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EMPIRICAL ANALYSIS OF THE IMPACT OF TECHNOLOGY IMPORT ON INDUSTRIAL INNOVATION IN CHINA: A TECHNOLOGY EXPENDITURE PERSPECTIVE

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Abstract. Promoting steady industrial innovation through technology import is an important initiative to accelerate innovation-driven and high-quality economic development in China. In this study, a model of the impact of technology import on industrial innovation is constructed from the perspective of technology expenditure, and empirical analysis is made by employing panel data from 2011 to 2019 in China. There exists obvious regional and industrial differences in the level of technological innovation and the intensity of technology import in China. The econometric results indicate that technology import and industrial innovation are complementary generally, but in the eastern region, as well as the labor- and the technology-intensive industries appear to be substitute. There are obvious regional differences when considering the impact of the interaction items, and the acceleration of technology digestion and absorption is conducive to the improvement of innovation, while that on various industries fail the significant test except for the technology-intensive industry.

Keywords: technology import, innovation, technology expenditure,heterogeneity, panel data model, China.

JEL Classification: C33, F10, O14.

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1. Introduction

Innovation is a strategic choice for China to cope with severe challenge in international environment, and it is also a requirement for building a new pattern of economic development, circumventing the "middle-income trap" and promoting high-quality economic development. Technology import is essential for facilitating innovation cooperation (Lee, 1996; Ramírez-Alesón & Fernández-Olmos, 2021), which might be an effective path for using advanced global technology for improving innovation efficiency, and reducing the cost of independent research and development (R&D) and innovation risks. It is an important way for developing countries to continuously achieve technological innovation leaps (Mitra, 2009; Mohamed et al., 2022), and China's modernization process could be an evident fact. In the context of China's current global value chain, the global industrial chain and the global supply chain being at the low end of the lock, technology import is important for China's reform and opening up policy switching to the implementation of the "market for technology" strategy. In addition, this would own positive effect on domestic technological upgrading. There is no doubt that industrial innovation would enhance the technological level of domestic industries by taking the "catfish effect" and the "push-back effect", and technology import would also influence the development of economy (Wang & Tao, 2019). Therefore, it is necessary to analyze the impact of technology import on China's industrial innovation. Considering of relevant literature about this topic, there are mainly two aspects, which is the effect of the import on innovation, the relationship between technology import and industrial innovation, respectively.

As per the effect of import on innovation, there is no doubt that import would influence innovation. E.g., Lu and Travis (2012) achieved that there existed regional difference between import and incremental innovation in China. Liu and Rosell (2013) found that higher import penetration would lessen the nature of firm innovation by taking the data of multi-product firms. Fernández and Gavilanes (2017) argued that importers from developing countries might use foreign technology inexpertly, for reason of the insufficiency of the national innovation system. Silva et al. (2019) found that importer's integration in product development had a significant effect on product innovation. Liu et al. (2021) detected China's effect of import competition on firm innovation, and achieved that it is consistent with the Schumpeterian effect. Montégu et al. (2022) found that the effects of importing activities on both technological and non-technological innovation would enhance these two patterns of innovation simultaneously in Chile. Shang et al. (2022) considered that there owned significant impacts of environmental regulation and import trade on green technology innovation and the transmission channel in China, and Chen et al. (2024) achieved the similar conclusion. Gu et al. (2024) found that import competition triggered a significant increase in the share of R&D workers at the firm level. In addition, the intermediate is generally considered to be important in the process of innovation (Yamamoto, 2003; Chang, 2016; Frietsch et al., 2019), and the impact of intermediate import on innovation are detected by scholars, such as Liu and Qiu (2016), Chen et al. (2017), Ramírez-Alesón and Fernández-Olmos (2020), Mazzi and Foster-McGregor (2021), Ramírez-Alesón and Fernández-Olmos (2021), Song et al. (2022), Eker et al. (2024), and usually achieved that would affect innovation significantly.

As per technology import' impact on industrial innovation, it is usually considered to be intimate (Yu et al., 2019; Lee, 2020; Lu et al., 2021; Asunka et al., 2022; J. Chen et al., 2023). Meanwhile, consideration of the relationship between technology import and industrial innovation, there own three opinions. Some considered it is complementary, e.g., Kim and Stewart (1993) evaluated the relationship between technology import and domestic R&D by taking data from 10 countries, and learned that there owned complementary correlation; Wang and Tao (2019) detected the relationship between product export and technology import by taking an interaction approach for detecting emerging market firms' innovation performance, and touched the fact that was in state of complementarity; Gao and Dong (2022) found that technological innovation had a positive impact on the complexity of imported technology. Some considered it is substitute, e.g., Wang et al. (2010) found that there owned substitute effect of technology import on industrial innovation by taking micro data in China; Liu et al. (2023) achieved that technology import and industrial innovation appeared to be substitute effect in China, based on the perspective of capability-opportunity. Some considered it is uncertain, e.g., Dai and Chen (2016) found that the influence of technology import on improving innovation capacity was not significant in the middle and western regions, but that was different in the eastern region, by taking the case of China's high-technology industries;

Reid (2019) questioned the conventional wisdom pertaining to China's failure to produce distinctive innovation, notwithstanding the evident regional difference; Liu (2019) detected the role of emerging multinational companies' technology-driven FDIs' impact on innovation, and demonstrated that various patterns had different influences; Yu et al. (2019) found that technology import and self-innovation had a higher performance in innovation quality, and achieved a U-shaped curve in innovation quantity in China; Liao et al. (2020) achieved that secondary innovation based on the embodied pattern had a negative effect, while the effect on the disembodied pattern appeared to be the opposite in China; Kishi and Okada (2021) demonstrated that trade welfare gains were smaller in economies with high frequency of industrial innovation than those in low frequency; Ayerst et al. (2023) found increased innovation and knowledge diffusion in sectors within importing countries appeared differentiated impact.

There is no doubt that technology import would influence industrial innovation, and scholars had made relevant analysis from many perspectives. Meanwhile, the impact of technology import on industrial innovation might be effected by initiatives of technology absorption, such as technology absorption and transformation, and scare literature cares about this, but relevant research makes valuable hints on this aspect. In this study, we construct a theoretical model of the impact of technology import on industrial innovation from the perspective of technology expenditure, and make a multidimensional econometric analysis by taking data in China. Here is the structure of this research, Section 2 is theoretical model established, Section 3 is data resource and index description, Section 4 is descriptive analysis, Section 5 is econometric result, and Section 6 is discussion. The novelty of this research is to detect technology import' impact on industrial innovation from the aspect of technology expenditure.

2. Theoretical model established

The impact of technology import on industrial innovation vibrates much when takes different data, indicators, and models. Given that examines the impact of technology import expenditure on technological innovation, its basic model is set as the following:

$$\ln CX_{it} = \alpha + \beta_1 \cdot \ln JJQ_{it} + \varepsilon_{it}, \tag{1}$$

where, CX and JJQ indicates the level of technological innovation expenditure and the intensity of introduced technology, respectively.

If we treat the technology expenditure in one certain region is constant, and technology import expenditure is only one part, then other categories would also affect the level of technological innovation, which implies these could be treated as corresponding influencing factors. Meanwhile, the purpose of this research focuses on the effect of technology import expenditure mainly, hence, we treat the interaction terms of other categories of technological expenditure combined with technological import expenditure as influencing factors. Therefore, Equation (1) could be rewritten as:

$$\ln CX_{it} = \alpha + \beta_1 \cdot \ln JJQ_{it} + \sum \beta_i \cdot \ln JJQ_{it} \cdot EX_{it} + \varepsilon_{it}, \tag{2}$$

where, EX indicates different types of technology expenditures.

Technology expenditure would influence technological innovation, as mentioned in the above literature. Meanwhile, technology expenditure would be divided into different categories, *e.g.*, it owns four categories in the China Science and Technology Statistical Yearbook, which is the expenditure on imported technology, the expenditure on digested and absorbed technology, the expenditure on domestic technology use, and the expenditure on technological transformation, respectively. Therefore, Equation (2) could be rewritten as:

$$\ln CX_{it} = \alpha + \beta_1 \cdot \ln JJQ_{it} + \beta_2 \cdot \ln JJQ_{it} \cdot \ln XXQ_{it} + \beta_3 \cdot \ln JJQ_{it} \cdot \ln JIQ_{it} + \beta_4 \cdot \ln JJQ_{it} \cdot \ln JGQ_{it} + \varepsilon_{it}, \quad (3)$$

where, XXQ, JGQ and JIQ denotes the intensity of absorbed technology, the intensity of domestic technology use and the intensity of technological transformation, respectively.

Technology expenditures might be affected not only by the interaction terms, but also other factors. Considering other factors as control variables, and thus Equation (3) is adjusted to:

$$\ln CX_{it} = \alpha + \beta_1 \cdot \ln JJQ_{it} + \beta_2 \cdot \ln JJQ_{it} \cdot \ln XXQ_{it} + \beta_3 \cdot \ln JJQ_{it} \cdot \ln JIQ_{it} + \beta_4 \cdot \ln JJQ_{it} \cdot \ln JGQ_{it} + \sum \lambda_i \cdot Control_{it} + \varepsilon_{it}. \quad (4)$$

In terms of other factors influencing innovation, scholars usually consider human capital as a kernel factor influencing innovation (Fonseca et al., 2019; Sun et al., 2020; Karadag et al., 2023). Hence, the perspective of the research talent is chosen to detect factors affecting industrial innovation, such as the intensity of investment in R&D personnel, the quality of R&D. In addition, considering taking time series data as the source, it is necessary to use time, i.e., the year, as a dummy variable, and thus Equation (4) is rewritten as:

$$\ln CX_{it} = \alpha + \beta_1 \cdot \ln JJQ_{it} + \beta_2 \cdot \ln JJQ_{it} \cdot \ln XXQ_{it} + \beta_3 \cdot \ln JJQ_{it} \cdot \ln JIQ_{it} + \beta_4 \cdot \ln JJQ_{it} \cdot \ln JGQ_{it} + \delta \cdot \ln RPQ_{it} + \varphi \cdot \ln RQU_{it} + \phi \cdot DUM_{it} + \varepsilon_{it}, \quad (5)$$

where, RPQ, RQU, and DUM denotes the intensity of R&D personnel input, the quality of R&D and time dummy variable respectively. Coefficients β_1, β_2, β_3, and β_4 are the core coefficients of interest for this study to characterize the impact of technology import expenditures and its interaction terms with digestion and absorption expenditures, domestic technology use expenditures, and technology transformation expenditures on industrial innovation.

Imported technology and the other three interactive items might own corresponding transmission mechanism. Imported technology might be digested and absorbed firstly, then gradually integrate with domestic technology and eventually affect the technical transformation of products. Therefore, we adopt the idea of "technology introduction – digestion and absorption – domestic linkage – technological transformation" to examine the impact of technology introduction when cares about empirical analysis. In the subsequent econometric analysis, all models fully account for the impact of dummy variables, but do not report the specific impact values of dummy variables, for the purpose of highlighting the impact performance of the core variables.

3. Data resource and index description

3.1. Data resource

The data sources selected for the study are mainly from the China Science and Technology Statistical Yearbook and the China Statistical Yearbook. In order to maintain the consistency of the statistical calibre, the China Science and Technology Statistical Yearbook 2012–2020 and the China Statistical Yearbook 2012–2020 selected, and the samples are the relevant data of industrial enterprises above the scale in the corresponding years. The required data are processed and explained accordingly.

(1) As the China Science and Technology Statistical Yearbook does not have the main business income indicator after 2017, the following treatment is adopted: the column of "Main Indicators of Industrial Enterprises above designated size by Industry" in the China Statistical Yearbook (2013), there is the indicator of "operating income", which is used to replace the "main business income" of each industry in 2017 and the following years. In view of the unavailability of the main business income indicators for industrial enterprises in each region, the relevant data after 2017 are replaced by the secondary industry GDP by region. It is generally considered that it is better to adopt the industrial GDP indicator, which is unavailable in the China Statistical Yearbook (2019) but is available in China Statistical Yearbook (2018 and 2020), and the secondary industry GDP is adopted as the measurement indicator to ensure the consistency of data from 2017 to 2019. Considering that the GDP indicator is not the same type as the main business income of regional industries, these two should show the same trend and thus this relatively simple alternative could be adopted, and this would not touch comparatively large bias as per the econometric result.

(2) Hainan, Tibet and Qinghai miss the expenditure of introduced technology funds for many years from 2011 to 2019 in the China Science and Technology Statistical Yearbook, respectively. For example, the data of Hainan from 2016 to 2019, Tibet from 2011 to 2019 and Qinghai from 2014 to 2015 and 2017 to 2019 are missing, thus, these three provincial regions are excluded for the following analysis. We define 10 provincial regions as the eastern, including Beijing, Tianjin, Liaoning, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong and Guangdong; define 8 provincial regions as the middle, including Jilin, Heilongjiang, Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan; define 10 provincial regions as the western, including Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia and Xinjiang. There is one thing that should make further implications, which is that both the China Science and Technology Statistical Yearbook and the the China Statistical Yearbook list the sub-regional and sub-industry statistics separately.

(3) There are relevant statistical data of industrial enterprises in the China Statistical Yearbook of Science and Technology (2012–2020), as well as certain differences in the division of industry categories in different years. For example, there is no automobile manufacturing industry in the China Science and Technology Statistical Yearbook (2012), but it own statistics on the automobile manufacturing industry in the China Science and Technology Statistical Yearbook (2013–2020). To facilitate the screening of industries for research, the following processing measures are taken: firstly, considering that the introduction of technology expenditure is the core indicator of the research, all industries with this indicator missing from 2011 to 2019 are removed. Given that the oil and gas extraction industry is in 2012–2019, the ferrous metal mining industry is in 2015–2016 and 2017–2019, the nonferrous metal mining industry is in 2013 and 2018–2019, the nonmetallic mineral mining industry is in 2017 (the introduced technology expenditures is also only US$ 10,000 and US$ 290,000 in 2016 and 2018, respectively), the automotive manufacturing industry is in 2011, the metal products, machinery and equipment repair industries are missing in 2011, thus, these industries are excluded from the subsequent analysis on industries; secondly, both technological innovation and introduction should be more reflected in the manufacturing industry, thus non-manufacturing industries in industrial enterprises are excluded, including the coal mining and washing industry; the electricity, heat production, and supply industry; the gas production and supply

industry; and the water production and supply industry; thirdly, considering the subsequent examination of the difference between various attributes of manufacturing industries in terms of technology introduction on industrial innovation, it is necessary to exclude the unclassified "other manufacturing" industries, for the reason of the feature of the specific manufacturing industry uncertain. Based on the above mentioned three steps, the panel data of 27 manufacturing industries from 2011 to 2019 are obtained.

(4) China's manufacturing industry is divided into four categories: the labor-, the resource-, the capital-, and the technology-intensive. It should be highlighted that there is no unified standard on how to classify the manufacturing industry. Combined with the manufacturing industry listed in the China Science and Technology Statistical Yearbook and referring to the classification made by Li et al. (2021), the manufacturing industry is divided into four categories as follows: the labor-intensive, including the agricultural and sideline food processing industry, the textile industry, the textile clothing, apparel industry, the food manufacturing, the leather, fur, feather and its products and footwear industry, the furniture manufacturing, the wood processing and wood, bamboo, rattan, palm, grass products industry, the education, industry, sports and recreational goods manufacturing, and eight other industries; the resource-intensive, including the wine, beverage and refined tea manufacturing, the paper and paper products industry, the tobacco products industry, the non-metallic mineral products industry, the petroleum processing, coking and nuclear fuel processing industry, the non-ferrous metal smelting and rolling processing industry, the ferrous metal smelting and rolling processing industry, metal products industry, and eight other industries; the capital-intensive, including the printing and recording media reproduction industry, the general equipment manufacturing, the rubber and plastic products industry, the special equipment manufacturing, the electrical machinery and equipment manufacturing, the railroad, ship, aerospace and other transportation equipment manufacturing, and six other industries; and the technology-intensive, including the chemical materials and chemical products manufacturing, the chemical fiber manufacturing, the pharmaceutical manufacturing, the instrumentation manufacturing, the computer, communications and the other electronic equipment manufacturing, and five other industries.

(5) The method of simple weighted average is used to resolve some missing data cases. For example, for the missing data of 2017–2019 in Gansu and the missing data of 2019 in Ningxia and Xinjiang, the value of digesting and absorbing funds expenditure is calculated via this method.

3.2. Index description

The units of some indicators differ between the China Science and Technology Statistical Yearbook and the China Statistical Yearbook. For example, the unit of the main revenue, innovation and other indicators are usually million yuan in the China Science and Technology Statistical Yearbook, while the unit of business income and other indicators are usually in billion yuan in the China Statistical Yearbook. However, considering that they are all denominated in RMB, each indicator is presented as a ratio. Thus, when using the same or similar indicators, the difference in the unit of measurement in different yearbooks should not have much impact on the results as per the following analysis. The indicators used in this study are shown in Table 1.

(1) The explanatory variable is the level of technological innovation. Usually, the innovation level of a region or industry (enterprise) could be measured by some certain indicators,

such as the value of the new product (Zerenler et al., 2008; Conti & Chiarini, 2021), the patent (Kwon et al., 2023; T. Chen et al., 2023). In the China Science and Technology Statistical Yearbook, “new product revenue” is listed in “main business revenue”, hence, it represents the output value of new products, and we treat this to be the level of technological innovation but not the patent. However, the revenue from new products cannot effectively reflect the level of technological innovation; thus, it is expressed as (revenue from new products/revenue from main business × 100) in logarithm. It should be noted that in the period of 2017–2019, as part of the data are obtained from the China Statistical Yearbook, the technological innovation level is calculated by using corresponding substitute indicators, but the indicator description is not separately described.

(2) The core variables are introduced to be technology intensity, interaction term between introduced technology intensity and digested and absorbed technology intensity, interaction term between introduced technology intensity and domestic technology use intensity, and interaction term between introduced technology intensity and technology transformation intensity. To match the level of technological innovation, the logarithms of the above four core indicators are also adopted. In the China Science and Technology Statistical Yearbook, “technology acquisition and technological transformation of industrial enterprises” is divided into expenditure on technology introduction, digestion and absorption, purchase of domestic technology, and technological transformation. For this reason, expenditure on technology introduction/main business income × 1000, expenditure on digestion and absorption/main business income × 1000, expenditure on purchase of domestic technology/main business

Table 1. Indicator description

	Symbol	Meaning	Measurement
Explained variable	CX	Technological innovation level	Output value of new products/Main business income × 100.
Core variables	JJQ	Intensity of imported technology	Foreign technology introduction expenses/ main business income × 1000.
	JJQ*XXQ	Interaction term of imported technology intensity and digested and absorbed technology intensity	Technology import intensity × digestion and absorption intensity. Where, the intensity of digestion and absorption is expenditure of digestion and absorption/income from main business × 1000.
	JJQ*JIQ	Intensity of imported technology and intensity of domestic technology use	Technology import intensity × technology transformation intensity. Expenditure on purchasing domestic technology/income from main business × 1000.
	JJQ*JGQ	The interaction of the intensity of imported technology and the intensity of technological transformation	Technology import intensity × technology transformation intensity. Where, the intensity of technological transformation is expenditure of technological transformation funds/income from main business × 1000.
Control variables	RPQ	R&D personnel investment intensity	Full-time equivalent of R&D personnel /R&D personnel × 10.
	RQU	Research and development of quality	Output value of new product /R&D personnel, unit: Million yuan/person.
	DUM	Change of statistical method	Take 0 for 2011–2016 and 1 for 2017–2019.

income × 1000, and expenditure on technological transformation/main business income × 1000 are taken as logarithms. They indicate the intensity of technology introduction, technology digestion and absorption, domestic technology use, and technology transformation, respectively. The reason for setting each value × 1000 is that the ratios of the above four types of expenditure to the main business expenditure are relatively small, so they are enlarged appropriately.

(3) The control variables include R&D personnel input intensity and R&D quality. The R&D personnel input intensity is removed from the R&D personnel full-time, and it is equivalent to the R&D personnel ratio perspective. In addition, considering of partial data in 2017–2019 got from the China Statistical Yearbook, there might be a corresponding difference between the value of the GDP of the secondary industry and the main business income of the enterprises. Hence, DUM is set for regulating the systematic differences caused by the processing of such indicators. Therefore, the dummy variables are set to 0 or 1, which represents the period being 2011–2016, 2017–2019, respectively.

4. Descriptive analysis

Based on the two calibers mentioned, relevant data are formed for the national, the eastern, the middle, and the western by region, and for the national, the labor-intensive, the resource-intensive, the capital-intensive, and the technology-intensive by industry. It should be noted that the breakdown by region is taken from the perspective of the industry, while the breakdown by industry is taken from the perspective of the manufacturing, which in turn leads to a correlation, but owns some differences. Considering that the core independent variable is the introduction of technology intensity, and the dependent variable is the level of technological innovation, only these two indicators are analyzed descriptively. In order to make descriptive analysis, they are made from both the mean and coefficient of variation, as detailed result in Table 2 and 3.

As per technological innovation: (1) It can be considered that in terms of regional industrial innovation capacity: the eastern > the middle > the western, and the technological innovation capacity of the eastern and the middle show an increasing trend while the trend of the western is not obvious (from the data of 2011, 2013, and 2015). However, the mean values after 2017 are significantly larger, which is related to the differences in the previously mentioned data sources (some datas got from the China Statistical Yearbook are used in 2017). The coefficient of variation in the western is smaller than that in the eastern and middle regions in each year, and it could be assumed that the level of technological innovation varies the least among the western regions. This is followed by the middle region, while the eastern region owns the largest internal variation. (2) In terms of industry, the national average level (by industry) shows a clear trend of increasing technological innovation capability. For example, it steadily increases from 11.54 in 2011 to 18.98 in 2019, which could be considered as a gradual increase in the level of technological innovation in China's manufacturing industries. However, there are obvious differences between manufacturing industries with different attributes, which are generally characterized as the following: the technology-intensive > the capital-intensive > the resource-intensive > the labor-intensive. In addition, the technological innovation level of the technology-intensive manufacturing industries is approximately three times or more than that of the labor-intensive manufacturing industries in each year. The trends of different attributes of manufacturing industries also show a dominant divergence. For example, the technological innovation levels of the technology-, the resource-, and the labor-intensive industry all increased by approximately one time during 2011–2019, which is 0.94, 1.17, and 0.75, respectively. However, the technological innovation levels of the capital-intensive manufacturing industries has not changed significantly, which demonstrates that owns comparatively stable state. From the coefficient of variation, the difference between the labor-, the resource-, and the capital-intensive industries is small and usually approximately 2 (3.31 for the resource-intensive in 2013, there is an obvious perturbation), while the value is about 3 or more for the technology-intensive industry, and it can be considered that the technology-intensive manufacturing technology innovation level varies more between industries. (3) Although the region and the industry are completely different perspectives, there is a certain correlation between them to some extend. For example, it could be generally considered that the intensive manufacturing (including the capital- and the technology-intensive) is the main manufacturing industry in the eastern in China, while the extensive manufacturing (including the labor- and the resource-intensive) is the main manufacturing industry in the middle and the western in China. It could be seen that the technological innovation ability of the intensive manufacturing industry is apparently stronger than that of the extensive manufacturing industry, and the technological innovation ability of the manufacturing industry in the eastern is obviously stronger than that in the middle and the western, which is also consistent with the fact that there are obvious differences in regional innovation ability in China (Li, 2009; Chen & Guan, 2011; Zhao & Wang, 2020; Gao & Zhai, 2021; Liang & Li, 2023).

Table 2. Mean value and variation coefficient of technological innovation level

	Mean					Coefficient of variation				
	2011	2013	2015	2017	2019	2011	2013	2015	2017	2019
National average (regional)	10.72	10.57	11.46	43.01	45.88	1.68	1.67	1.63	1.54	1.64
The eastern	14.49	15.43	16.33	65.37	70.05	2.41	2.43	2.30	2.33	2.64
The middle	9.20	8.79	10.14	41.40	45.68	2.05	1.72	1.79	2.34	2.60
The western	8.18	7.14	7.64	21.92	21.86	1.21	1.72	1.44	1.41	2.12
National average (industry)	11.54	12.40	13.09	15.45	18.98	1.44	1.60	1.57	1.72	1.68
Labor-intensive	5.52	7.92	9.02	10.58	9.68	2.32	1.51	2.01	2.04	1.92
Resource-intensive	8.88	8.42	10.80	13.50	19.26	1.47	3.31	1.57	1.94	2.40
Capital-intensive	17.03	16.93	11.51	13.92	16.41	1.88	1.90	2.56	2.43	2.14
Technology-intensive	18.86	20.50	25.17	28.19	36.50	2.87	2.98	2.82	2.97	6.07

Considering the intensity of technology introduction: (1) Seen from a regional perspective, the national average increases significantly, which is from 0.57 in 2011 to 1.47 in 2019, indicating that industries, especially manufacturing enterprises, in each region of China have increased the intensity of technology introduction to help promote the optimization and adjustment of industrial structure and transformation and upgrading (Wang & Yu, 2013; Wang & Chanda, 2018; Liao et al., 2020). The intensity of technology introduction in the eastern is higher than that in the middle and the western, and the gap shows a widening trend. In particular, for example, it is 0.33 in the western and 2.41 in the eastern in 2019, respectively. Seen from the coefficient of variation, the value presents a trend across the country, showing that China's provincial regions pay more attention to technology transfer. However, there is also a certain difference, that is, the coefficient of variation in the eastern or the middle region is relatively higher than that in the western region, respectively. (2) In terms of sub-industries, the mean value of introduced technology intensity in the national manufacturing industry shows a relative reduction trend, which is 0.46, 0.15 and 0.20 in 2011, 2017 and 2019, respectively, and this could be seen as a more significant difference from the comparison of the mean values of the regions in the country. This might be related to inconsistencies in the databases used. Under background of a new normal and pattern of economic development and dual economic cycles, China's enterprises have not increased the introduction of technology rapidly, which might become a clamp on the difficulty of achieving a robust transformation of China's manufacturing industry, and this might be the reason for existing certain substitute between domestic technology promotion and technology import (Rauf et al., 2023). However, this might also be the result of China's apparent technological upgrading, and thus, there is no need to introduce too much foreign technology. Considering different types of manufacturing industries, both types show a declining trend of introducing technology intensity; in particular, the technology import levels of the labor-, the resource-, and the capital-intensive industries is only 0.15, 0.09, and 0.15 in 2017, respectively. Seen from the coefficient of variation perspective, the labor-, the resource-, and the capital-intensive industry have remained around 1.0 in recent years, and that of the technology-intensive industry shows a decreasing

Table 3. Mean value and variation coefficient of imported technology intensity

	Mean					Coefficient of variation				
	2011	2013	2015	2017	2019	2011	2013	2015	2017	2019
National average (regional)	0.57	0.42	0.62	1.16	1.47	1.11	0.74	0.50	0.54	0.44
The eastern	0.77	0.66	0.53	2.28	2.41	1.29	0.87	0.94	0.72	0.58
The middle	0.28	0.17	0.33	0.49	1.71	2.35	1.52	0.87	1.62	0.42
The western	0.60	0.38	0.93	0.56	0.33	1.09	0.72	0.47	0.46	0.79
National average (industry)	0.46	0.25	0.21	0.15	0.20	1.18	1.25	1.11	1.03	0.68
Labor-intensive	0.22	0.12	0.14	0.10	0.13	0.67	0.88	0.92	0.96	0.49
Resource-intensive	0.37	0.16	0.18	0.09	0.11	1.41	1.01	1.03	1.23	1.10
Capital-intensive	0.75	0.40	0.16	0.15	0.15	1.43	1.89	0.92	0.91	0.95
Technology-intensive	0.64	0.43	0.41	0.32	0.53	2.96	4.07	2.42	1.93	1.08

trend. (3) Comparing the above both perspectives, it is evident that the coefficient of variation examined from the regional perspective is generally smaller than the value resolved from the perspective of different categories of manufacturing industries. It could be argued that the internal variation in the intensity of imported technology from a regional perspective is smaller than that of the industry attributes. This is directly related to the fact that the level of technology importation varies significantly between different types of manufacturing industries, and the existence of different types of manufacturing industries in the same region (by the three regions) relatively smooths out this gap.

5. Econometric result

A panel data model is adopted and E-views 7.2 is used for making econometric analysis, with the period being from 2011 to 2019. Considering seven variables taken the mixed estimation model has a better econometric effect after making comparative analysis. Therefore, the mixed estimation model is adopted for the subsequent empirical analysis, and the ordinary least squares estimation method is taken. In the concrete demonstration, the following operations are adopted: (1) to highlight the import of imported technology intensity on technological innovation, the effects of control variables are not reported; (2) if the control variables of the national sample (from the perspective of sub-regions and sub-industries) pass the significance test of 10%, "Yes" is used to indicate the use of these variables, and whether these control variables pass the significance test is not considered in the subsequent classification demonstration; (3) when judging the core indicators, 10% is taken as the standard of the significance level; (4) the intensity of imported technology is taken as the core index, and whether the index passes the test is taken as the basic criterion for model selection. The interaction indexes are considered only when the imported technology intensity index fails to pass the test. (5) Based on the core indicators passing the test, the equations with relatively more indicators passing the test are selected as the models for subsequent analysis.

5.1. Sub-regions

Seen from the perspective of the sub-region, the econometric results show that all core and control variables pass the significance test. Therefore, these control variables are selected for the sub-regional econometric analysis, with detailed results in Table 4.

According to the results got from different regions, the increased intensity of imported technology significantly improves the technological innovation level of the industry, and the effect of the interaction term is stronger. Thus, Model 4 is used to analyze the effect of non-regional influence. Seen from Model 4, it could show that the intensity of imported technology has a positive impact on China's technological innovation level, with the coefficient being 0.359. However, there are differences in the effects of the interaction terms. For example, the interaction term with the intensity of digestion and absorption is positive, whereas the interaction terms with the intensity of domestic technology use and technological transformation are negative. It could be concluded that, with a focus on technology import, existing domestic technology use and investment in technological transformation in China do not effectively improve the level of technological innovation. In fact, the improvement of the domestic technology level would reduce the dependence on foreign technology import (Zhang, 2020), which might lead to a negative relationship between technology import and domestic technology upgrades (represented by the increase in enterprises' expenditure on using domestic technology).

Table 4. Econometric results on sub-regions

	The national				The eastern			
	Model1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
a	2.858	2.735	2.077	2.252	–5.402	–5.387	–5.340	–5.496
JJQ	0.179 (0.000)	0.324 (0.000)	0.220 (0.000)	0.359 (0.000)	–0021 (0.453)	–0.068 (0.052)	–0.068 (0.053)	–0.323 (0.010)
JJQ*XXQ		0.041 (0.000)	0.052 (0.000)	0.044 (0.000)		–0.027 (0.029)	–0.026 (0.110)	–0.037 (0.030)
JJQ*JIQ			–0.081 (0.000)	–0.060 (0.001)			–0.002 (0.928)	–0.046 (0.094)
JJQ*JGQ				–0.068 (0.014)				0.116 (0.034)
RPQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RQU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DUM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-R^2	0.527	0.554	0.598	0.606	0.928	0.932	0.931	0.934
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	The middle				The western			
	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
a	–0.330	–0.330	–0.396	1.758	2.989	3.076	2.910	3.314
JJQ	0.054 (0.194)	0.030 (0.703)	0.025 (0.744)	0.497 (0.002)	0.087 (0.000)	0.183 (0.000)	0.136 (0.006)	0.275 (0.000)
JJQ*XXQ		–0.006 (0.713)	0.001 (0.961)	0.032 (0.106)		0.021 (0.008)	0.022 (0.006)	0.010 (0.195)
JJQ*JIQ			–0.021 (0.272)	0.049 (0.072)			–0.025 (0.060)	–0.014 (0.275)
JJQ*JGQ				–0.158 (0.001)				–0.078 (0.004)
RPQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RQU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DUM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-R^2	0.860	0.858	0.859	0.879	0.768	0.784	0.791	0.818
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Seen from different regions, a comprehensive comparison of Models 5–8 in the eastern, Models 9–12 in the middle, and Models 13–16 in the western, reveals that all four core variables in Model 8 pass the significance test, and three core variables in Models 12 and 15 pass the significance test (in Model 12, the *P*-value of the interaction term with digestion and absorption 0.106, which could also be considered to pass the 10% significance test generally). The adjusted correlation coefficients are generally good, so the above three models could be used for judging the impact of the technology import on technological innovation in the eastern, the middle, and the western. Model 8 shows that technology import in the eastern is not conducive for regional enterprises improving technological innovation level. The coefficients of the interaction terms with the intensity of digestion and absorption and the intensity of domestic technology use are both negative, which might be directly related to the fact that the level of independent R&D in the eastern region is significantly stronger than that in the middle and the western. The impact of technology import on technological innovation in the middle and the western is similar, but that in the middle is greater than the other two regions, *e.g.*, the coefficients in the middle and the western is 0.497 and 0.136, respectively. This indicates that the impact of technology import needs to be paid more attention to accelerate economic development, due to the improvement in the technological innovation capacity in the middle. In addition, regardless of different regions, the intensity of imported technology and its interaction term with the intensity of digestion and absorption vary in the same direction, even though the impact of imported technology intensity is negative in the eastern. It could be argued that the increase in digestion and absorption intensity contributes to the improvement of the technological innovation capacity of Chinese enterprises, but there are obvious regional differences in the effects of the other two interaction terms.

5.2. The industry

Manufacturing industries are classified as the labor-, the resource-, the capital-, and the technology-intensive. Econometric analysis of the impact of technology import on technological innovation is conducted in five dimensions, as detailed in Tables 5 and 6.

Seen from the non-segmented industries, two variables in Model 19 pass the 1% significance test, and one variable passes the 10% significance test generally (p = 0.109). In contrast, one and two variables of Models 18 and 20 do not pass the test, respectively. Therefore, Model 19 is used to characterize the performance of technology importation affecting technological innovation regardless of industry. It could be seen that technology importation is beneficial to enhance the technological innovation capability of the manufacturing industry. The effect of the interaction term between the intensity of imported technology and the intensity of digestion and absorption is also positive, but the effect of the interaction term between the intensity of imported technology and the intensity of domestic technology use is negative.

Table 5. Econometric results with no industry differentiation

	No industry differentiation			
	Model 17	Model 18	Model 19	Model 20
a	–2.819	–2.869	–3.052	–3.230
JJQ	0.275(0.000)	0.263(0.000)	0.198(0.000)	0.251(0.001)
JJQ*XXQ		–0.002(0.736)	0.013(0.109)	0.018(0.058)
JJQ*JIQ			–0.037(0.005)	–0.027(0.117)
JJQ*JGQ				–0.023(0.304)
RPQ	Yes	Yes	Yes	Yes
RQU	Yes	Yes	Yes	Yes
DUM	Yes	Yes	Yes	Yes
A-R^2	0.575	0.574	0.586	0.586
P-value	0.000	0.000	0.000	0.000

Considering that imported technology intensity is the main concern for the study, it is taken as the most important indicator to be considered, Based on the mentioned criteria of model selection, Models 21, 25, 30, and 36 is used as econometric models to measure the impact of technology import on technological innovation in the labor-, the resource-, the capital-, and the technology-intensive industries, respectively. From the econometric results, we could detect that: (1) under the condition being the indicator of imported technology intensity passing the significance test, the labor- and the resource-intensive industries does not have any interaction term that passes the robustness test, and the impact coefficients of the two types of manufacturing industries are the similar, that is 0.153 and 0.144, respectively. (2) The interaction terms for intensity of the capital-intensive imported technology and intensity of absorption, the intensity of technology-intensive imported

Table 6. Econometric results with industry differentiation

	Labor-intensive				Resource-intensive			
	Model 21	Model 22	Model 23	Model 24	Model 25	Model 26	Model 27	Model 28
a	–0.268	–0.720	–1.168	–1.528	–0.699	–0.607	–0.213	0.090
JJQ	0.153 (0.000)	–0.022 (0.717)	–0.063 (0.390)	0.069 (0.563)	0.144 (0.002)	0.119 (0.308)	0.042 (0.723)	–0.085 (0.542)
JJQ*XXQ		–0.024 (0.001)	–0.013 (0.300)	–0.007 (0.614)		–0.004 (0.814)	0.010 (0.611)	–0.004 (0.849)
JJQ*JIQ			–0.026 (0.315)	0.009 (0.800)			–0.036 (0.035)	–0.057 (0.007)
JJQ*JGQ				–0.049 (0.164)				0.077 (0.090)
RPQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RQU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DUM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-R^2	0.472	0.547	0.547	0.554	0.512	0.505	0.531	0.545
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Capital-intensive				Technology-intensive			
	Model 29	Model 30	Model 31	Model 32	Model 33	Model 34	Model 35	Model 36
a	0.278	0.497	–0.523	–0.821	–1.210	–0.938	–0.467	4.012
JJQ	0.258 (0.000)	0.550 (0.000)	0.577 (0.000)	0.635 (0.001)	0.162 (0.074)	0.260 (0.212)	0.229 (0.292)	–0.657 (0.094)
JJQ*XXQ		0.074 (0.000)	0.073 (0.000)	0.073 (0.000)		0.034 (0.598)	0.045 (0.503)	–0.000 (0.994)
JJQ*JIQ			0.010 (0.799)	0.028 (0.602)			–0.045 (0.569)	–0.236 (0.025)
JJQ*JGQ				–0.027 (0.614)				0.536 (0.010)
RPQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RQU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DUM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-R^2	0.562	0.670	0.663	0.658	0.413	0.403	0.392	0.480
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

technology, the intensity of domestic technology use, and the intensity of technological transformation all passes the robustness test, respectively. In terms of the influence of imported technology intensity on technological innovation, there is a positive correlation for capital-intensive innovation, but a negative correlation for technology-intensive innovation, and the coefficients are obviously larger, for example, that is 0.550 and –0.657, respectively. (3) The interaction term of technology intensity and domestic technology use intensity of technology-intensive manufacturing is negatively correlated with technological innovation. Combined with the effect of imported technology intensity on technology-intensive, it could be concluded that the increase in domestic technology use intensity could promote technological innovation in enterprises. In other words, there is a certain degree of substitutability between the effects of introduced technology intensity and domestic technology use intensity on technological innovation, which is consistent with the findings of Liu and White (1997), and Liu et al. (2014).

Considering the relationship between technology import and industrial innovation, the results are positively correlated regardless of the region and the industry, while the results are not clear, which confirms the uncertainty in the relationship mentioned in the previous part of the literature review (Kishi & Okada, 2021). Comparing the results of the sub-regional and sub-industry measures, it is clear that the sub-regional results are significantly better than the sub-industry results. The introduced technology intensity is negatively related to technological innovation in the eastern region and the technology-intensive industries, while positively related to technological innovation in other regions and types of industries. This might be related to the higher level of economic development in the eastern, and the significantly rapid speed and pace of transformation and upgrading of manufacturing industries than that in the middle and western regions, with the result of more technology-intensive industries.

6. Discussion

Given that the classification is based on the column of "Technology acquisition and technological transformation of industrial enterprises" in the China Science and Technology Statistical Yearbook, it is assumed that the four categories of expenditures are relatively independent during the period of the research. However, if the relevant data could not be obtained from the corresponding yearbook, the differences in statistical caliber and statistical sources might own different classifications for technical expenditures. In addition, based on statistical or research needs, the classification criteria on technology expenditures might differ according to the country, the region and the industry (Holemans & Sleuwaegen, 1988; Chen et al., 2022), which might have a corresponding impact on the econometric results.

As per the regional classification, the regions are traditionally divided into the eastern, the middle and the western, but technology importation affecting innovation should be better guided by the level of economic development (Kishi & Okada, 2021). There are explicit differences in the impact on regions at different levels of development, and the aforementioned classification of the three in China does not reflect such differences in economic development levels. For example, the eastern region includes both developed and moderately developed regions. Therefore, it is necessary to classify China into regions according to the level of economic development and develop an in-depth analysis.

There is no apparent controversy about the industry classification given in the study, either at the academic or government development initiative level. Nevertheless, there is no consensus as to which specific industries are included in these four categories. For example, the 27 manufacturing industries adopted are divided into four categories without any effective theoretical explanation on which type each manufacturing industry belongs to. Furthermore, as the economy develops, the manufacturing industry might undergo a shift in factor intensity (Antras, 2003), which would make the feature of one certain industry to be more complicated. Meanwhile, this study only attempts to classify manufacturing industries to examine the impact of technology import on innovation in different types of industries.

7. Conclusions

7.1. Implications

This paper constructs a theoretical model to measure the impact of technology import on industrial innovation from the perspective of technology expenditure, which is divided into four types, and focuses on the impact of technology import expenditure and its interaction terms. It might give a hint for analyzing the impact of technology import from this perspective, and could provide a new attempt to explore corresponding theoretical mechanism.

The results show that there owns complementary between technology import and domestic technology innovation in general, but owns the feature of heterogeneity in the relationship between these two in different regions and different industry attributes. It could be believed that there might be no squeezing effect between China's technology import and domestic technology innovation, which requires increasing technology import to achieve two-wheel drives being domestic independent innovation and foreign technology introduction. However, the results of heterogeneity show that different practical measures should be taken to promote domestic technological innovation through technology import according to the reality of different regions and industries, while the substitution effect of these two needs to be effectively taken into account in the eastern region and the technology-intensive industry.

7.2. Limitations

The limitations of this study are mainly reflected in the following: one is the theoretical analysis of the impact of technology import on industrial innovation needs to be further, especially the logical relationship between technology import expenditure and other types of technology expenditure needs to be more clear; the other is the internal relationship between technology import and industrial innovation should be better reflected if micro-data and more samples could be adopted from the perspective of industrial innovation.

7.3. Future research directions

Due to the limitations of this study, subsequent research might need to be deepened in the following aspects: one is to build a more efficient theoretical model for bettering characterizing the relationship between technology import and industrial innovation while conducts more detailed theoretical mechanisms; the other is to take micro data with large samples, such as the Chinese Industrial Enterprise Database, and analyzes the correlation between these two from the perspective of technology expenditure.

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