Vertical Fiscal Imbalance and Transformation of Industrial Innovation Achievements: Based on Panel Data of 30 Provinces in China

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Abstract. Based on the background of deepening the financial system reform and innovation-driven development strategy, this paper incorporates the vertical imbalance of finance and the transformation of industrial innovation achievements into the theoretical analysis framework, and explains the mechanism of the vertical imbalance of finance on the transformation of industrial innovation achievements through theoretical analysis. Based on the panel data of 30 provincial regions in China from 2003 to 2020, it is found that the current vertical fiscal imbalance in China has a significant negative impact on the transformation of industrial innovation achievements. Furthermore, there are regional and time heterogeneity, which is manifested in the fact that the transformation of industrial innovation achievements in the eastern region is not easily affected by the vertical fiscal imbalance, while the central and western regions are easily affected by the vertical fiscal imbalance. Meanwhile, the negative impact of fiscal vertical imbalance on the transformation of industrial innovation achievements after 2012 is significantly stronger than that before 2012. In addition, the scale of science and technology education expenditure has a mitigating effect on the negative effects of fiscal vertical imbalance and the transformation of industrial innovation achievements. In order to promote the implementation of innovation-driven development strategy, China should further deepen the reform of financial system, improve the performance appraisal system of local governments, and accelerate the optimization and upgrading of industrial structure.

Keywords: Transformation of Industrial Innovation Achievements; Science and Education Expenditure Heterogeneity; Mediating Effect Fiscal Vertical Imbalance.

1. Introduction

Since the 18th National Congress of the Communist Party of China, the state has clearly put forward the innovation-driven development strategy, taking scientific and technological innovation as the key to new kinetic energy and new mechanism for high-quality development. The 20th National Congress of the Communist Party of China further pointed out that adhering to the core position of innovation in the overall situation of modernization. In addition, 2019-nCoV has put downward pressure on the current economic situation, and industrial innovation has become an important engine to boost the economy.

As an innovation activity, industrial innovation has stage characteristics. Roper and other scholars divided the innovation process into three stages: knowledge acquisition, knowledge transformation and development and utilization, and collectively referred to as the innovation chain. The effect of industrial innovation transformation is related to the sustainability of the innovation chain and the key to the effectiveness of the innovation-driven development strategy. However, technological innovation has the characteristics of long investment cycle, high risk and slow return. Industrial innovation transformation needs stable fiscal policy to provide sufficient resources for its development (Julio and Yook, 2012). Therefore, how to achieve economic transformation by improving the efficiency of innovation achievements has become an important issue for the government.

Since the reform of the tax-sharing system, China has defined the responsibility of the central and local revenue and expenditure. There is a vertical financial relationship between governments at all levels, in which financial power is collected by the central government and power is delegated to

local governments. Under this system, local governments enjoy more independent control over financial funds for investment (Bellofatto and Besfamille, 2018). In addition, due to the asymmetry of the division of local financial power and administrative power, that is, the vertical fiscal imbalance (Huang and Li, 2015). Under the influence of government investment preference and the transformation of innovation achievements, the allocation of innovation resources is also affected, which is crucial to the efficiency of the overall innovation system of the country (Nasierowski and Arcelus, 2003). Therefore, under the background of emphasizing the implementation of innovation-driven development and the deepening of fiscal and taxation system reform, this paper studies the mechanism of vertical fiscal imbalance on the transformation of industrial innovation achievements.

2. Theoretical Analysis and Research Review

At present, the influence mechanism of fiscal vertical imbalance in related fields is still a hot issue in academic circles at home and abroad. Although most scholars believe that the fiscal vertical imbalance is caused by the unreasonable allocation of government powers and financial powers at all levels, the direction and conclusions of the research on the effect of fiscal vertical imbalance are quite different. For example, at the local debt level, fiscal vertical imbalances lead to long-term balanced budgets among local governments, and persistent local fiscal deficits occur when local governments rely on transfer payments and government bonds (Rodden, 2002). At the regional economic level, Deyin Chu and Maosheng Fei (2021) believed that fiscal vertical imbalance has an inhibitory effect on the sustained growth of local economy, but it can indirectly promote economic growth by inhibiting local government tax efforts. At the level of regional innovation, Borge, Brueckner and Rattso (2014) believe that fiscal decentralization encourages local governments to prefer productive investment while ignoring non-productive investment, which hinders the long-term development of regional innovation. In terms of land finance, Jia Junxue et al. (2016) believe that vertical fiscal vertical imbalance has a positive effect on land finance, and can promote local government land finance behavior through ' political promotion incentives.

2.1 The Direct Effect of Fiscal Vertical Imbalance on the Transformation of Industrial Innovation Achievements.

Most researchers tend to analyze the mechanism between fiscal decentralization and innovation from the perspective of innovation input efficiency, but there are still different views, which can be divided into the following two categories.

The first view is that moderate fiscal vertical imbalance can promote the development of technological innovation. From the perspective of fiscal resource allocation efficiency, under the traditional fiscal decentralization theory, scholars represented by Tiebout, Charles (1952) and Oates (1972) believe that the free flow of production factors among regions is conducive to maximizing resource utility. Local governments play an irreplaceable role in allocating local financial resources and guiding the high-quality development of local economy, and the free flow mechanism of factors is the key to promoting the efficient supply of local government public goods. Meanwhile, local governments often have a better understanding of local socio-economic development and more efficient access to decision-making information, which is conducive to improving the efficiency of local government public resource allocation, mobilizing the enthusiasm of local industrial innovation and promoting the high-quality development of regional economy. From the perspective of science and technology innovation input and output efficiency, fiscal decentralization will increase the autonomy of local government fiscal expenditure, thereby enhancing the leading and guaranteeing role of local governments in regional innovation activities (Li and Yang, 2018). In addition, changes in local government expenditure responsibilities can encourage technological innovation of enterprises through tax incentives and project funding, thereby increasing the income of new products (Li and Zhang, 2014). Its social return is not only higher than the output of private investment, but also can make up for the cost gap of local technological innovation (Ali-Yrkko, 2004). Since the

reform of the tax sharing system in 1994, there is still a mismatch between the financial power and the of local governments in China 's financial system, which needs to be further solved. Therefore, under the premise of asymmetric financial power, some scholars put forward a second view on the problem of fiscal imbalance, and believe that fiscal vertical imbalance has an inhibitory effect on the level of technological innovation.

From the perspective of the impact of vertical fiscal imbalance on local government behavior, local fiscal expenditure decentralization is higher than fiscal revenue decentralization, that is, power is greater than financial power (Sorens, 2016). Local fiscal pressure will distort the structure of fiscal expenditure. In order to fulfill the basic functions of the government and complete the assessment indicators of officials, financial resources often flow to productive areas that can stably generate tax sources, rather than innovative areas (Gu and Shen, 2012). From the perspective of the impact of fiscal vertical imbalance on the market economy, the excessive intervention of local governments within the market is not conducive to giving full play to the superiority of the market economy to a certain extent. This not only reduces the efficiency of financial resource allocation and the level of residents' welfare, but also inhibits the transformation of technological achievements in innovative industries and hinders R&D investment, thus reducing regional innovation capabilities (Wang et al., 2020). Moreover, this mechanism will also have a negative impact on the surrounding areas through spatial spillover effects (Liu, 2022). In addition, from the positive externalities of science and technology output, the output of science and technology R & D investment in the region has a spillover effect, which promotes the efficient output of scientific and technological innovation achievements in the surrounding areas. Therefore, the externality of innovation income greatly weakens the enthusiasm of local governments to invest in this field, thus affecting the level of innovation.

H1 Fiscal vertical imbalance has a significant impact on the transformation of industrial innovation achievements.

2.2 The Indirect Effect of Fiscal Vertical Imbalance on the Transformation of Industrial Innovation Achievements

The relationship between fiscal vertical imbalance and the transformation of industrial innovation achievements is not simply the unreasonable allocation of direct financial funds and the reduction of expenditure efficiency. As important financial expenditure items, science and technology expenditure and education expenditure have positive externalities compared with other productive expenditure.

From the perspective of the nature of innovative products and the self-interest of local officials, innovation output, as a public product, has the characteristics of high externality, strong liquidity, long investment cycle and slow return. Driven by the promotion tournament, local government officials with political attributes tend to choose self-interested productive investment under the existing financial pressure to pursue higher economic development indicators (Zhou and Zhang, 2008. Borge, Brueckner and Rattso, 2014). The increase in such productive investment and infrastructure investment will lead to a negative impact on private investment (Wu, 2009). Moreover, under pressure from political promotions and local finances, governments tend to invest limited financial resources in productive expenditure projects that are relatively more exclusive. The diversity of government goals makes local officials pay more attention to GDP as a measure of assessment. Fiscal expenditure is more likely to breed rent-seeking phenomenon, and is more inclined to areas that are easy to obtain political benefits, rather than taking long-term economic development and overall social welfare improvement as standards (Wang and Liu, 2022). Yi Xinghua and Cheng Yanan (2022) found in the study of 30 provinces in China from 2011 to 2019 in the stage of scientific and technological research and development and achievement transformation that fiscal decentralization will reduce the efficiency of fiscal expenditure, thus inhibiting the efficiency of two-stage regional innovation.

H2 Fiscal vertical imbalance has a negative impact on the transformation of industrial innovation achievements by inhibiting science and education expenditure.

In summary, the predecessors have provided rich data and reliable theoretical basis for studying the mechanism of fiscal vertical imbalance on innovation. On this basis, the marginal contribution of this paper to the mechanism of fiscal vertical imbalance affecting the transformation of industrial innovation achievements is mainly reflected in the following three aspects. First, in terms of topic selection, although there are many studies on technological innovation in the existing literature, there are few studies on the transformation of industrial innovation achievements as a measure of innovation level. This provides a new research perspective for the series of problems of the mechanism of fiscal vertical imbalance on innovation. Secondly, in the empirical aspect, this paper not only explores the influence mechanism of fiscal vertical imbalance on the transformation of industrial innovation achievements, but also explores from the aspects of mediating effect and heterogeneity analysis, which provides further explanation and empirical basis for further understanding the influence of fiscal vertical imbalance on the transformation of industrial innovation achievements. Third, in terms of research enlightenment, according to the empirical results, policy recommendations are proposed to alleviate the inhibitory effect of fiscal vertical imbalance on the transformation of industrial innovation achievements.

3. Model Building and Variable Selection

3.1 Data Sources

The data in this paper are mainly derived from *China Statistical Yearbook* and EPS database. Due to the lack of original data in some provinces, the empirical analysis samples involve 30 provinces, autonomous regions and municipalities (excluding Tibet, Hong Kong, Macao and Taiwan), with a time span of 2003-2020. The original numerical statistical characteristics of each variable are shown in Table 1.

Table 1. Statistical characteristics of variables

variable name	number of samples	mean value	standard error	minimum value	maximum value
Inn	540	16.260	1.728	10.497	19.910
Vfi	540	0.682	0.192	0.149	0.938
Inv	540	0.675	0.253	0.210	1.480
Tra	540	0.294	0.336	0.007	1.668
Thir	540	0.436	0.096	0.286	0.839
Stu	540	13.256	0.870	10.171	14.729
Fun	540	0.841	0.511	0.035	2.225
Tec	540	0.019	0.013	0.004	0.072
Edu	540	0.161	0.025	0.099	0.222

3.2 Variable Selection

3.2.1 Explained Variables

This paper studies the impact of fiscal vertical imbalance on the transformation of industrial innovation achievements. In academia, the measurement indicators of the transformation of enterprise innovation achievements mainly include the number of patent applications, the output value of new products, the sales income of new products, etc. Due to the time lag of the number of patent grants and the realization of innovation achievements, this paper refers to previous studies and selects the natural logarithm of new product sales revenue (Inn), which can better reflect the realization ability of regional technological innovation achievements, as the explained variable.

3.2.2 Core Explanatory Variables

Based on the experience of Eyraud (2013), this paper measures the vertical fiscal imbalance index of China, and the specific calculation formula is shown in table 2.

Table 2. Financial vertical imbalance calculation formula

Name of indicator	formula	Meaning of variable
Vfi:vertical fiscal imbalance	$\mathrm{Vfi} = 1 - \frac{\mathrm{Fqr}}{\mathrm{Fqs}} * (1 - \mathrm{Lbd})$	Lgr:Local general public budget revenue
Fqr:fiscal revenue decentralization	$\mathrm{Fqr} = \frac{\mathrm{Lgr/Lpop}}{\mathrm{Lgr/Lpop} + \mathrm{Cgr/Pop}}$	Cgr:Central general public budget revenue
Fqs:fiscal expenditure decentralization	$\mathrm{Fqs} = \frac{\mathrm{Lgs/Lpop}}{\mathrm{Lgs/Lpop} + \mathrm{Cgs/Pop}}$	Lgs:Local general public budget expenditure
Lbd:Local government financial self-sufficiency gap rate	$\mathrm{Lbd} = \frac{\mathrm{Lgs} - \mathrm{Lgr}}{\mathrm{Lgs}}$	Cgs:Central general public budget expenditure
		Lpop:Total local population
		pop:Total population of the country

When the central financial power is concentrated and the local power is higher, that is, the higher the degree of fiscal expenditure decentralization, the lower the degree of fiscal revenue decentralization, the greater the degree of vertical fiscal imbalance. This paper takes the natural logarithm of the fiscal vertical imbalance index (Vfi) as the core explanatory variable.

3.2.3 Control Variables and Mediating Variables

According to the existing relevant research, this paper selects five variables such as, Inv, Tra, Thir, Stu, Fun and other control variables that affect the transformation of industrial innovation achievements and two variables as mediating variables. The variable setting is shown in Table 3.

Table 3. Variable definition and calculation formula

variable symbol	Meaning of variable	computing formula
Inv	Investment intensity of fixed assets(%)	The ratio of total fixed assets investment / The ratio of GDP is the logarithm
Tra	Foreign trade scale(%)	The ratio of import and export amount of goods / GDP is logarithm.
Thir	Proportion of tertiary industry(%)	The tertiary industry output value / GDP ratio takes logarithm.
Stu	Number of students in institutions of higher learning	The number of students in in school
Fun	Traffic density (km / km^2)	The ratio of the total mileage of railways and highways in each province to the area of each province is logarithmic.
Tec	Science and technology expenditure scale(%)	Science and technology expenditure / national general public budget expenditure ratio
Edu	Scale of education expenditure(%)	Ratio of education expenditure to national general public budget expenditure

Investment factor (Inv): fixed asset investment can promote the upgrading of production equipment, thus promoting technological innovation, thereby improving the production efficiency of enterprises and promoting the transformation of innovation achievements. Trade factors (Tra) : strengthening foreign trade is conducive to the introduction of foreign advanced production technology and management experience, forcing domestic enterprises to transform and upgrade production technology and promote the transformation of innovation achievements . Industrial structure (Thir): The situation of industrial structure reflects the allocation of a country 's production factor resources in various industrial sectors, which can significantly affect the transformation of innovation achievements. Human capital (Stu): Human capital is one of the driving forces to promote the development of social production and has a positive effect on the transformation of innovation achievements. Infrastructure (Fun): As an important condition for material production, it plays a fundamental role in the transformation of innovation achievements, and traffic density as a proxy index can objectively reflect the level of infrastructure construction in various places.

This paper sets up two mediating variables, namely, the scale of science and technology expenditure and the scale of education expenditure. The larger the index values of the scale of science and technology expenditure (Tec) and the scale of education expenditure (Edu), the more resources allocated by the government to the field of science and education.

3.3 Model Establishment

This paper constructs a panel econometric model as shown in (1):

$$Inn_{it} = \beta_0 + \beta_1 Vfi_{it} + \beta_2 X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (1)$$

In formula (1), i and t represent the region and time, and the explanatory variables are the transformation of industrial innovation achievements, represented by Inn. The core explanatory variable is the index of fiscal vertical imbalance, which is represented by Vfi and the estimated coefficient represented by β_1. X represents a series of control variables controlled in this paper, representing the estimated coefficient of X. Then λ_i, μ_t and ε_{it} denote provincial fixed effect, time fixed effect and random error term. The core coefficient of this paper is β_1. if β_1 is significantly greater than zero, it shows that the vertical imbalance of finance significantly promotes the transformation of industrial innovation achievements; if it is significantly less than zero, it indicates that the vertical imbalance of finance has an inhibitory effect on the transformation of industrial innovation achievements.

Further, in order to study the influence path of fiscal vertical imbalance on the transformation of innovation achievements, the scale of technology expenditure and the scale of education expenditure are introduced to test whether the two have mediating effects.

$$Mid_{it} = \alpha_0 + \alpha_1 Vfi_{it} + \alpha_2 X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (2)$$

$$Inn_{it} = \alpha_0' + \alpha_1' Vfi_{it} + \alpha_2' Mid + \alpha_3' X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (3)$$

$$\beta_1 = \alpha_1' + \alpha_1 \alpha_2' \quad (4)$$

This paper refers to the intermediary effect analysis method of Wen and Ye (2014) to deal with the influence mechanism of fiscal vertical imbalance and industrial innovation achievement transformation. In the model, Mid represents the mediating variable. When the scale of science and technology expenditure is used as an intermediary variable, the influence mechanism of fiscal vertical imbalance on the scale of science and technology expenditure is expressed by the formula (2) model, and the coefficient α_1 is tested. The influence mechanism of fiscal vertical imbalance and science and technology expenditure scale on innovation output is expressed by Equation (3) model, and the coefficient α_1' and α_2' are tested. First of all, after the test of formula (4), if α_1' and α_2' are significant, the indirect effect is significant, otherwise the indirect effect is not significant. Again, judging the significance of the coefficient, if not significant, the direct effect is not significant, indicating that only the mediating effect, and vice versa. Finally, comparing the symbols of $\alpha_1\alpha_2$' and α_1', the same sign is a partial mediating effect, and the different sign is a masking effect. Similarly, the mediating effect mechanism of education expenditure scale on innovation achievement transformation can be known.

4. Empirical Regression and Result Analysis

4.1 Benchmark Regression and Heterogeneity Test

4.1.1 Benchmark Regression Analysis

After testing the mechanism of fiscal vertical imbalance on the transformation of scientific and technological innovation achievements, the experimental results obtained in this paper are shown in Table 4.

Table 4. Benchmark analysis results and heterogeneity analysis

variable	lnn(1)	lnn(2)	lnn(3)	lnn(4)	lnn(5)
Vfi	−0.534** (−2.19)	−0.196 (−0.72)	−2.730*** (−4.12)	−0.197 (−0.52)	−1.036*** (−3.31)
Inv	0.282*** (3.10)	0.129*** (2.87)	0.381*** (2.62)	0.206 (1.07)	0.193* (1.88)
Tra	0.204*** (3.37)	0.048 (0.26)	0.207*** (3.09)	0.288** (2.09)	−0.279*** (−2.65)
Thir	−0.322 (−1.23)	−0.723 (−1.36)	−0.260 (−0.77)	−0.299 (−0.73)	0.552 (1.58)
Stu	−0.004 (−0.02)	−0.210 (−0.10)	0.098 (0.47)	0.261 (1.58)	0.195 (0.50)
Fun	0.315** (2.24)	0.551** (2.56)	−0.087 (−0.43)	21.939*** (5.47)	8.566** (2.18)
constant	14.889*** (7.28)	16.414*** (5.91)	12.224*** (4.65)	−0.551* (−1.77)	0.576** (1.97)
time effect	YES	YES	YES	YES	YES
local effect	YES	YES	YES	YES	YES
R^2	0.853	0.863	0.868	0.798	0.554
N	540	198	342	270	270

Note: * * *, * * and * are expressed as significant at the levels of 1 %, 5 % and 10 %, respectively. The t test values are in parentheses, and the following table is the same.

Based on the correctness of H1 hypothesis verified by Column (1), it is further concluded that the core explanatory variable-fiscal vertical imbalance index has a significantly negative impact. This is because the asymmetry of local fiscal power and financial power aggravates the distortion of fiscal pressure on expenditure structure, which makes the input of industrial science and technology innovation limited, thus inhibiting the further output transformation of innovation achievements. In addition, the externality of innovation income will also weaken the input of local government, thus inhibiting the investment of innovation industry in R & D and reducing the enthusiasm of innovation output. Moreover, the negative impact mechanism of fiscal vertical imbalance is not only reflected in the output level of scientific and technological innovation, but also has a significant inhibitory effect on its input and efficiency (Wu , 2017; liu and He, 2022), it can be seen that the previous research conclusions in the relevant fields of academia coincide with this article.

From the perspective of control variables, the level of investment, the level of foreign trade and infrastructure have a positive effect on the transformation of industrial innovation output, which is reflected in the index of influencing factors per 1 % unit of growth, which promotes the average growth of industrial innovation output transformation level by 28.2 %, 20.4 % and 31.5 %

respectively. The above results can be explained as the stronger the investment in fixed assets, the faster the upgrading of production equipment, and the further promotion of production efficiency and the transformation of innovation achievements; The higher the index of foreign trade level, the greater the degree of opening to the outside world, which is more conducive to the introduction of advanced production technology and the transformation of innovation achievements. In addition, perfect infrastructure is an indispensable material basis for regional economic innovation and development and the transformation of technological innovation achievements. In summary, the level of investment and the level of infrastructure construction have played an important role in the transformation of industrial innovation achievements. However, the industrial structure and human resources indicators have not passed the 10 % significance level test. The reasons can be analyzed from the following two perspectives. From the perspective of output value structure, the increase of China 's non-agricultural output value mainly comes from low-end manufacturing and some non-technology-intensive service industries. From the perspective of the talent structure of colleges and universities, the employment direction of college students after graduation is not necessarily all engaged in local innovation and development, and the transformation of industrial innovation achievements cannot be directly reflected by the number of college students. Therefore, the above two indicators have no significant impact on the transformation of industrial innovation achievements.

4.1.2. Regional Heterogeneity Test

Due to the differences in economic and social development across China, in order to explore regional differences, this paper divides the sample into two parts, namely the eastern and central and western regions [the eastern region includes 11 provinces (cities) such as Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; the central and western regions include Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, Inner Mongolia and other 19 provinces (cities).]. The regional heterogeneity test results of fiscal vertical imbalance on the transformation of scientific and technological innovation achievements are shown in column (2) and column (3).

The inhibitory effect of fiscal vertical imbalance on the transformation of industrial innovation achievements is mainly reflected in the central and western regions, with a coefficient of − 2.730. Although the eastern region is negative, the inhibition coefficient is-0.196 and not significant. On the one hand, the eastern region has superior geographical conditions and enjoys a more favorable foreign trade environment and policy dividends, which provides favorable conditions for the transformation of high-tech industry R & D investment results . On the other hand, the eastern region has a high level of economic and social development, a wide range of local fiscal revenue sources, and a low fiscal self-sufficiency gap, which makes the local government have a strong autonomy to control financial funds. The central and western regions are inland and relatively backward compared with the eastern regions. The relative lack of infrastructure and market conditions has led to the lagging development of technological innovation. Correspondingly, the central and western regions have fewer sources of fiscal revenue than the eastern region, the fiscal self-sufficiency gap is high, and the pressure on local fiscal funds is greater. In summary, the negative impact of fiscal vertical imbalance on the transformation of industrial innovation achievements in the central and western regions is stronger than that in the east, and there is significant regional heterogeneity. Different from the analysis based on the driving force of industrial development and the pressure of fiscal gap in this paper, Guan and Fu (2023) are based on the difference between the old and new kinetic energy conversion efficiency of developed regions and underdeveloped regions. The suppression effect of the eastern (developed) region is stronger than that of the central and western (underdeveloped) regions, and its innovation level is more sensitive to the response of fiscal vertical imbalance suppression.

4.1.3 Time Heterogeneity Analysis

Since the 18 National Congress of the Communist Party of China, China 's economic policy has undergone major adjustments. With the deepening of economic reform, the impact on the

transformation of scientific and technological innovation achievements is bound to show stage differences. In order to explore the differences before and after the adjustment of economic policy, this paper takes 2012 as the time node and divides the sample into two parts before and after 2012. The regional heterogeneity test results of fiscal vertical imbalance on the transformation of scientific and technological innovation achievements are shown in table 4.

From Table 4 column (5), it can be seen that after 2012, the vertical fiscal imbalance has a significant inhibitory effect on the transformation of industrial innovation achievements as-1.036, and the negative effect before 2012 is not significant as-0.197. The reasons for time heterogeneity lie in the following two points. On the one hand, the division of powers between the central and local governments is becoming more and more perfect, and local affairs are more specifically divided among governments at all levels, but local governments still lack the financial power to match the powers to achieve efficient use of funds. On the other hand, with the deepening of innovation-driven development strategy, the further protection of intellectual property rights and the continuous optimization of business environment, the transformation potential of industrial innovation achievements has been further stimulated. However, the problem of local fiscal vertical imbalance cannot meet the financial input of regional industrial innovation and development. In summary, with the continuous advancement of the fiscal system reform and the new growth model, the asymmetry of the division of local power and financial power, the need for industrial innovation and development, and the relative lag of the fiscal system reform have aggravated the inhibitory effect of fiscal vertical imbalance on the transformation of industrial innovation results to a certain extent. The test results are different from those found in the study of Guan and Fu et al. (2023). That is, before and after 2012, the inhibitory effect of fiscal vertical imbalance on regional innovation capacity has not changed, and it has always been significantly negative at the level of 1 %.

4.2 The Mediating Effect Test of Science and Education Expenditure Scale

Through the theoretical analysis of this paper, it can be seen that the scale of science and technology expenditure and the scale of education expenditure may have an intermediary effect on the impact of fiscal vertical imbalance on the transformation of industrial innovation achievements. The empirical method of this paper uses stepwise regression method to verify this hypothesis, and brings the scale of science and technology expenditure and the scale of education expenditure into Equation (2) and Equation (3) respectively. The empirical results are shown in Table 5.

As shown in column (1) of Table 5, vertical fiscal imbalance has a negative impact on the transformation of industrial innovation achievements. Firstly, the two intermediary variables are brought into the equation (2) to test, and the results show that the vertical fiscal imbalance has a significant inhibitory effect on the scale of science and technology expenditure and education expenditure, and the coefficients are-0.698 and-0.109, respectively, as shown in column (2) and column (4). The reason may be that the aggravation of local fiscal vertical imbalance leads to the expansion of fiscal gap and the reduction of fiscal self-sufficiency. In order to ensure the realization of the basic functions of local governments, local governments have to use limited financial resources for projects with quick economic benefits, and innovation fields such as science and education have certain risks, so the expenditure on science and education has a crowding-out effect. This verifies the correctness of the hypothesis H2. However, Bai Junhong and Dai Wei (2017) believed that the vertical imbalance of finance under expenditure decentralization has a positive effect on the investment in science and technology of local governments, which is consistent with the conclusion drawn from the perspective of expenditure and income decentralization.

Then the two mediating variables are brought into Equation (3) respectively. The results are shown in Column (3) and Column (5). It can be seen that science and technology investment and education talents have a significant role in stimulating industrial innovation potential and enhancing the transformation ability of innovative products. This strongly proves the driving force of innovation-driven development strategy and talent power strategy for the transformation of industrial innovation achievements. In addition, this also shows that the scale of science and technology expenditure and

the scale of education expenditure have a significant indirect effect on the impact of fiscal vertical imbalance on the transformation of industrial innovation achievements.

Table 5. Analysis of the mediating effect of science and education expenditure scale on the transformation of industrial innovation achievements

variable	Inn(1)	Tec(2)	Inn(3)	Edu(4)	Inn(5)
Vfi	−0.534** (−2.19)	−0.698*** (−4.13)	−0.315 (−1.30)	−0.109*** (−2.58)	−0.453* (−1.86)
Tec			0.314*** (4.93)		
Edu					0.746*** (2.88)
Inv	0.282*** (3.10)	−0.034 (−0.55)	0.293*** (3.30)	−0.042*** (−2.69)	0.314*** (3.45)
Tra	0.204*** (3.37)	0.111*** (2.65)	0.169*** (2.83)	0.027*** (2.60)	0.183*** (3.03)
Thir	−0.322 (−1.23)	−0.308* (−1.69)	−0.226 (−0.88)	0.018 (0.41)	−0.336 (−1.29)
Stu	−0.004 (−0.02)	−0.355*** (−3.24)	0.108 (0.69)	0.017 (0.61)	−0.016 (−0.10)
Fun	0.315 ** (2.24)	−0.109 (−1.11)	0.349** (2.53)	0.012 (0.48)	0.306** (2.19)
constant	14.889*** (7.28)	−0.367 (−0.26)	15.003*** (7.51)	−2.100*** (−5.92)	16.456*** (7.83)
time effect	YES	YES	YES	YES	YES
local effect	YES	YES	YES	YES	YES
R^2	0.853	0.196	0.860	0.466	0.856
N	540	540	540	540	540

In addition, it is found by testing the coefficient of the explained variable in Equation (3). In the case of the scale of science and technology expenditure, the inhibitory effect (direct effect) of fiscal vertical imbalance on the transformation of industrial innovation achievements is not significant. It can be seen that the scale of science and technology expenditure has a complete mediating effect in the sitting mechanism. In the case of the scale of education expenditure, the vertical imbalance of finance has an inhibitory effect on the transformation of industrial innovation achievements at the significance level of 10 %, that is, the direct effect is significant. According to α_1 in Equation (2) and α_2' in Equation (3), the product of the two coefficients is the same as α_1'in Equation (3), it can be inferred that the scale of education expenditure has a partial mediating effect.

4.3 Robustness and Endogeneity Analysis

This paper uses the method of sample change and core explanatory variable replacement to test the robustness. The robustness test results are shown in table 6. Column (1) of Table 6 removes the samples of Beijing, Tianjin, Shanghai and Chongqing from the observation objects. Table 6 column (2) uses (local budget expenditure-local budget revenue) / local budget expenditure as the new core explanatory variable. The empirical results show that the impact of fiscal vertical imbalance on the transformation of scientific and technological innovation achievements is basically consistent with the previous text, indicating that the model is robust.

Table 6. Robustness and endogeneity test results

variable	lnn(1)	lnn(2)	lnn(3)
Vfi	−0.865** (−2.45)	−1.817*** (−3.71)	−0.454* (−1.71)
Inv	0.038 (0.39)	0.325 *** (3.66)	0.251 *** (2.86)
Tra	0.250 *** (3.51)	0.227*** (3.76)	0.210** (2.51)
Thir	−0.332 (−1.14)	−0.280 (−1.08)	−0.342 (−1.25)
Stu	−0.138 (−0.86)	0.028 (0.18)	0.137 (0.69)
Fun	0.228 (1.25)	0.302** (2.17)	0.200 (0.95)
constant	16.436*** (6.72)	15.722*** (7.71)	13.736*** (5.40)
time effect	YES	YES	YES
local effect	YES	YES	YES
Cragg			2325.261
R^2	0.853	0.856	0.959
N	468	540	510

However, considering that the model may still have missing variables, the missing variables included in the error term are correlated with other explanatory variables, which leads to endogenous problems. Referring to the existing research, this paper draws on the practice of Liu Shuxin et al. (2022), takes the natural logarithm of the mean value of the current value of the fiscal vertical imbalance variable and the lag expectation as the instrumental variable, and takes the natural logarithm of the fiscal vertical imbalance as the endogenous explanatory variable to control the endogenous problem. Under the premise of ensuring the significant correlation between instrumental variables and fiscal vertical imbalances and the exogeneity of instrumental variables relative to model error terms, the estimation results are shown in Column (3) of Table 6. The statistical value of the weak instrumental variable is greater than the bias value at the 10 % level, that is, the null hypothesis of the existence of the weak instrumental variable is rejected. Because the number of instrumental variables selected in this paper is equal to the number of endogenous explanatory variables, there is no problem of over-identification test. The impact of fiscal vertical imbalance on the transformation of industrial innovation achievements is inhibited at a significant level of 10 %, indicating that the estimation results alleviate the endogenous problem to a certain extent, and further verify the previous conclusions.

5. Conclusion and Policy Recommendations

5.1 Conclusion

Based on the panel data of 30 provinces from 2003 to 2020, this paper empirically explores the influence mechanism of fiscal vertical imbalance on the transformation of industrial innovation achievements by means of panel fixed effect model, dynamic panel threshold model, intermediary effect test and heterogeneity test. The following conclusions are drawn: First, fiscal vertical imbalance has a significant inhibitory effect on the transformation of industrial innovation achievements. second, vertical fiscal imbalance has an inhibitory effect on the transformation of industrial innovation

achievements by inhibiting the scale of science and technology expenditure and education expenditure. Third, there is regional and time heterogeneity in the ability of fiscal vertical imbalance to transform industrial innovation achievements.

5.2 Policy Proposal

First, deepen the reform of the financial system and improve the efficiency of government public resource allocation. First, rationally divide the financial power and administrative power between the central and local governments, alleviate the vertical imbalance of finance to rationalize the financial system of governments at all levels, match the expenditure responsibility with the disposable income, and enhance the financial self-sufficiency of local governments. The second is to optimize the structure of fiscal transfer payment to reduce the vertical imbalance of finance, and grasp the ' two grasps ' of general transfer payment and special transfer payment. While using general transfer payment to ensure local financial balance, we should make full use of special transfer payment for scientific and technological innovation, and focus on supporting areas with low innovation vitality and areas where the growth rate of innovation achievement transformation output value is not significant, so as to boost its industrial innovation and development momentum.

Second, increase support for scientific and technological innovation and create good conditions for enterprises to transform innovative achievements. First, enrich the standards of local government political promotion and official assessment, incorporate the output indicators of industrial innovation achievements into the assessment index system, and encourage local government officials to increase financial investment in the field of scientific and technological innovation. Second, set the minimum standards for scientific and technological innovation expenditures, and regularly assess local government budget expenditures, strengthen the government 's main responsibility to support the development of high-tech industries to prevent other fiscal expenditure projects from crowding out scientific and technological research and development projects. The third is to improve the intellectual property protection system, continue to adhere to the protection of intellectual property rights, give equal protection to the intellectual property rights of various market entities and innovation entities according to law, and ensure the enthusiasm and initiative of innovation investment of market entities and innovation entities.

Third, promote the equalization of regional innovation and promote industrial transformation and upgrading in the central and western regions. The first is to provide more convenient financing channels for high-tech enterprises while increasing subsidies and tax incentives for industrial transformation in the central and western regions, and encourage the transformation and upgrading of resource-based and labor-intensive industries into technology-capital-intensive industries. Second, we should pay attention to improving the quality and efficiency of public service supply, especially in areas where public service supply is insufficient or inefficient, we should pay attention to ' making up for shortcomings ' and ' optimizing structure '. It is necessary to make full use of local resources and promote regional coordinated and innovative development according to local conditions. The third is to build a comprehensive new open economic system, so that the majority of the central and western industries to fully participate in the international market competition, forced the transformation and upgrading of industrial structure, and ultimately achieve the purpose of narrowing the regional development gap.

References

[1] Ali Yrkko,J..Impact of Public R&D Financing on Private R&D - Does Financial Constraint Matter?[J]. Discussion Papers, 2004, 214(2859):24-24.

[2] Bellofatto,A.A. & Besfamille,M..Regional State Capacity and the Optimal Degree of Fiscal Decentralization [J]. Journal of Public Economics, 2018, 159(3).

[3] Borge,L.E.,Brueckner ,J.K. & Rattso,J..Partial fiscal decentralization and demand responsiveness of the local public sector: Theory and evidence from Norway[J]. Journal of Urban Economics, 2014, 80(mar.):153-163.

[4] Eyraud, L. & Lusinyan, L. Vertical fiscal imbalances and fiscal performance in advanced economies[J]. Journal of Monetary Economics, 2013, 60(5):571-587.

[5] Julio,B. & Yook,Y..Political Uncertainty and Corporate Investment Cycles[J]. Journal of Finance, 2012, 67(1):45-83.

[6] Nasierowski,W. & Arcelus,F.J..On the efficiency of national innovation systems[J]. Social Economic Planning Sciences, 2003, 37(3):215-234.

[7] Rodden,J.A..The Dilemma of Fiscal Federalism: Grants and Fiscal Performance around the World Jonathan Rodden (MIT) The Dilemma of Fiscal Federalism: Grants and Fiscal Performance around the World[J]. American Journal of Political Science, 2002, 46(3).

[8] Roper, S, Du, J. & Love, J. H. Modelling the innovation value chain[J]. North-Holland, 2008(6).

[9] Sorens, J. Vertical Fiscal Gaps and Economic Performance[J]. 2016.

[10] Tiebout & Charles, M. A. Pure Theory of Local Expenditures[J]. Journal of Political Economy, 1956, 64(5):416-424.

[11] Wright, Deil. S. Fiscal Federalism. By Wallace E. Oates. (New York: Harcourt, Brace, Jovanovich, 1972. Pp. 256. $7.95.)[J]. American Political Science Review, 1974, 68(4):256-1778.

[12] Wu, D. & Zhang, Z. Effects of Government Expenditure on Private Investment - China Empirical Evidence [C] // First International Workshop on Education Technology & Computer Science. IEEE Computer Society, 2009.

[13] Bai Junhong, Dai Wei. The impact of fiscal decentralization on local government investment in science and technology[J]. Statistical Research,2017,34(03):97-106.

[14] Chu Deyin, Fei Maosheng. Fiscal vertical imbalance, tax effort and local economic growth[J]. Contemporary Finance &Economics, 2021(10):30-42.

[15] Huang Wenzheng, Li Hong. Research on the construction of public finance emergency safeguard mechanism at present stage[J]. Guizhou Social Science,2015,No.311(11):139-143.

[16] Gu Yuanyuan, Shen Kunrong. Local government behavior and corporate R & D investment - An empirical analysis based on China 's provincial panel data[J]. China Industrial economics, 2012(10):77-88.

[17] Gun Zhichao, Fu Minjie. Fiscal vertical imbalance, expenditure structure bias and regional innovation ability [J/OL]. Journal of Beijing University of Technology (Social Sciences Edition):1-17[2023-01-30].

[18] Jia Junxue, Zhang Chao, Qin Cong, Feng Jing. Vertical fiscal imbalance, political promotion and land finance [J]. China Soft Science, 2016, (09):144-155.

[19] Li Chenguang, Zhang Yongan. An empirical study on the impact of regional innovation policy on enterprise innovation efficiency[J]. Science Research Management, 2014,35(09):25-35.

[20] Li Zheng, Yang Siying. Fiscal decentralization, government innovation preference and regional innovation efficiency[J]. Management World, 2018,34(12):29-42+110+193-194.

[21] Liu Liangliang. Will vertical fiscal imbalance inhibit technological innovation [J]. Forum on Science and Technology in China, 2022(06):68-74.

[22] Liu Liangliang, He Jun. Will fiscal vertical imbalance inhibit the improvement of regional innovation efficiency [J]. Contemporary Finance &Economics, 2022, (07):27-37.

[23] Liu Shuxin, Shi Chuanlin, Fang Youwei. Fiscal vertical imbalance and the income gap between urban and rural residents: theoretical and empirical[J]. Journal of Central University of Finance & Economics, 2022, No. 416(04):3-14.

[24] Wang Liping, Liu Yong, Wu Wentao. The impact of fiscal system imbalance on high-quality economic development [J]. Journal of Industrial Technological Economics,2020,39(07):22-30.

[25] Wang Yuqin, Liu Chengkui. Fiscal decentralization, technological innovation and high-quality economic development[J]. Finance and Accounting Monthly, 2022, (20):133-139.

[26] Wen Zhonglin, Ye Baojuan. Mediating Effect Analysis: Method and Model Development[J]. Advances in Psychological Science,2014,22(05):731-745.

[27] Wu Yanbing. Biased investment under Chinese decentralization [J]. Economic Research Journal, 2017, 52 (06):137-152.

[28] Yi Xinghua, Cheng Yanan. The two-stage mediating effect of fiscal decentralization on regional innovation efficiency[J]. Science and Technology Management Research,2022,42(17):87-99.

[29] Zhou Yean, Zhang Quan. Fiscal decentralization, economic growth and volatility [J]. Management World, 2008 (03):6-15+186.