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Financial subsidies, tax incentives and technological innovation in China's integrated circuit industry

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ABSTRACT

The integrated circuit (IC) industry's role in promoting sustained economic growth makes it highly valued by governments worldwide. Based on the late-mover advantage and market failure theories, this study demonstrates the importance of government intervention in industrial technological innovation. This study uses panel data from 81 A-share listed integrated circuit companies in China for 2011–2019 to analyze the effects and differences between the two most widely used policy tools, financial subsidies and tax incentives. The conclusion shows that financial subsidies inhibit technological innovation in the integrated circuit industry, while the promotion effect of tax incentives is weak. The robustness test also supported this conclusion. Further analysis shows that industry heterogeneity affects both policy tools. In terms of branches of the industrial chain, the policy effect of the core link is more significant than that of the support link. The inhibitory effect of financial subsidies is more obvious in the Pearl River Delta region, and the promotional effect of tax incentives is more pronounced outside the Pearl River Delta region. In addition, the current fiscal decentralization will hinder the promotion effect of the policy, and market competition will enhance the promotion effect of the policy. On the one hand, the research in this paper provides empirical evidence and policy reference for China to optimize fiscal policies related to the integrated circuit industry. On the other hand, a reference for development paths for late-mover countries is also provided in the early stage of industrialization.

Introduction

China's economic and social development environment faces increasing uncertainty and instability. Technological innovation, as a breakthrough, has become a consensus in seeking new growth points for economic and social development, and vigorously developing technology-intensive industries have also risen to the national strategic level. However, the "first-mover countries" represented by the United States regard China as an important competitor; the international competition situation has also become more complicated, and the technology-intensive industries, especially the integrated circuit industry, have suffered. Therefore, it is urgent to break through the complex and severe international competition situation and break through the key core "stuck neck technology" to occupy a favorable position in the global industrial chain and form a sustainable competitive advantage. Furthermore, for "late-mover countries," the way to promote their industrial development and achieve sustainable economic growth is an important topic for scholars. Many scholars have studied the factors influencing industrial technological innovation from different perspectives. The innovation ecosystem (Sydow & Müller-Seitz, 2018; Li et al., 2022; Seddighi & Mathew, 2020; Zhu et al., 2022), independent intellectual property rights (Chen & Xue, 2010; Wang, 2019), and fiscal policy (Zhang & Zheng, 2021; Luo et al., 2022; Li & Li, 2022b) are all important factors affecting technological innovation in the integrated circuit industry. Among them, fiscal policy could be the most relevant to the research. Still, the research conclusions of related literature are inconsistent and can be divided into two views. The first view believes that fiscal policy is effective. Some scholars have studied China, Taiwan (Chen and Jan, 2005; Yang et al., 2012), Japan (Fang, 2006; Yu, 2008; Feng, 2018), South Korea (Wu et al., 2015), and Thailand (Patarapong et al., 2015) in the development of integrated circuit industry, finding that among all the factors promoting technological progress, the influence of fiscal policy is the most important. Specifically, the government's fiscal subsidy policy incentives, tax credits, and other tax incentives guide developing industries and technological progress. Lu et al. (2014) found that financial subsidies can significantly positively impact the innovation output of strategic emerging industries. In particular, under financial subsidies, China's listed IC companies can obtain more equity

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financing, thereby increasing technological research and development (R&D) investment (Gu, 2019). Chinese government support has effectively promoted the participation of Integrated Circuit enterprises in technological R&D activities (Kong et al., 2014); the efficiency improvement of China's integrated circuit industry is closely related to preferential tax policies, having significantly different effects in technology research, development, and achievement transformation (Wang & Wang, 2019).

Second, fiscal policies had limited effects. Compared with the development process of the integrated circuit industry in Japan and the United States, the fiscal policies represented by subsidies and government procurement only drove the development in the first 30 years in Japan; the fiscal policies of the United States government may negatively impact the long-term strength of the industry (Lynn, 2000). In addition, the development process of the integrated circuit industry in China has benefited from alleviating government agency problems rather than the success of the government fiscal policy implementation and other interventions (Hongwu, 2006). This study believes that differences in policy tools are observed in the above literature. Still, fiscal policy and the reasons for the differences are not discussed in depth, providing a literature basis to study the relationship between fiscal policy and technological innovation in the integrated circuit industry in China.

The Chinese government attaches great importance to developing the integrated circuit industry. Since The Eighth Five-Year Plan for tackling key problems in science and technology" (1991–1995),[1] China has actively supported the development of the integrated circuit industry, emphasizing breakthroughs in key core technologies. The national system has concentrated its efforts on industrial development. The "China 14th Five-Year Plan" (2021–2025) stated, "Aiming at the frontier fields such as integrated circuits…to promote the advanced industrial base and the modernization level of the industrial chain to be significantly improved…"[2] Relevant industrial policies were also introduced. Since 2006, the State Council, National Development and Reform Commission, Ministry of Finance, and Ministry of Science and Technology have successively issued policies to support and regulate the development of the integrated circuit industry. Fiscal policies, including fiscal subsidies and tax policies, have many issues, strong implementations, and small policy granularity. However, it is difficult for the private sector to afford, and its willingness to invest is low. Therefore, the government typically uses fiscal policies to promote technological progress and industrial development. "Insist on strengthening the overall planning of financial resources, concentrating financial resources on major tasks…to promote the optimization and upgrading of the industrial chain and supply chain,"[3] the 2020 National Public Financial Work Video Conference once again emphasized the role of fiscal policy in coordinating and allocating industrial resources.

Foreign integrated-circuit industrial giants continue to impact China's local products through related products, the integrated-circuit industry as a national strategic emerging industry, and China's willingness to develop an integrated-circuit industry has become increasingly strong. Therefore, fiscal policy, one of the primary means of national regulation and control, has attracted considerable attention. To improve the existing fiscal policy system further and give full play to the guiding role of fiscal policy in the technological progress of the integrated circuit industry, it is necessary to objectively evaluate the effect of the existing fiscal policy and clarify the internal linkage mechanism between fiscal policy and industrial technological progress. Therefore, a study on the relationship between fiscal policy and the technological progress of the integrated circuit industry is necessary through theoretical and empirical research on the role of fiscal policy to determine and analyze the problems of the current fiscal policy in promoting industrial technological progress to a certain extent. Solving these problems might provide a reference for China's integrated circuit industry to achieve technological progress and further development.

Therefore, this study examines the impact of financial subsidies and tax incentives on technological innovation in the integrated circuit industry based on data from China's A-share listed integrated circuit companies for 2011–2019. Research shows that, in the current environment, financial subsidies have not achieved a theoretical incentive effect, and there is room for improvement in the incentive effect of tax incentives. Furthermore, the heterogeneity of enterprises leads to differences in policy instruments; however, factors such as fiscal decentralization and market competition cause policy effects to deviate from theoretical expectations. Therefore, this study had the following three objectives:

(1) To prove the importance of fiscal policy to industrial technological innovation.

(2) To provide a theoretical and practical reference for developing countries such as China to use intervention methods to develop related industries.

(3) To provide significant reference suggestions for governments in developing countries, such as China, to further optimize the relevant policy system.

The remainder of this paper is structured as follows: The second part reviews the existing financial policies of China's IC industry based on late-mover theory, analyzes the theoretical path of technological innovation in later-developing countries, and the necessity of financial policies to support technological innovation in the IC industry from the perspective of market failure. The third part uses the Ordinary Least Squares (OLS) Estimation Method and panel data of China's A-share IC-listed companies to analyze the effects of fiscal subsidies and tax incentives on the technological innovation of the IC industry. It introduces fiscal decentralization and market competition to discuss their regulatory effects on the effect of fiscal policies. The fourth section draws conclusions based on theoretical and empirical analyses and provides corresponding policy recommendations.

Policy background and theoretical analysis

Policy background

The Chinese government's attention to the IC industry can be traced back to the founding of the People's Republic of China. Still, the policy recognized by the industry as a milestone is the "Several Policies to Encourage the Development of the Software Industry and IC Industry" ("Document No. 18″) promulgated in 2000. In the late 1990s, the status and role of the IC industry became increasingly prominent, and the economic development situation at home and abroad led the Chinese government to make a major strategic decision to strengthen the encouragement for the development of software and IC industries. Therefore, a policy drafting group was established, drawing on relevant domestic and foreign materials, conducting many interviews and research, and forming Document No. 18. With this document as a sign; China used its fiscal policy to support the development of the IC industry into a new stage.

[1] The Eighth Five-Year Plan for tackling key problems in science and technology, https://baike.baidu.com/item/%E2%80%9C%E5%85%AB%E4%BA%94%E2%80%9D%E5%9B%BD%E5%AE%B6%E7%A7%91%E6%8A%80%E6%94%BB%E5%85%B3%E8%AE%A1%E5%88%92/15596750?fr=aladdin.

[2] Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035, https://cset.georgetown.edu/publication/china-14th-five-year-plan/.

[3] http://www.mof.gov.cn/zhengwuxinxi/caizhengxinwen/202012/t20201231_3638632.htm

Based on improving the identification of IC enterprises, Document No. 18 mainly provided preferential treatment for IC design enterprises regarding value-added tax, customs duties, business tax, and corporate income tax. After the expiration of some policies in Circular 18, to ensure the continuity of policies and respond to changes in domestic and foreign economic situations, the Chinese government issued the "Several Policies to Further Encourage the Development of the Software Industry and Integrated Circuit Industry" in January 2011 ("Document No. 4″), Document No. 4 had made greater efforts to support the technological progress of the IC industry by relaxing the criteria for the recognition of corporate income tax incentives, using central budget funds to support IC industry projects, and adopting market-oriented methods to alleviate the difficulties of corporate financing. To alleviate the situation of high financing constraints in the IC industry, the Chinese government issued the "National Integrated Circuit Industry Development Promotion Outline" ("Promotion Outline") in June 2014 through the establishment of the National Integrated Circuit Industry Investment Fund, the use of financial funds Attract social capital to participate in support for the IC industry. Entering a new era, everyone in China has realized that the IC industry urgently needs to improve its industrial technological autonomy. The central government has timely introduced policies to promote enterprises to invest in technology R&D, namely "Several Policies for Promoting the High-Quality Development of the Integrated Circuit Industry and Software Industry in the New Era" ("Document No. 8″). Document No. 8 exempts qualified IC enterprises from corporate income tax for ten consecutive years and encourages global cooperation in the IC industry to cultivate leading domestic IC enterprises. In addition to the up- and downstream of the industrial chain, Document No. 8 covers the various growth stages of IC companies, from the early stage of entrepreneurship to listing in the value, innovation, capital chains, and other industrial ecological layouts. The policy has a wider coverage and a longer time, consistent with the IC industry. China's fiscal policy may profoundly impact the independent and innovative development of the IC industry. Table 1 shows important changes in fiscal and taxation policies from Document No. 18 to Document No. 8.

Theoretical analysis

Based on the previous review of China's relevant fiscal policies in Table 1, some scholars found that policies and measures in the actual implementation had a specific deviation and did not benefit China's IC enterprises. This study initially found that some fiscal policy tools did not achieve the expected results, and there were differences in the effects and applicability of the policies (MIITC, 2011; Zhu, 2016). To analyze these differences, it is necessary first to discuss the realization path of China's technological progress, highlight the necessity of fiscal policy and some influencing mechanisms, and finally, discuss the relevant factors affecting the policy.

The realization path of technological progress in late-mover countries

Based on the basic fact that China is still a developing or late-mover country (Hu, 2015), discussions on the technological progress realization path from the perspective of a late-mover country are necessary.

After reviewing the economic development history of some countries, Gerchenkron (1962) found that under certain conditions, backward countries can reduce the economic growth gap with advanced countries by introducing advanced technology, the so-called "late-mover advantage." The more popular view was that technological progress could be divided into "general" and "breakthrough" technological progress. The former can be gradually accumulated through "learning by doing," while the latter is promoted through national power, often leading to transformative technological changes. The latter introduces or imitates the relevant technologies of the first-mover countries, and the late-mover countries improve their independent innovation capabilities through their digestion and absorption of the acquired technologies. They then select advanced technologies to focus on breakthroughs and improve their technical level in specific fields. Therefore, late-mover countries may also catch up with first-mover countries through the so-called "leapfrog" phenomenon.

China's catch-up path in most industries also proves this phenomenon. However, the "leapfrog" phenomenon is not inevitable. The rise of Japan, South Korea, and other countries was unique. Most developing countries cannot achieve technological progress after introducing or imitating the technology of developed countries and even fall behind. Acemoglu (1998) showed that a country's purposeful technological R&D activities produce technological progress, and first-mover countries have a higher technological accumulation and human resource elements, which can meet the needs of related advanced technologies. Existing technological accumulation and human resources in late-discovering countries do not match the requirements of advanced technology, and the introduction of advanced technology cannot lead to technological progress.

Then, how we solve the "later-mover advantage paradox" phenomenon is the key problem. Abramovitz (1989) believed that late-mover countries must meet the needs of related technologies in terms of infrastructure and accumulation of knowledge to match existing conditions to give full play to introduced technologies. If a late-mover country only cares about which technologies to introduce but not the adaptability of its factor endowments and related technologies, then the production technology will only hinder late-mover countries from improving productivity rather than promoting them to achieve technological progress. Yi et al. (2007) and Liu (2011) showed that in addition to the accumulation level of factors such as technical level, human resources, capital, and decision-making of the path adopted by late-mover countries, they would be closely related to the intellectual property protection system. Given the initial technical level of late-mover and first-mover countries, when the intellectual property protection system is not perfect, late-mover countries can use the method of introduction or imitation to improve their technological level. As the intellectual property protection systems are gradually standardized and refined, the cost of technology introduction or imitation will increase, and late-mover countries will be more inclined to use independent innovation to improve their technological level.

Moreover, according to the above factor analysis for solving the "later-mover advantage paradox" phenomenon, Wei (2014) and Peng (2019) regarded government intervention as an exogenous variable to construct a theoretical model of technological progress. The model analysis showed that the late-mover countries could not improve the social and technological level simply by relying on the market mechanism and needed state support to move towards independent innovation (Aghmiuni et al., 2019). Furthermore, considering the competition between countries, late-movers need to maintain a longer, more continuous, and higher investment to achieve the same level of technological progress. Behind the development of the industry, the essence is national power competition between first-mover and latter-developing countries. Therefore, support for government intervention does not imply opposition to market mechanisms. In this model, late-mover countries take relevant measures to shift the curve to create a fairer and more competitive market environment for industrial development so that the market mechanism can play a decisive role in resource allocation. This reflects the situation in which the government and market form a joint force to achieve a dynamic balance.

The necessity of implementing financial support policies

When government intervention is necessary, combined with a policy review, it is necessary to implement fiscal support policies to provide theoretical support for optimizing the fiscal policy system.

Table 1
Important changes in fiscal and taxation policies from Document No. 18 to Document No. 8.

	Document No. 18	Document No. 4	Promotion Outline	Document No. 8
Value-added tax	For software products developed and produced by oneself, the part of the actual tax burden exceeding 3% shall be "refunded immediately after collection."	Continue to implement Document No. 18 and adopt special measures to solve financial problems encountered in major projects.	Continue to implement the relevant measures stipulated in Documents No. 18 and 4 and speed up supporting measures.	Continue to implement the relevant measures stipulated in Documents No. 18 and 4.
Customs duties and import value-added tax	When the relevant raw materials, and equipment, meet the conditions, import duties and value-added tax are exempted.	Import taxes are implemented under current regulations; for qualified enterprises, more emphasis is placed on expediting customs clearance services.	Ditto.	For enterprises with line width ≤ 65 nm and characteristic process manufacturers with line width ≤ 0.25 μm, when the relevant raw materials, and equipment, meet the conditions, import duties and value-added tax are exempted. For compound manufacturers and advanced packaging and testing companies with line widths ≤ 0.5 μm, import duties are exempted when the relevant raw materials meet the conditions.
Business tax	N/A	Exemption from business tax for qualified IC design enterprises	Ditto.	"Replacement of business tax with value-added tax" has abolished business tax.
Corporate income tax	Newly established design enterprises enjoy "two exemptions and three halvings" starting from the profit-making year.	Integrated circuit manufacturers with line width ≤0.8 μm enjoy "two exemptions and three halvings"; Integrated circuit manufacturers with line widths ≤ 0.25 μm can enjoy "five exemptions and five halvings"; Newly established design enterprises will enjoy the preferential policy of "two exemptions and three-half reductions" starting from the profit-making year.	Ditto.	Production enterprises or projects with a line width of ≤28 nm and an operating period of ≥15 years can enjoy the preferential policy of "10-year exemption"; Production enterprises or projects with a line width of ≤65 nm and an operating period of ≥15 years can enjoy the preferential policy of "five exemptions and five halvings"; Production enterprises or projects with a line width of ≤130 nm and an operating period of ≥10 years can enjoy the preferential policy of "two exemptions and three halvings"; Integrated circuit design, equipment, material, packaging, testing companies and software companies enjoy "two exemptions and three halvings"; Key IC design enterprises are exempted from corporate income tax from the first year to the fifth year and levied corporate income tax at a reduced rate of 10% in subsequent years.

Note: The author summarizes all information based on the Chinese government's website.
Source: http://english.www.gov.cn.

Externality and corrective fiscal policy of ic technology. To develop the IC industry, we rely on independent innovation to break the technological monopoly of first-mover countries to upgrade the industry to a leading supply chain within the global value chain. Technology R&D requires considerable investment, but the externalities of R&D make the private sector less willing to invest; therefore, financial intervention is needed to increase investment enthusiasm.

The R&D results produced by technological progress can bring about transformative or revolutionary improvements in society, thereby promoting productivity improvement. However, the private sector is usually reluctant to carry out technological R&D. From the perspective of externality, on the one hand, the private sector cannot obtain an investment return commensurate with the benefits obtained by the whole society in developing new technologies, which inhibits its willingness to invest in R&D. On the other hand, new technologies are non-exclusive in consumption, allowing other private sectors not directly involved in R&D to benefit from the R&D of new technologies only at the cost of using the technology. This "free-rider" behavior also reduces the private sector's enthusiasm to invest in technology R&D.

Technological R&D have noticeable external effects on the IC industry. Fiscal policies can internalize external benefits by compensating related firms for innovation. Here, the fiscal policy can increase enterprises' technological R&D investment, accelerate the output and

transformation of innovation results, and enable them to invest more resources in the next round of R&D, thus forming a virtuous circle.

Uncertainty of technological R&D and compensatory fiscal policy. The complexity of the IC production process implies that its industrial technology does not develop according to established routes. In other words, related technologies may stagnate in the long term or cause significant changes in the short term. Rapid technology development is the uncertainty of technological R&D caused by human beings' lack of understanding of the future. This uncertainty characterizes the IC industry by a large investment scale, an extended return period, and uncertain returns, reducing the investment willingness of the private sector and requiring financial intervention to compensate for uncertainty.

From the perspective of investment scale, the industry chain is relatively long, and the technological R&D activities in each link, from basic materials to final product manufacturing, are different. However, they all show high technical complexity, resulting in high technological R&D costs. This cost is also reflected in the joint participation of interdisciplinary teams, and the private sector is usually unable to provide related services when material and human costs are high.

From the perspective of the return cycle, based on profit maximization, the private sector tends to adopt a higher discount rate; thus, its investment can obtain returns in the short term. Otherwise, it will not invest because the expected returns cannot be realized. An extended return period may also cause different private sectors to invest repeatedly in technological R&D for the same project. Under patents, the success of one party's technological R&D leads other investors to choose between abandonment and transformation, the loss of which the private sector cannot bear.

From the perspective of income uncertainty, the nonlinear development of technology makes it difficult for the market to predict technological breakthrough nodes, and the Matthew effect of the IC industry makes the trial and error cost unbearable for enterprises.

Fiscal policies have an incentive to compensate for uncertainty. The R&D of IC technology requires the dual investment of materials and talent, and the uncertainty of technological R&D reduces the willingness and investment scale of the private sector. Currently, the government's intervention measures provide a certain degree of protection for private sector investment, thereby reducing the uncertainty of technological R&D and mobilizing the enthusiasm of the private sector for investment. In addition, owing to information asymmetry, the unilateral adjustment of the market causes an imbalance in resource allocation. Under maximizing interests, personal choices and material input are often misaligned with social needs, affecting technology R&D output. A fiscal policy adjusts the balance of resource allocation among regions. Additional government compensation, incentives, and other policy measures can compensate for the acquisition of resources in regions with relatively backward resource endowments and adjust the balance of resource allocation.

Publicity and financial support of the IC industry. ICs are closely related to national security, and this connection enables countries to use IC trade friction between them to affect economic development and even the social stability of competitors. National security is a typical public product of political markets. One responsibility of a state is to protect society from security threats. In other words, the legitimacy of state power originates from maintaining national security. Therefore, it is justifiable to financially encourage and cultivate the IC industry to achieve independent control in many links, from basic materials to final product manufacturing. Behind the IC industry is the support and competition of governments of various countries, also a reflection of the protection of national security by the governments of various countries. Without strong support, international competitiveness cannot be achieved, and national security is threatened.

The use of fiscal policies to promote technological progress in the IC industry also manifests in the nationality of finance. Deng (2014) pointed out that socialist finance with Chinese characteristics should have a national character and emphasized that national character is the primary character of Chinese finance. From a national character, finance should always adhere to the supremacy of national interests, pay taxes and financing to the country, and strive to strengthen the country, which means supporting China in international competition. Therefore, China's finance sector should support the IC industry to achieve technological progress, maintain national security, and enhance China's international competitiveness.

Based on sections 2.2.2.1–2.2.2.3, the effectiveness of financial support would be indicated by the technical externality, the uncertainty of R&D, and the publicity of the IC industry. Therefore, government intervention in developing the IC industry should develop into financial support. This view does not deny the effectiveness of other interventions, such as monetary interventions. However, at this stage, the main channels of monetary intervention in industrial development include interest rates, exchange rates, and credit, among which credit is the main channel in late-moving countries. To control risk, banks tend to lend to projects with short-term returns rather than long-term and unprofitable projects (Song & Bian, 2017). In addition, the IC industry is characterized by large-scale investment and an extended return period, making it easier for fiscal policy support to achieve industrial technological progress in late-moving countries.

Relevant factors affecting the effect of fiscal support policies

The previous discussion on the technological progress of late-mover countries shows that to solve the "later-developing advantage paradox," an effective system is needed as a guarantee. As a centralized country, the division of powers and responsibilities among local governments, the construction of a market system, and appropriate policy tools all affect the allocation of public funds, affecting the technological progress of the IC industry.

The impact of fiscal decentralization on policy effectiveness. The first generation of fiscal decentralization theory believes that, compared with the central government, local governments can better understand the development status of their jurisdictions to make more targeted factor resource allocations, making it easier to maximize welfare. However, factor mobility causes competition among local governments and optimal efficiency of public goods provision (Musgrave, 1959; Tiebout, 1956). Therefore, the second generation of fiscal decentralization theory believes that incentive mechanisms and information symmetry should be emphasized to improve the efficiency of local government intervention. Simultaneously, as government officials must satisfy their interests, they may seek rent from political decisions (Weingast, 1995; Qian & Roland et al., 2003).

Montinola et al. (1995) believed that China's rapid economic growth is related to "Chinese-style federalism," Chinese-style federalism, and the organizational structure between the central and local governments conforms to "market-maintained federalism." However, some scholars oppose this view. Rodden and Rose-Ackerman (1997) believed the theory had significant limitations due to its lack of consideration of real politics. Yang and Nie (2008) believed that the theory did not pay attention to decentralization, leading to the neglect of the negative effects of decentralization.

Theoretically, fiscal decentralization can trigger competition among local governments, promote efficient resource allocations, and achieve technological innovation. However, China's fiscal decentralization is based on a vertically centralized official governance model (Wang et al., 2007). Under this decentralized system, local government officials pursuing political promotion would pay more

attention to whether policies can achieve economic benefits during their tenure, thus forming their governing achievements and less attention to the long-term economic development of their jurisdictions. In addition, factors such as physical distance could cause the central government to have an information disadvantage over local governments. Therefore, It is difficult to fully grasp the implementation of central policies at the local level, making it difficult to effectively change the local government officials' behaviors to pursue short-term economic benefits. IC industry technology R&D has a long cycle, slow effect, and high risk, which means that it is difficult to achieve the performance goals of local officials in a short period. Therefore, local officials do not value relevant technological R&D.

To obtain support from the local government regarding political and economic resources, enterprises usually choose rent-seeking to reduce their competitive pressure. Rent-seeking enables relevant companies to obtain additional support from local governments. However, it disrupts market order, creates unnecessary barriers, and makes it more difficult for potential competitors to enter the market, thereby weakening the incentives for the industry to invest in technology R&D. Moreover, rent-seeking behavior can make companies spend more on maintaining additional support and diverting R&D funds, thereby hindering them from achieving technological innovation.

The impact of market competition on policy effects. The effect of fiscal policy in promoting technological innovation is related to how enterprises allocate financial funds and are affected by the market environment in which enterprises are located. For example, implementing financial subsidies results from the subjective selection of enterprises by government departments. As the market mechanism plays a small role in this selection process, coupled with information asymmetry and the rent-seeking behavior of enterprises to obtain subsidies, resources may not be optimally allocated among enterprises, thereby weakening the promotional impact of subsidies on technological progress. However, in the case of a high degree of market competition, the government selects ex-ante incentive objects fairly.

Market competition affects enterprises' willingness to invest in technological R&D. In China, the technological gap between companies in the same industry is generally low. Therefore, companies increase investments in technology R&D when market competition is high to gain a competitive advantage. However, when competition is weak, low survival pressure will prompt the management of enterprises to develop steadily to reduce their risks rather than increase investment in technology R&D. Therefore, sufficient market competition will pressure enterprises to survive, prompting them to increase their technology R&D investment to obtain or maintain a competitive advantage (Wang & Zhang, 2020).

Market competition reduces the distorted allocation of financial funds and fully stimulates enterprises' willingness to innovate. By playing a regulatory role in the market, financial funds can be used more rationally, thereby improving the allocation efficiency of enterprises' technological R&D funds and finally realizing industrial technological innovation.

The influence of policy tool choice on policy effect. This study focuses on the effects of two of the most widely used policy tools: financial subsidies and tax incentives. Theoretically, these two tools have different focuses and policy effects (Wang & Ding, 2020).

From the perspective of support, government subsidies usually provide direct financial support to enterprises. Tax incentives rely mainly on reductions and exemptions, tax reductions, and so on, to support enterprises in technological R&D, and the support path is relatively indirect. From the perspective of support methods, most government subsidies are provided in advance, and the government is responsible for deciding whether to grant funding by reviewing enterprises' funding applications. Tax incentives are ex-post incentives that require enterprises to conduct businesses that meet the relevant tax incentives, and the initiative rests with the enterprise.

In addition, enterprises engaged in technological R&D face financing constraints. The higher the degree of technological uncertainty, the higher the financing constraints and the longer the commercialization of technological R&D results. It is difficult for enterprises to obtain corresponding taxes in the research, development, and transformation processes. Preferential incentives reduce the promotional effects of tax incentives. However, more intuitive government subsidies can release investment signals to the capital market while supplementing technological R&D funds, enhancing the possibility of enterprises obtaining relevant investments. Therefore, while other conditions remain unchanged, government subsidies have a stronger theoretical incentive effect on enterprises' technological R&D than tax incentives.

Empirical evidence on the impact of fiscal policy on the sustainable development of China's IC industry

In 2000, China issued fiscal policies related to the IC industry through central-level documents. Subsequently, major fiscal policies were implemented in 2011, 2014, and 2020. After 2011, China's IC-listed companies increased, providing a good sample for studying the effects of the fiscal policy. Based on financial data of A-share listed companies for 2011−2019, this section analyzes the effects of financial subsidies and tax incentives.

Model design and variable description

This study constructed a static panel model with fixed effects on fiscal subsidies and tax incentives. The reason for modeling financial subsidies and tax incentives was that the government's accounting standards issued in 2017 changed the disclosure method for financial subsidies from non-operating income to non-recurring profit and loss items. Therefore, separately exploring the effects of financial subsidies and tax incentives is necessary.

Accordingly, this study sets a model for the two types of policy tools as follows:

$$y_{i,t} = \alpha_0 + \alpha_1 sub_{i,t}(tax_{i,t}) + \sum_{i=1}^{N} a_j X_{i.t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

where y is the technological innovation of enterprises in the sample. Sub and tax represent financial subsidies and tax incentives, respectively, and X is the control variable of the corresponding model, which controls some related variables that affect the total factor productivity of enterprises.μ is the individual fixed effect of the enterprise, which represents the characteristics of the company's registration place that do not change with time. δ controls the annual fixed effect and some external shocks that affect enterprises over time, such as economic fluctuations and national policy changes, etc., ε is the disturbance term. Control variables include firm size, firm age, financial leverage, and return on assets.

Variable selection and data description

Technological innovation is key to developing the IC industry; the explanatory variable in this study is enterprises' technological innovation. It is represented by total factor productivity (TFP) (Hu &Wang, 2020; Li & Li, 2022a; Zhang, 2018; Feder, 2018). In the TFP estimation method, Lu and Lian (2012) believed that the OLS and the Olley-Pakes (OP) estimation methods have limitations and cannot estimate the sample with zero investment or missing. The LP method proposed by Levinsohn and Petrin (2003) (LP henceforth) avoids this problem. This study used the LP method to estimate total factor

Table 2
Variable Definition Table.

Variable type	Variable name	Variable symbol	Variable definitions
Explained variable	total factor productivity	TFP	Total Factor Productivity of Listed IC Enterprises
Explanatory variables	financial aid	Sub	The natural logarithm of financial subsidies enjoyed by listed IC companies
	direct tax benefits	di-tax	The natural logarithm of the direct tax benefits enjoyed by listed IC companies
	Indirect tax benefits	in-tax	Natural logarithm of indirect tax benefits enjoyed by listed IC companies
Control variable	Enterprise size	Size	The logarithm of the company's total assets
	business age	Age	Enterprise age during the sample period
	financial leverage	Lev	Total Liabilities/Total Assets
	Return on Assets	ROA	Net Profit/Total Assets

productivity, expressed as follows:

$$\ln Y_{it} = \alpha_0 t + \alpha_1 \ln L_{it} + \alpha_2 \ln K_{it} + \alpha_3 \ln M_{it} + \varepsilon_{it}$$

where i represents the corresponding enterprise, and t represents the corresponding year. In the above variables, Y represents the output, which is represented by the main business income of the enterprise, and the unit is million yuan. L is the labor input expressed by the number of employees, and the unit is a person. K is the capital investment expressed in net fixed assets in millions of yuan. M is the intermediate input, expressed in cash for purchasing goods and accepting labor services in millions of yuan. This study adopts the method of adding 1 to the above variables to ensure the logarithm of the variable value and minimize the impact on estimation accuracy.

Among the core explanatory variables, this study uses Sub to represent financial subsidies, so that financial subsidies = government subsidies - tax rebates received, to exclude the interference of tax incentives on financial subsidies, and takes the natural logarithm of this value as the variable value of Sub. Corporate tax incentives include direct and indirect ones. Ditax represents direct tax incentives, that is, the tax incentives enterprises enjoy through preferential tax rates. Take the total profit * (nominal tax rate-applicable tax rate) as the direct tax preference and the natural logarithm as the variable value of the di-tax. In-tax represents indirect tax benefits, achieved through lowering the tax base, measured as "plus deductions for technological R&D expenses." When there is no such item in the annual report, the method of technological R&D expenses × 50% × applicable tax rate is used as an approximation, and the value is taken as the natural logarithm and used as the variable value of in-tax.

This study controls for other factors that affect enterprises' technological innovation as follows:

(1) Enterprise size (size). Let Size=ln (total assets of the enterprise), where the unit of total assets is millions of RMB. Yang et al. (2015) found that enterprises' technological innovation is highly correlated with scale. With increased enterprise scale, enterprises can devote more resources to R&D under the same conditions. Therefore, the natural logarithm of firm size is used as a control variable.

(2) Age of enterprise (years). Let age = observation time (year of establishment + 1). As the age of the enterprise grows, the technological accumulation, talent, capital, and other elements mastered by the enterprise become more comprehensive. Therefore, this study draws on the existing literature to control for the impact of firm age on technological innovation.

(3) Financial Leverage (Lev). Let Lev = enterprise asset-liability ratio = total liabilities/total assets. Yang et al. (2018) showed that an enterprise's asset-liability ratio is closely related to the resources invested in technological R&D activities. When the asset-liability ratio reaches a certain level, the enterprise may face insufficient funds, negatively impacting its R&D investment. Therefore, we use the debt-to-assets ratio to measure corporate debt levels.

(4) Return on Assets (ROA). Let ROA = net profit/total assets. As the return on assets increases, companies can access more disposable funds. Thus, enterprises must make investment decisions based on disposable funding. Given other conditions, technological innovation is affected by the level of investment in R&D, which depends on the disposable funds available for R&D. Therefore, controlling for ROA's impact of return on assets on technological innovation is necessary.

Table 2 summarizes the types, names, symbols, and definitions of these variables.

The data was obtained from the financial reports of listed companies in China's A-share IC industry for 2011−2019. Notably, after synthesizing the data from the Ministry of Industry and Information Technology and the China Semiconductor Association, the initial sample of this study contains 81 IC companies to ensure the integrity of the data in the industry chain. Only nine enterprises in the sample were state-owned or state-controlled; the rest were private. Drawing on existing research (Chen, 2010), we eliminate ST types, financial industries, and companies with missing variable data, while double-ended tailing is used to eliminate the influence of extreme values. Thus, the final sample comprises 442 valid observations. However, due to the inconsistent listing times of companies and their failure due to poor management and other reasons that affect the overall research effect, this sample is an unbalanced panel, and the sample selection process is no longer carried out.

Table 3 presents the descriptive statistics of the main variables. Table 3 shows that the standard deviation of TFP during the observation period is 0.939, the minimum value is 5.968, the maximum value is 10.400, and the mean value is 7.681, indicating specific differences in TFP among enterprises within the sample, reflecting the different effects of fiscal policy, and further testing (Section 3.3) is necessary. Regarding the fiscal policy variables, the subsidy value is higher than the indirect tax preference, and the indirect tax preference is higher than the direct tax preference. Regarding enterprise characteristics, enterprises' size, age, financial leverage, and return on assets show large fluctuations, indicating significant differences among listed companies in China. Regarding moderating variables, the enterprises in the sample face relatively fierce market competition, and the competitive environment in which each enterprise is located differs. The average value of fiscal decentralization in the regions where the sample enterprises are located is relatively high, and the fluctuation is small, indicating that local governments have strong initiatives to promote technological innovation in the IC industry. These facts provide good test material for the empirical investigation.

Empirical test and result analysis

The overall impact of different policy tools on the sustainable development of the IC industry

Table 4 presents the regression results of Models (1) and (2). The representative variables of financial subsidies and tax

Table 3
Descriptive Statistics for Primary Continuous Variables.

Variable name	Observations	Average value	Standard deviation	Minimum	Maximum value
TFP	442	7.681	0.939	5.968	10.400
Sub	442	12.544	6.657	0.000	20.232
di-tax	442	1.037	0.105	0.701	1.284
in-tax	442	10.808	0.845	0.001	13.653
Size	442	7.908	1.083	5.998	10.948
Age	442	18.077	5.100	8.000	31.000
Lev	442	0.331	0.193	0.046	0.775
ROA	442	0.044	0.055	−0.164	0.266
MP	442	0.529	0.500	0.000	1.000
FD	442	0.861	0.068	0.755	0.963

Table 4
The effect of policy tools on the sustainable development of the IC industry.

	Technological innovation	
	(1) Subsidies	(2) Tax incentives
Sub	−0.038**	
	(−2.22)	
di-tax		0.039***
		(2.6)
in-tax		0.094***
		(2.76)
Size	0.176***	0.387***
	(4.79)	(7.99)
Age	−0.155	−0.023**
	(−1.39)	(−2.26)
Lev	0.463***	0.711***
	(2.93)	(4.59)
ROA	2.160***	1.396***
	(6.81)	(6.05)
_cons	3.960**	2.542***
	(2.54)	(6.36)
individual	control	control
years	control	control
N	442	442
r2	0.222	0.571

Note: 1. t-values are in parentheses; *,.
** , and.
*** indicate passing the 10%, 5%, and 1% significance tests, respectively. 2. All models control for the fixed effects of individuals and time, which are omitted from subsequent tables.

incentives passed the significance test, which preliminarily shows that both policy tools significantly impact the technological innovation of IC enterprises. Specifically, the coefficient of financial subsidies (Sub) is significantly negative at the 5% level, and both direct tax preference (di-tax) and indirect tax preference (in-tax) are significantly positive at the 1% level. It can be seen that during the observation period, financial subsidies cannot improve the total factor productivity of enterprises for the technological innovation of the IC enterprises in the sample. However, direct and indirect tax incentives can significantly improve the total factor productivity, thereby promoting the technological innovation of the IC industry.

Notably, the effect of financial subsidies is negative, which proves that the incentives for technological innovation in the IC industry are insufficient. Owing to information asymmetry, policy management model mismatch, rent-seeking, and other reasons, financial subsidies are not fully converted into R&D investments, reducing the effect of subsidies on promoting technological innovation. Therefore, the relevant expenditures for enterprises to obtain financial subsidies will also occupy the original R&D resources such that the subsidies will negatively impact technological innovation. Simultaneously, financial subsidies may also cause price distortions, such that the production function of enterprises cannot be optimized. Although the effect of tax incentives is positive, the coefficient value is low, indicating that tax incentives are insufficient. This may be because most companies invest in R&D to enjoy preferential treatment rather than achieve technological innovation, to reduce relevant investment as much as possible after the investment scale reaches the minimum standard for preferential treatment. This may also be because tax incentives are currently not systematic, and most are issued as departmental regulations, which cannot make enterprises form stable expectations.

For the control variables, the effects of firm size (Size), asset structure (Lev), and return on assets (ROA) are significantly positive. The effect of firm age (Age) is negative, but the coefficient is low and passes the significance test only from the perspective of preferential tax policies. The above estimation results are because the overall asset-liability ratio of listed companies in the IC industry is low, and the age distribution is uneven. According to relevant information from the Wind database, in 2017, the average asset-liability ratio of the industry was the lowest at 59.5%. In contrast, the simple arithmetic average of the asset-liability ratio of IC enterprises was 33.99%, significantly lower than the average level of various industries. This may be related to the high risk of technological R&D in the IC industry and the large-scale investments required. Usually, the asset-liability ratio is related to the medium- and long-term loans of commercial banks. The low index may be because companies must consider their costs and banks their risks. This shows that IC companies still have sufficient debt financing space to invest in R&D, so there is a positive correlation.

Robustness check

Table 5 reports the effects of the three types of policy tools, ensuring the robustness of the results in Table 4. Columns (1) and (3) replace the denominator of the calculation of financial subsidies and tax preference variables with the total profit from the main business income and delete the 2013 data in Column (3). Column (2) refers to Wu et al. (2020) and uses the provincial fiscal deficit with a lag of one period as an instrumental variable for fiscal subsidies. This is because the correlation between fiscal deficit and the scale of R&D investment is low, which satisfies the exogenous nature of the instrumental variables. The larger the scale of the local government's fiscal deficit in period t-1 and the higher the proportion, the more inclined it is to reduce subsidies to enterprises in period t, which satisfies the condition that the instrumental and endogenous variables are strongly correlated. Column (4) represents the robustness results obtained using the explanatory variable with a lag of one period as an instrumental variable, and Columns (2) and (4) are estimated using the generalized method of moments (GMM).

Table 5 shows that the coefficient significance and direction of the core explanatory and control variables in Columns (1)–(4) are consistent with those in Table 4, and the coefficient values have not

Table 5
The robustness test of fiscal policy on technological innovation of the IC industry.

	Technological innovation			
	(1) Replacement of subsidies	(2) GMM	(3) Replacement of tax incentives	(4) GMM
Sub	−1.271***	−0.225**		
	(−2.75)	(−2.34)		
di-tax			0.046***	0.194***
			(2.81)	(2.86)
in-tax			0.096***	0.382***
			(2.77)	(5.89)
AR(1)		0.006		0.007
AR(2)		0.704		0.587
Sargan		40.549		53.693

Note: t-values are in parentheses; *,.
** , and.
*** represent passing the 10%, 5%, and 1% significance tests, respectively.

changed significantly. Based on the above analysis, the results presented in Table 4 are robust.

Heterogeneity test

Enterprises of different types have different coping methods and characteristics when faced with preferential government policies. When discussing the promotional effects of fiscal policies, it is necessary to consider the heterogeneity of enterprises. The level of economic development in various regions of China and the degree of marketization are different. The development of different links in the IC industry chain has unique characteristics. These are important characteristics of the current development of the IC industry and have an important impact on the fiscal policy and technological innovation of enterprises. This study analyzes heterogeneity from two aspects: differences in the regions where the enterprises are located and differences in the branches of the industrial chain where they are located.

Industry chain heterogeneity. From the perspective of the heterogeneity of the industrial chain, owing to the different links in the industrial chain, the difficulty and willingness of enterprises to achieve technological innovation in the production process are not the same, which leads to different financial policy effects in different links. Upstream industries supporting ICs include electronic design automation (EDA for short) tools, Intellectual Property (IP for short) cores, materials, and manufacturing equipment. Midstream core industries include chip design, manufacturing, packaging, and testing. The downstream application industries include computers, network communications, consumer electronics, and automotive electronics. This part only considers the core industries in the midstream and will be divided into supporting links and core links according to the industrial chain, to simplify the research. Supporting links include the materials and equipment industries and core links include the design, manufacturing, packaging, and testing industries.

Table 6 reports the impact of fiscal policy on the technological innovation of IC companies in different links. Table 6 shows that only the coefficient of indirect tax preference (in-tax) for supporting enterprises is significantly positive, and the rest of the policy tools are insignificant. During the observation period, only the indirect tax preference was based on reducing and exempting technological R&D expenses to promote innovation for enterprises in the supporting link in the sample. For enterprises in the core link, except for indirect tax incentives (in-tax), the coefficients remain significant, and the direction is consistent with the overall regression results. In contrast, the effect of indirect tax incentives is not obvious.

Table 6
The influence of fiscal policy on technological innovation of IC enterprises in different links.

	Technological innovation			
	(1)	(2)	(3)	(4)
	Subsidies		Tax incentives	
	Support link	Core link	Support link	Core link
Sub	−0.015	−0.034*		
	(−0.30)	(−1.72)		
di-tax			0.025	0.034*
			(0.84)	(1.74)
in-tax			0.217***	0.029
			(4.15)	(0.63)
Size	0.357***	0.116**	0.471***	0.413***
	(5.07)	(2.54)	(5.35)	(6.32)
Age	−0.113	−0.064	−0.058***	−0.019
	(−1.02)	(−0.16)	(−3.08)	(−1.45)
Lev	0.373*	0.633***	0.442**	0.888***
	(1.81)	(2.65)	(2.15)	(3.77)
ROA	1.758***	2.373***	1.508***	1.486***
	(3.59)	(5.53)	(2.97)	(5.17)
_cons	2.245	3.034	0.778	3.330***
	(1.44)	(0.56)	(1.23)	(6.28)
N	205	237	205	237
r2	0.274	0.253	0.617	0.588

Note: t-values are in parentheses;.
* ,.
** , and.
*** represent passing the 10%, 5%, and 1% significance tests, respectively.

A possible reason for the above results is that in developing the IC industry in China, the emphasis on the materials and equipment industry is weaker than on other branches, and most policy tools are ineffective. However, the materials and equipment industry is the weakest supporting link in China's IC industry. Foreign companies have accumulated more patents, and high technical barriers and industrial concentrations exist. Therefore, enterprises in the supporting link need to invest more resources in R&D to complete technology accumulation, so the effect of indirect tax incentives is more obvious. However, for enterprises in the core link, the technology accumulation is relatively weak, the products are in the middle- and low-end links and neither financial subsidies nor tax incentives produce obvious effects.

Regional heterogeneity. From the perspective of regional heterogeneity, there are differences in resource endowment and industrial structure among regions, which bring about different levels of economic development and policy implementation. Simultaneously, the behavioral patterns of enterprises are closely related to the development environment of their regions. For example, in a region with a high level of economic development, enterprises would have a more suitable investment and financing environment, and the government also has sufficient financial resources to support them; thus, enterprises may be better able to achieve technological innovation in this region.

Table 7 reports the impact of financial subsidies (Sub) on the technological innovation of IC companies in different regions. The effect of financial subsidy (Sub) significantly differs between regions and is negative only in the Pearl River Delta region. However, although the coefficient is in the same direction as the overall regression, the significance test fails in other regions. The results show that financial subsidies can inhibit the technological innovation of IC enterprises in the Pearl River Delta region but have no obvious effect on enterprises in other regions. The Pearl River Delta region has the least use of financial subsidies in the sample and is mainly used in the design industry. In the case of insufficient high-end products, financial subsidies have an inhibitory effect on technological innovation. The scale of financial subsidies in the other three regions may create local

Table 7
The impact of financial subsidies on the technological innovation of IC enterprises in different regions.

	Technological innovation			
	(1) Pearl River Delta	(2) Yangtze River Delta	(3) Beijing-Tianjin-Hebei Rim Bohai Sea	(4) Midwest
Sub	−0.110**	−0.049	−0.067	−0.099
	(−2.14)	(−1.12)	(−1.13)	(−1.07)
Size	0.308***	0.262***	0.151	0.116*
	(4.27)	(4.49)	(1.64)	(1.83)
Age	−0.012	−0.094	−0.341	−0.094
	(−0.54)	(−0.86)	(−0.97)	(−0.84)
Lev	−0.934**	0.427*	1.460***	−0.029
	(−2.54)	(1.91)	(2.84)	(−0.13)
ROA	2.140***	1.862***	3.056***	2.332***
	(2.94)	(4.6)	(3.06)	(5.49)
_cons	1.017**	2.581*	6.829	3.728**
	(2.11)	(1.67)	(1.27)	(2.35)
N	69	204	85	185
r2	0.509	0.286	0.364	0.264

Note: t-values are in parentheses;.
* ,
** , and.
*** represent passing the 10%, 5%, and 1% significance tests, respectively.

barriers. The role of financial subsidies attracts enterprises to settle in rather than promote technological innovation, so it has no obvious effect.

Table 8 reports the effect of tax incentives among IC companies in various regions. Table 8 shows that the coefficients of direct tax preference (di-tax) and indirect tax preference (in-tax) are significantly positive in the Yangtze River Delta region and the central and western regions. The indirect tax incentives in the triangular and the central and western regions are more effective. The Pearl River Delta region has no significant tax preference; the Beijing-Tianjin-Hebei Bohai Rim region has a significantly positive direct tax preference (di-tax) and an indirect tax preference (in-tax) that is not significant. These results show that tax incentives significantly promote the technological innovation of IC companies in the Yangtze River Delta, the Beijing-Tianjin-Hebei Rim Bohai Sea, and the central and western regions but have no obvious effect on the Pearl River Delta region. The possible reasons for the above results are that the economic development level of the Yangtze River Delta is higher than that of the central and western regions, and the investment and financing environment of enterprises is more suitable. Hence, the tax incentives have a greater effect. For the Pearl River Delta and the Beijing-Tianjin-Hebei region around the Bohai Sea, the technological R&D investment and total profit in the sample are concentrated in key enterprises, so although the coefficient is consistent with the overall regression in value, it is not significant enough.

Table 8
The impact of tax incentives on the technological innovation of IC enterprises in different regions.

	Technological innovation			
	(1) Pearl River Delta	(2) Yangtze River Delta	(3) Beijing-Tianjin-Hebei Rim Bohai Sea	(4) Midwest
di-tax	0.063	0.088***	0.111**	0.071***
	(1.58)	(3.41)	(2.45)	(3.54)
in-tax	0.086	0.117**	0.071	0.099**
	(0.77)	(2.46)	(0.77)	(2.04)
Size	0.619***	0.241***	0.549***	0.177**
	(5.15)	(3.45)	(3.5)	(2.58)
Age	−0.017	−0.023	−0.026	0.013
	(−0.72)	(−1.54)	(−0.90)	(0.81)
Lev	−0.282	0.482**	1.678***	0.058
	(−0.65)	(2.13)	(3.46)	(0.27)
ROA	1.425*	0.882**	4.461***	1.283***
	(1.76)	(2.45)	(4.59)	(5.12)
_cons	0.518	2.775***	3.412***	3.324***
	(0.36)	(4.61)	(3.66)	(5.52)
N	69	204	85	185
r2	0.853	0.512	0.634	0.558

Note: t-values are in parentheses;.
* ,
** , and.
*** represent passing the 10%, 5%, and 1% significance tests, respectively.

In summary, fiscal policy significantly impacts the technological innovation of IC enterprises, in which fiscal subsidies have a restraining effect and tax incentives have a promoting effect. When government departments formulate fiscal policies, they should consider the "regional barriers" formed by financial subsidies. Attention should also be paid to the different effects of different policy types in different regions and between different industrial chain links. Furthermore, it is necessary to focus on supporting links so that policies can invest more resources. Finally, more resources should be invested in small and medium-sized enterprises to improve the structure of IC enterprises so that China's IC industry can develop in a more competitive environment and continuously innovate.

The moderating effect of fiscal decentralization and market competition on the effect of fiscal policy

Model settings

This study analyzed the regulatory effects of fiscal decentralization and market competition on fiscal policies. Based on this analysis, we set up the following models to examine the regulatory role of fiscal decentralization and market competition:

$$TFP_{i,t} = \omega_0 + \omega_1 Sub_{i,t}(tax_{i,t}) + \omega_2 MP_{i,t}(FD_{i,t}) + \omega_3 Sub_{i,t}(tax_{i,t}) \cdot MP_{i,t}(FD_{i,t}) + \sum_{i=1}^{N} \omega_j X_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (12)$$

The coefficient ω_3 of the multiplication term for policy tools, market competition, and fiscal decentralization requires special attention. If ω_3 is significantly positive, it means that market competition or fiscal decentralization can positively enhance the promotion effect of fiscal policy, and it is easier for enterprises to achieve technological innovation with financial support. If ω_3 is not significant or significantly negative, it means that market competition or fiscal decentralization cannot positively adjust the promotion effect of subsidies and tax incentives on the technological innovation of enterprises.

Empirical results and analysis

Table 9 reports the estimated results of fiscal decentralization moderator variables. In Column (1), the coefficient of Sub·FD, the cross-multiplication item concerned in this study, is significantly negative, indicating that fiscal decentralization inhibits the promotion of financial subsidies to the technological innovation of enterprises—Inhibition of technological innovation. Column (2) shows the moderating effect of fiscal decentralization on tax incentives. Notably, both di-tax·FD and in-tax·FD are significantly negative, indicating that fiscal decentralization will reduce the extent of tax incentives to promote technological innovation. This result is similar to that of Wu (2019): Chinese-style fiscal decentralization cannot achieve the effect of theoretically promoting technological innovation due to the shortsighted behavior of local governments. The autonomy of local governments in economic and political resources aggravates the distortion of factors by financial subsidies. It further magnifies the negative effects of financial subsidies on the technological innovation of enterprises. However, fiscal decentralization also weakens the promotion effect of tax incentives on

Table 9
The adjustment effect of fiscal decentralization on subsidies and tax incentives.

	(1) Subsidies	(2) Tax incentives
Sub·FD	−0.048**	
	(−2.17)	
Sub	−0.006*	
	(−1.67)	
di-tax·FD		−0.546***
		(−2.77)
in-tax·FD		−0.349**
		(−2.26)
di-tax		0.508***
		(3.00)
in-tax		0.408**
		(2.15)
FD	11.376*	13.428*
	(1.85)	(1.81)
Size	0.176***	0.374***
	(4.61)	(7.78)
Age	−0.049***	−0.024**
	(−4.14)	(−2.34)
Lev	0.426***	0.570***
	(2.61)	(3.58)
ROA	1.417***	1.355***
	(6.10)	(5.91)
MP	2.688	−9.071
	(0.69)	(−1.41)
_cons	442.000	442.000
	0.207	0.585

Note: t-values are in parentheses;.
* ,.
** , and.
*** represent passing the 10%, 5%, and 1% significance tests, respectively.

technological innovation, indicating that the funds obtained through tax incentives have not been fully invested in R&D. Instead, funds are used for rent-seeking to obtain additional government support, weakening the enthusiasm for R&D.

Table 10
The regulating effect of market competition on subsidies and tax incentives.

	(1) Subsidies	(2) Tax incentives
Sub·MP	0.333*	
	(1.74)	
di-tax·MP		0.054*
		(1.69)
in-tax·MP		0.029*
		(1.85)
Sub	−0.405**	
	Subsidies	Tax incentives
di-tax		0.056*
		(1.91)
in-tax		0.095**
		(2.27)
Size	0.175***	0.389***
	(4.8)	(7.74)
Age	−0.157	−0.053
	(−1.41)	(−0.48)
Lev	0.481***	0.768***
	(3.02)	(4.84)
ROA	2.106***	2.161***
	(6.15)	(5.79)
MP	−0.025	0.266
	(−0.55)	(0.5)
_cons	4.037***	2.623
	(2.6)	(1.63)
N	442	442
r2	0.233	0.586

Note: t-values are in parentheses.
* ,
** , and.
*** represent passing the 10%, 5%, and 1% significance tests, respectively.

Table 10 reports the estimated results of market competition moderator variables. In Column (1), the coefficient of Sub·MP, the cross-product term that this study focuses on, is significantly positive, indicating that market competition can improve financial subsidies—inhibition of technological innovation. Column (2) shows the moderating effect of market competition on tax incentives. Notably, both di-tax·MP and in-tax·MP are significantly positive, indicating that market competition can increase the extent of tax incentives and promote technological innovation. This result shows that market competition can correct the distortion effect of subsidies to a certain extent. In an environment with high market competition, local governments will distribute financial subsidies to enterprises more fairly. In addition, under the influence of market competition, tax incentives can play a more important role in promoting the technological innovation of enterprises. The reason is that enterprises are more willing to invest in R&D when faced with relatively fierce market competition. With the help of market competition, enterprises can save more technological R&D costs, which makes enterprises invest more resources in R&D under the same conditions, thus forming a virtuous circle.

Research conclusions and policy recommendations

Research conclusions

As a late-developing country, the technological innovation of China's IC industry cannot rely solely on market mechanisms but requires the government to take appropriate intervention measures to promote it. From the perspective of market failure, the public nature, externality, and uncertainty of the IC industry technology, coupled with the close connection between the IC industry and national security, make fiscal policy more appropriate for promoting technological innovation in the IC industry.

From the perspective of policy effect, subsidies are not satisfactory as ex-ante incentives. The main reason is that the local government leads the subsidy to the IC industry, thus forming regional market barriers. When local governments support the IC industry, they do not fully consider their technical level, resource endowment, or market demand, making it challenging to clarify the development direction. To complete relevant political achievements, local governments use subsidies to expand the local IC industry by "poaching" rather than "cultivating." In theory, this idea of "keeping enterprises in the local area" through subsidies can promote the development of the local IC industry in a short period. Still, it has limited improvement in the overall strength of China's IC industry.

Although direct and indirect tax incentives significantly impact the IC industry, their effects are weak. This is because the current tax incentives are all ex post facto resolutions, and enterprises must undertake relevant technological R&D activities before enjoying them. However, the demand for technological R&D investment in the IC industry is relatively high, and companies are prone to losses when they invest large amounts of technological R&D in the early stages. Therefore, large enterprises will weaken their willingness and level of technological R&D investment, while small enterprises cannot compensate for the losses due to the extended return period. Therefore, it will reduce the enthusiasm of enterprises to enter the IC industry, the investment in technology R&D of the entire industry, and hinder the industry from achieving technological innovation.

Notably, fiscal decentralization and market competition can significantly affect the effect of fiscal policy. The study finds that intense regional competition under a decentralized system restricts industrial technological innovation. This is because local governments deviate from low-end manufacturing, resulting in insufficient development of high-end manufacturing and many resources locked in low-end manufacturing. The development of low-skilled labor-intensive industries caused by decentralization has hindered the improvement of the human capital level of the labor force in the non-

agricultural sector, thus forming an important factor restricting the policy from achieving the desired effect. Appropriate market competition can amplify these policies' promotional effects. The market tends to be more competitive so that more disposable funds from enterprises can flow to technological R&D innovation, improving the efficiency of enterprises' allocation of technological R&D funds.

Additionally, the conclusions are significant for developing countries in the early stage of industrialization. This study found that developing countries must rely on fiscal policies to promote industrial development. However, such countries have not yet perfected system construction, and decentralization reform and market mechanisms cannot give full play to the theoretical incentives for policy effects, thus delaying industrial technological innovation and hindering the improvement of national competitiveness. This also explains why many countries worldwide have not crossed the middle-income trap.

Policy recommendations

This study mainly researches the impact of fiscal policy on technological innovation in China's IC industry. It discusses the importance of fiscal policy from the perspective of late-developing countries. Based on China's basic national conditions, this study proposes relevant policy suggestions from the perspectives of financial subsidies, tax incentives, and differences in policy effects.

Formulate a reasonable financial subsidy policy

Financial subsidies are usually implemented as ex-ante subsidies, making it difficult to ensure a fair selection of subsidy recipients and supervise the use of financial funds. In-process subsidies and ex-post incentives should be supplemented based on ex-ante subsidies to improve the promotional effect of financial subsidies on the technological innovation of IC enterprises. Through the subsidy, the government can effectively follow the progress of relevant enterprise projects and arrange the scale and form of the follow-up subsidy according to the project. Through ex-post incentives, the government can meet the capital needs of enterprises for technical reserves and ensure the successful completion of related projects. The combined use of pre- and mid-event subsidies and post-event incentives can enable financial subsidies to run through the enterprise's R&D projects, which can meet the needs of the enterprise's technological R&D process for funds and improve the efficiency of using financial funds.

Optimize existing tax incentives

Tax incentives play a prominent role in promoting the technological innovation of IC enterprises; the effects of direct and indirect tax incentives differ in the mechanism. Cooperation between direct and indirect tax incentives should be strengthened to give full play to the effects of tax incentives, such as the deduction of technological R&D expenses and preferential tax rates to make the policy system more complete. The government can consider improving the calculation method for the super deduction of R&D expenses and appropriately expand the scope of applying the policy. However, the government can consider improving the standards for identifying IC enterprises and appropriately increasing the types of enterprises that can enjoy preferential tax rates, in addition to the items explicitly prohibited by the state, to encourage enterprises to increase R&D investment.

Considering industrial chain and regional coordination

Fiscal policies should consider the coordination between the branches of the industrial chain and regions. The government must implement targeted fiscal policies according to the heterogeneity of industrial chain branches and regional levels. Based on the results, the government should consider the characteristics of different industrial chain branches, increase indirect tax preferential support for supporting enterprises, increase investment in direct tax incentives for core enterprises, moderately reduce the scale of financial subsidies, and establish a performance appraisal of financial subsidies—evaluation methods for improving the promotional effect of financial subsidies. Similarly, the government can consider adjusting the proportion of policy incentives by increasing the scale of tax incentives for enterprises in the Yangtze River Delta or the central and western regions, moderately increasing investment in direct tax incentives for enterprises in the Beijing-Tianjin-Hebei region around the Bohai Sea, appropriately reducing the scale of financial subsidies, or establishing a performance evaluation method for financial subsidies for enterprises in the Pearl River Delta region.

Strengthen inter-regional cooperation to cooperate to promote local government competition

The theoretical analysis and empirical test results show that Chinese-style fiscal decentralization leads to shortsightedness in local governments, weakening the effect of fiscal policy. In order to promote reasonable and appropriate competition among local governments, combined with the experience of developing the IC industry in European countries, it is necessary to strengthen the cooperation in financial expenditure among local governments, and promote competition through cooperation, to achieve the theoretical effect of promoting technological innovation through competition among local governments.

Cooperation among local governments is the basis for existence. Under the central government, promoting the technological innovation of the IC industry is the common goal of all local governments. However, the interests of local governments do not exist independently but are interconnected through political, economic, and geographical factors to form a system of interests. Competition between local governments causes economic efficiency losses, rendering the competition unable to achieve theoretical results. Financial cooperation can improve the overall interests of the region and local government's interests. Therefore, from the perspective of maximizing benefits, local governments can cooperate financially (Crespo & Cabral, 2010).

Fiscal cooperation helps integrate local resources, avoid vicious competition among local governments, and create complementary advantages and win-win cooperation, thereby improving the promotion effect of fiscal policy. Specifically, a coordinated expenditure mechanism between local governments should be established and perfected to integrate the funds of various local governments for rational arrangement and utilization and give play to the guiding role of financial funds. However, cooperative supervision and punishment mechanisms should be established, information technology should be used to build a supervision platform, an open and transparent supervision environment should be established, and a strict accountability mechanism should be established to ensure smooth cooperation among local governments.

Promote the process of marketization in various regions and promote full competition among enterprises

This study examines the regulatory effects of market competition on fiscal policy, arguing that market competition can enhance fiscal policy promotion. Therefore, it is necessary to promote the marketization process in various locations and promote full competition among circuit enterprises. Furthermore, market competition can change the behavioral patterns of enterprises, and fierce competition encourages enterprises to invest in R&D. The 19th National Congress of the Communist Party of China proposed the importance of the marketization of factors. Therefore, the market must play a decisive role in resource allocation by promoting market-oriented reforms to stimulate the progress of industrial technology. At the government level, it should reduce the degree of market intervention, determine the principle of competitive neutrality at the legal level, improve the market access mechanism in terms of policies to build a fairer and

more orderly competitive environment for enterprises and enhance the willingness of enterprises to carry out technology R&D to promote technological innovation in the industry.

Future prospects

This study has made much effort in fiscal policy and industrial technology innovation and obtained some research results with reference values. However, the research has some limitations. First, although this study demonstrates the need to implement fiscal policies from a theoretical analysis, it is biased towards qualitative analysis. It fails to use an appropriate economic mathematical model to examine the significance of fiscal policy in late-developing countries. Second, the empirical research conducted by this study can be improved. Although the heterogeneity and moderating effects of some factors have been examined, the mechanism analysis of policies can continue to be improved and perfected. Finally, owing to the short period of rapid development of China's IC industry, there are limitations to data mining and research timelines.

Based on this study, we can continue examining the effects of fiscal policies on industrial technological innovation. The role mechanism of fiscal policy can be further explored, such as its impact on financing constraints and human capital. However, the impact of updated changes in fiscal policy can be further explored. For example, what are the effects of the updates from Document No. 18 to Document No. 8?

Author contributions

Li Song: Conceptualization, Methodology, Supervision, Investigation, Writing-Review & Editing; Providing critical feedback, shape the analysis and finalize the manuscript.

Yating Wen: Formal analysis, Software, Data Curation, Visualization, Validation.

Declaration of Competing Interest

The authors declare that they have no competing interest.

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