels.

The descriptive analysis results of the research variables and data in this paper are shown in Table 1 below.

5 Empirical results and analysis

5.1 Baseline regression results

Table 2 shows the regression results of the national innovative city PILOT POLICY on the urban–rural income gap in prefecture-level cities. Among them, M2, M3 and M4 sequentially add control variables, control city fixed effects, and simultaneously control city and year fixed effects on the basis of M1. It can be seen from Table 2 that under each model, the regression coefficient of the core explanatory variable $Treat * Post$ is significantly positive; the results of the two-way fixed effects model (M4) show that the impact coefficient of $Treat * Post$ on the urban–rural income gap is 0.01, passing Significance test at 10% level. This shows that the national innovative city PILOT POLICY has significantly exacerbated the urban–rural income gap, which preliminarily verifies the research hypothesis H1. Coincidentally, Li and Yan (2016) pointed out that under the combined effect of factors such as the urban–rural dual structure of scientific and technological innovation and the bias of technological progress caused by innovation activities, the improvement of innovation investment intensity, innovation capabilities and efficiency will be significantly expanded. Urban–rural income gap.

From M4, it can be seen that regarding the control variables: (1) The regression coefficient between the level of economic development and the urban–rural income gap is significantly negative, and its square term coefficient is significantly positive, indicating that the two have a "U-shaped" relationship. Lin and Chen (2013) further demonstrated that China's urban–rural income disparity follows a U-shaped pattern as economic development advances. (2) The regression coefficient of

TABLE 1 Descriptive statistics of variables.

Variable	Sample size	Mean	S. D	Min	Max
Theil	3,612	0.0961	0.0561	0.0008	0.5061
Treat*Post	3,640	0.1291	0.3354	0	1
ais	3,640	0.8115	0.0639	0.5992	1.0111
ris	3,640	0.2761	0.2088	−0.0290	1.7205
lnagdp	3,640	9.5705	0.6937	7.6944	12.3683
open	3,621	0.0184	0.0191	0	0.1988
gov	3,640	0.2291	0.2845	0.0043	3.4630
talents	3,640	0.0273	0.0157	0	0.1462
ainternet	3,640	0.1581	0.1665	0.0008	1.9866
urban	3,621	0.5006	0.1626	0.1151	1

TABLE 2 Benchmark regression results.

Variable	M1	M2	M3	M4
Treat*Post	0.0257*** (0.0020)	0.0129*** (0.0033)	0.0128*** (0.0034)	0.0097** (0.0023)
lnagdp	–	−0.7114*** (0.0886)	−0.7515*** (0.1069)	−0.4455*** (0.1079)
$lnagdp^2$	–	0.0343*** (0.0045)	0.0362*** (0.0054)	0.0212*** (0.0055)
open	–	−0.0499*** (0.0221)	−0.0469** (0.0231)	−0.0213 (0.0186)
gov	–	−0.0064*** (0.0020)	−0.0070*** (0.0023)	−0.0040* (0.0024)
talents	–	−0.0146 (0.0899)	−0.0814 (0.1092)	−0.1312 (0.1037)
ainternet	–	−0.0007*** (0.0001)	−0.0007*** (0.0001)	−0.0002** (0.0001)
urban	–	−0.0011 (0.0021)	−0.0008 (0.0022)	−0.0003 (0.0017)
_cons	0.0991*** (0.0029)	3.7605*** (0.4377)	3.9958*** (0.5213)	2.4606*** (0.5286)
City fixed effects	No	No	Yes	Yes
Year fixed effects	No	No	No	Yes
Observed values	3,612	3,580	3,580	3,580
R-squared	0.0595	0.4228	0.8584	0.8975

***, **, and * indicate significance at the 1, 5, and 10% significance levels respectively; the values in parentheses indicate robust standard errors.

the degree of openness to the outside world is significantly negative at the 1% significance level, indicating that the expansion of the degree of openness to the outside world can narrow the urban–rural income gap. (3) The regression coefficient of the degree of government macro-control is also significantly negative, which indicates that the increase in the level of government intervention is conducive to alleviating the urban–rural income gap. The reason may be that government fiscal expenditures are more biased toward the rural sector, which increases the income level of rural residents, thus exerting a play a role in narrowing the urban–rural income gap (Jiao, 2022; Hong et al., 2014). (4) The Internet penetration rate is significant at the 1% level and the coefficient is negative, which means that increasing the Internet penetration rate can reduce the urban–rural income gap, indicating that China is in an opportunity period to use the Internet and other information technologies to continuously reduce the imbalance between urban and rural development (Cheng and Zhang, 2019). (5) The regression coefficient of urbanization is negative, but it is not significant in the model. A reasonable explanation is that controlling for the spatial spillover effect of urban–rural income distribution will make this narrowing effect insignificant (Li and Yan, 2016).

5.2 Parallel trend test

Since the premise of the difference-in-difference method (DID) estimation is that the experimental group and the control group have the same trend before the policy is implemented, this study tests whether the sample meets the parallel trend hypothesis in order to accurately identify the impact of the national innovative city PILOT POLICY on the urban–rural income gap. This paper uses the coefficients of the regression of the urban–rural income gap and the relative time value dummy variable to depict the trend changes of the experimental group and the control group during the sample period, and uses the event study method to draw the coefficient image, as shown in Figure 1. As mentioned above, and as previously mentioned, the relative time dummy variable represents the values for each city in the *i* years before, the year of, and the *i* years after being designated as a pilot city, while non-pilot cities have a value of 0 throughout. Among them, this paper removes the time dummy variables before and during the −4 period of some cities to avoid multicollinearity, and selects the policy −1, −2, and −3 periods as the reference years for the parallel trend test before the policy occurs.

It can be seen from Figure 1 that the coefficients of the relative time dummy variables before the policy occurred are not significant, which shows that before the policy occurred, there was no significant difference in the urban–rural income gap between the experimental group and the control group, that is, the national innovative city PILOT POLICY. The hypothesis of parallel trend test is met. Based on the background that the number of national innovative pilot cities reached the largest scale in 2010 (44 cities/districts), this article chooses 2010 as the starting point to analyze the dynamic effects before and after the pilot policy. The results show that: in the current period when the policy occurred in the first year, the impact of the innovative city pilot policy on the urban–rural income gap was not significant; after 3 years of the implementation of the pilot policy, the impact coefficient stabilized at a significance level of 1% year by year. This shows that the national innovative city PILOT POLICY has had a widening policy effect on the urban–rural income gap at the prefecture-level city level; but there is a certain lag, which is consistent with the reality that the effect of policy implementation will not be immediate. In other words, the development of innovative cities represents a protracted, long-term endeavor. It takes a certain amount of time from being approved to join the national innovative pilot city to the emergence of the impact of pilot policies, which is specifically reflected in the demonstration and adjustment of industrial policies, high-tech industries Park planning and construction, etc.

5.3 Robustness test

In order to further verify the robustness of the benchmark regression conclusion, this paper conducts the following robustness test. It includes constructing a PSM-DID model, replacing the measurement indicators of the explained variables, excluding the impact of other policies, placebo tests, and solving possible heterogeneous treatment effects. The robustness test results are shown in Table 3.

5.3.1 PSM-DID

In order to eliminate the selection bias problem that may be caused by the non-random selection of pilot cities, this article constructs a multi-time point propensity score matching-difference-in-difference (PSM-DID) model, and uses the nearest neighbor matching method (1:k) for propensity score matching. There is no significant difference between the matching variables of the experimental group and the control group before and after matching, and the standardized mean deviations after matching are all less than 10%, which meets the balance test conditions. Finally, the matched data were used to conduct multi period DID regression. The results showed that: the coefficient of $Treat * Post$ was 0.0528 and passed the significance test at the 1% level, which was basically consistent with the benchmark regression results. This verifies that the research conclusion is robust.

5.3.2 Replacing the measure of the explained variable

The urban–rural income ratio is widely employed to indicate income disparities between urban and rural areas. However, relative to the 1 % index, it overlooks heterogeneities in population composition and is constrained by data availability. Therefore, this article uses the per capital disposable income of urban residents and the ratio of per capital net income of rural residents is calculated to

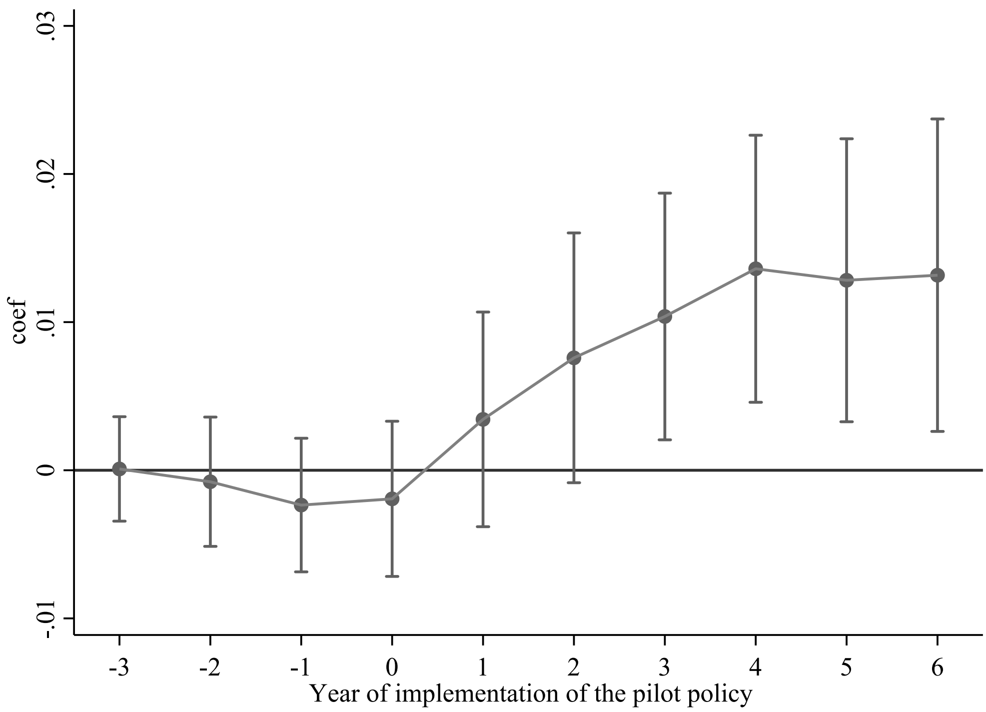

FIGURE 1
Parallel trend test results before and after the implementation of the pilot policy.

TABLE 3 Robustness test results.

Variable	M5	M6	M7
	PSM-DID	Urban–rural income ratio	Excluding the impact of smart city policies
Treat*Post	0.0528*** (0.0148)	0.0490*** (0.0188)	0.0225*** (0.0059)
Policy*Post	–	–	0.0014 (0.0029)
Control variables	YES	YES	YES
Fixed effects	YES	YES	YES
Observed values	3,312	2,492	3,037
R-squared	0.8981	0.9044	0.8927

***, **, and * indicate significance at the 1, 5, and 10% significance levels respectively; the values in brackets indicate robust standard errors; the fixed effects model controls both city and year fixed effects.

obtain the "urban–rural income ratio," which is used as a replacement indicator for the explained variable for robustness testing. The regression results are shown in M6 in Table 3. The influence coefficient of $Treat * Post$ is 0.0490, which is significantly positive at the 1% level, indicating that the pilot policy has significantly improved the income ratio of urban and rural residents and verified the robustness of the benchmark regression results.

5.3.3 Excluding the impact of other policies

During the sample examination period of this article from 2010 to 2018, the urban–rural income gap at the prefecture-level city level may also be affected by the smart city pilot policies established in batches since 2012. Therefore, this study adds a dummy variable for the year of smart city pilot policy implementation to control the interference of other policies on the estimation results. The regression results are shown in M7 in Table 3. After excluding the impact of smart city policies, the coefficient of the interaction term $Treat * Post$ is 0.0225 and is still significantly positive at the 1% level, verifying that the above research conclusion is robust and reliable.

5.3.4 Placebo test

Due to the differences in the policy impact time of pilot cities in the multi-time point DID model, this article refers to Bai et al. (2022) and Cantoni et al. (2017), while randomizing the policy time and treatment group, and bringing it into the generation New treatment groups of pseudo city type and pseudo policy impact dummy variables are estimated to effectively deal with the possible impact of some non-observed city characteristic factors on the pilot policy effect evaluation results. The results of the placebo test show that the DID estimated coefficients obtained by random processing are concentrated around 0, and the corresponding p value is higher than 0.1; the random coefficient is basically located to the left of the true value, and the vertical dotted line representing the actual estimated value of the baseline regression is significantly different from the overall value. Distribution, differ significantly from the estimated coefficients of the actual policy. This indicates that the baseline regression results are not affected by this potential factor, confirming that the research conclusions are robust and reliable.

5.3.5 Heterogeneous treatment effects

Scholars De Chaisemartin and D'Haultfoeuille (2020) and Baker et al. (2022) found that when multi-point DID is used for policy evaluation, the existence of heterogeneous treatment effects may cause bias in the estimation results. This paper conducts a robustness test on the possible heterogeneity when using Model 1 to identify policy effects. The results show that the annual treatment effects of 457 ATTs are all positive (receive a positive weight), and the heterogeneous treatment robustness index is close to 1, indicating that the model heterogeneity test results are robust.

5.4 Heterogeneity analysis

The heterogeneous characteristics of the city itself and the actual situation of regional differences will make the policy effects different (Hu et al., 2020). In order to explore whether there are significant differences in the impact of the national innovative city PILOT POLICY on the urban–rural income gap for urban objects at different administrative levels and different regions, this study conducted heterogeneity analysis, and the results are shown in Table 4.

5.4.1 Heterogeneity of urban administrative levels

This paper assigns the city level dummy variable of provincial capital cities, cities under separate state planning and special economic zones to 1, and other cities to 0. By adding the interaction term between the city level dummy variable ($rank$) and the pilot policy dummy variable ($Treat * Post$), we can examine whether the treatment effect of the innovative city pilot policy will show differential effects depending on the city level. From M8 in Table 4, it can be seen that the coefficient of the interaction term (0.0211) is significantly positive, indicating that the national innovative city PILOT POLICY has a stronger impact on the urban–rural income gap in cities with higher administrative levels. This disparity may stem from the fact that, relative to standard prefecture-level cities, higher-tier urban centers—including provincial capitals and core cities—enjoy more advanced economic development, infrastructure, and market environments (Hua and Ye, 2023; Yang et al., 2023). On this basis, the marginal effect of pilot policies on the urban–rural income gap through mechanisms such as technological progress, labor mobility, and industrial structure optimization is also more significant.

5.4.2 Heterogeneity of regions

Due to the large differences in social-economic development, policy concentration, and factor resource flows among the three major regions of the east, Central, and west (Zhao et al., 2023), this may lead to different effects of the pilot policy on cities in different regions. Therefore, a group regression is performed according to the different

TABLE 4 Results of heterogeneity analysis.

Variable	M8	M9		
	City level	East	Central	West
Treat*Post	0.0319*** (0.0027)	0.0094*** (0.0031)	0.0075 (0.0048)	0.0033 (0.0041)
Rank*(Treat*Post)	0.0211*** (0.0055)	–	–	–
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observed values	3,580	1,491	1,033	1,056
R-squared	0.8975	0.8438	0.8823	0.8937

***, **, and * indicate significance at the 1, 5, and 10% significance levels respectively; the values in brackets indicate robust standard errors; the fixed effects model controls both city and year fixed effects.

regions where the prefecture-level cities are located. M9 in Table 4 shows the estimated results of the policy effects in the eastern, central, and western regions, respectively.

For the eastern, central and western grouped regression samples, the regression coefficients of the pilot policies are all positive, indicating that the creation of national innovative city pilots has played a policy effect in exacerbating the urban–rural income gap in different regions. However, for cities with different location characteristics, the impact shows certain heterogeneity. The regression coefficient in the eastern region $Treat * Post$ is significantly positive at the 1% level, indicating that in the eastern region, innovative urban pilot policies have the effect of widening the urban–rural income gap. Scholars Liu et al. (2016) obtained consistent research conclusions and pointed out that the innovative activities promoted by pilot cities will, on the one hand, lead to an increase in the productivity and wage levels of non-agricultural industries, which will lead to an expansion of the urban–rural income gap. On the other hand, the demand for high-skilled labor has also increased relatively, creating a substitution effect for low-skilled labor located in rural areas. The influence coefficients in the central and western regions are not significant. The reason may be that the impact of the pilot policies on their urban–rural income gap has not yet appeared, or that there are only 23 and 17 pilot cities in the central and western regions, and the number of experimental groups is small. Caused by.

5.5 Mechanism test and analysis

In Table 5, M10 and M11, respectively, show the results of the mechanism test with industrial structure upgrading and rationalization as mediating variables.

From M10 in Table 5 above, it can be seen that the impact coefficient of the pilot policy ($Treat * Post$) on the upgrading of industrial structure is 0.1389, which is significantly positive at the 1% level. This means that the innovative city pilot policy will promote the upgrading of the industrial structure. Scholars Yang and Li (2023) also found that the implementation of the innovative city pilot policy will allow more resources to be used in industries with higher production efficiency. This will further enhance the upgrading of the industrial structure. In addition, the impact coefficient of industrial structure upgrading (ais) on the urban–rural income gap (gap) is 0.1140, passing the significance test at the 1% level, which means that the impact of industrial structure upgrading on the urban–rural income gap is significantly positive. In addition, the coefficient φ=0.0341 is significantly positive, consistent with the $\delta^{*}\theta$ sign. Therefore, the existence of some intermediary effects is confirmed, indicating that the national innovative city PILOT POLICY can widen the urban–rural income gap by improving the upgrading of the industrial structure, and the research hypothesis H2 is verified. After calculation, the partial intermediary effect exerted by the advanced industrial structure contributed 31.71% to the total effect.

Similarly, according to the M11 test results in Table 5, it can be seen that the regression coefficient of pilot policy $(Treat * Post)$on industrial structure rationalization (ris) is −0.1161, which is significantly negative at the 1% level, indicating that the national innovative city PILOT POLICY is not conducive to industry Structural rationalization. This may be related to the failure to take into account the professional division of labor and cooperation between industries before the design and creation of the pilot policy, leading to misallocation of resources, convergence of industrial structures, low correlation and complementarity (Feng, 2017). The impact coefficient of industrial structure rationalization (ris) on the urban–rural income gap (gap) is −0.1502, and passed the significance test at the 1% level, indicating that the reduction in the degree of industrial structure rationalization is not conducive to alleviating urban–rural income inequality. In summary, both coefficients are significant, indicating that the mechanism test using industrial structure rationalization as the intermediary variable has passed. The contribution of part of the intermediary effect is 35.13%, and the research hypothesis H3 has been verified.

6 Conclusion and policy recommendations

Based on the panel data of 280 prefecture-level cities in China from 2006 to 2018, this paper constructs a multi-period DID model and a mediation effect test model to empirically test the impact and mechanism of the national innovative pilot cities on the urban–rural income gap from the perspective of industrial structure upgrading and rationalization. The empirical research results show that: (1) The national innovative city PILOT POLICY has aggravated the urban–rural income gap at the prefecture-level level in China. This conclusion still holds after a series of relevant robustness tests such as PSM-DID, replacement measurement indicators, exclusion of other policy influences, and placebo tests. At the same time, this policy effect shows different characteristics in cities of different administrative levels and regions. (2) The mechanism test results show that the innovative city

TABLE 5 Mechanism test results.

Variable	M10		M11	
	Advanced industrial structure		Rational industrial structure	
	ais	gap	ris	gap
Treat*Post	0.1389*** (0.0066)	0.0341* (0.0195)	−0.1161*** (0.0015)	0.0322** (0.0154)
ais	–	0.1140*** (0.0013)	–	–
ris	–	–	–	−0.1502*** (0.0081)
Control variables	YES	YES	YES	YES
Fixed effects	YES	YES	YES	YES
Observed values	3,640	3,612	3,640	3,612
R-squared	0.9435	0.8820	0.8386	0.8816

***, **, and * indicate significance at the 1, 5, and 10% significance levels respectively; the values in brackets indicate robust standard errors; the fixed effects model controls both city and year fixed effects.

pilot policy can aggravate the urban–rural income gap by improving the upgrading of industrial structure and inhibiting the rationalization of industrial structure. The contribution of these two types of mediating mechanisms is 31.71 and 35.13%, respectively. Based on the above research conclusions, this paper proposes the following policy recommendations for the current situation of "you cannot have both fish and bear's paw" under the impact of this policy:

6.1 Optimize policy design and implementation mechanisms

In top-level design, the goals of innovation-driven growth and balanced development must be integrated organically. Metrics such as urban–rural income levels, equity of income distribution, and common prosperity should be incorporated into the planning, oversight, and evaluation framework for building innovative cities. For example, in accordance with relevant directives, performance appraisals could include hard targets like the narrowing of urban–rural income gaps to ensure that the benefits of innovation reach all segments of society. At the same time, complementary support policies should be refined—using fiscal transfers, tax incentives, and increased investment in education and healthcare—to guide factors of production (technology, capital, and talent) toward rural areas, thereby enhancing the inclusive effects of innovation. Empirical studies indicate that pilot policies for innovative cities help advance common prosperity; accordingly, a dual emphasis on innovation and sharing is required, with a tiered implementation mechanism that combines central coordination and local execution to ensure that innovation and reductions in urban–rural disparity proceed in tandem.

6.2 Strengthen differentiated and tiered policy provision

Tailored implementation plans should be developed for regions and city types with different characteristics. The literature highlights that the common-prosperity effects of pilot innovative-city policies are particularly pronounced in the central and western regions and in prefecture-level cities, and that policy impacts vary by urban location and administrative level. Therefore, following the principle of "central coordination, local implementation," the central government should establish an overall framework and allocate additional resources to the central and western regions and lower-tier cities. Local governments, in turn, should propose specific measures based on their development foundations and factor endowments, avoiding one-size-fits-all approaches. For instance, graded support funds could be established, and greater efforts made to attract talent, capital, and innovation services to small and medium-sized cities and the central and western regions. Such a differentiated, tiered execution mechanism will enable place-based policymaking and fully leverage the ability of innovative-city pilots to support balanced regional development.

6.3 Coordinate industrial-structure optimization with urban–rural income distribution

Industrial upgrading and employment generation should be key levers for narrowing the urban–rural divide. On the one hand, high-tech industries and modern service clusters must be vigorously cultivated, while labor-intensive manufacturing should be encouraged to provide more job opportunities and wage income for surplus rural labor. For example, pilot cities could establish industrial parks and innovation incubation platforms that foster industry–university–research integration and urban–rural collaboration, promoting the spillover of knowledge, technology, and capital into rural areas to enhance productivity and wages. On the other hand, the linkage and complementarity between upstream and downstream segments of industrial chains, as well as between horizontal industries, should be reinforced. By optimizing factor allocation and fostering collaborative innovation, resources can flow rationally across industries, achieving coordinated industrial-structure development. Research shows that innovative-city policies influence common prosperity primarily through urbanization and industrial upgrading. Therefore, at the macro level, industrial policies and incentive mechanisms should be perfected to ensure a balanced portfolio of industries, so that the gains from industrial upgrading more effectively contribute to income growth for both urban and rural residents.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JZ: Conceptualization, Data curation, Methodology, Writing – original draft. XZ: Funding acquisition, Resources, Supervision, Writing – review & editing. DZ: Formal analysis, Investigation, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

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