The Effect of Technological Innovation and Market Size on Manufacturing Structure: Evidence from the World's Largest Tobacco Producer and Seller

Song Teng, PhD
Liu Yuxin, PhD

Song Teng, PhD in Industrial innovation & industrial structure, School of Business, Renmin University of China, Beijing, 100872, China. Liu Yuxin, PhD in environmental pollution & green technology, School of Economics and Management, China University of Geosciences (Beijing), Beijing, 100083, China. Correspondence author: Song Teng, songteng2016@ruc.edu.cn

Objectives: As the world's largest tobacco producer and seller, China's rapid development of the tobacco industry is inextricably linked to the promotion and support of the manufacturing industry. The optimization and adjustment of the manufacturing structure (MS) is critical in determining the competitiveness of the manufacturing industry. This study examines the impact of technological innovation and market size on MS optimization in China using provincial data from 2001 to 2016. We obtain the following main results. First, market size and technological innovation are important drivers in optimizing MS. Technological innovation increases productivity and results in the redistribution of production factors across industrial sectors, altering the industrial structure. The market size facilitates labor division, which boosts productivity. Second, institutional innovation is critical for optimizing MS. It strengthens the impact of technological innovation and market size on MS rationalization. Furthermore, the study's findings are robust to a variety of estimation techniques, several alternative proxies for core explanatory variables, and a long list of control variables. An important implication of the study's findings is that the Chinese government should implement effective institutional reforms to accelerate China's manufacturing industry's development. China's tobacco industry, in particular, will achieve higher quality development based on the transformation and upgrading of the overall manufacturing industry.

Keywords: Technological innovation; Market size; Tobacco industry; Manufacturing structure.
Tob Regul Sci.™ 2021;7(5-1): 2422-2444
DOI: doi.org/10.18001/TRS.7.5.1.12

China is the world's largest producer and seller of tobacco, accounting for nearly 45 percent of combustible cigarette sticks produced in 2019, totaling 2.36 trillion sticks. With over 300 million smokers, China accounts for nearly one-third of the world's 1.3 billion tobacco users.[1] The Chinese tobacco industry, which has the highest tax payer proportion in the country—China National Tobacco Corporation (CNTC), which contributes between 7% and 11% of annual tax revenue and is the fourth largest Chinese company in terms of profit—has largely laid the financial groundwork for promoting China's economy and society's stable and rapid development.[2] What is more, the development of the tobacco industry has strong dependence on other related manufacturing industries, as industry competition forces the industry to improve processing quality, and the high-margin tobacco products industry has access to cutting-edge production equipment, manufacturing systems, and software technology.[3] Simultaneously, the material industry, electronic information industry, and intelligent machinery manufacturing play an important role in promoting the development of the tobacco products industry. By and large, China's manufacturing industry has played an important role in promoting the growth of the country's tobacco industry.[4]

China's manufacturing sector has made significant progress in recent decades. Its manufacturing enterprises have consistently accelerated technological innovation and transformation, aided by supportive government policies, and the industry's overall technological level has continued to improve. Despite the fact that China's economy is adjusting to a new normal, its manufacturing industry's industrial structure has been further optimized, and firms' technical innovation capability has been continuously enhanced. However, Chinese manufacturing enterprises remain at the middle and low end of the industrial chain, relying on the import of technologies and equipment. Since the early 2000s, industry sources have emphasized the importance of restructuring the Chinese tobacco sector for CNTC's global competitiveness.[1] Thus, in a country like China, industrial policy is regarded as critical during the structural change process, as it entails a variety of actions aimed at resolving market failure and promoting the redistribution of productive factors from low- to high-productivity activities. Additionally, such policies would aid the Chinese tobacco industry in establishing new competitive advantages in the international market for new innovative tobacco products. In this light, it is critical to strengthen manufacturing enterprises' innovation capacity and optimize the structure of China's manufacturing industry in order to ensure the country's manufacturing industry's long-term development in general and tobacco industry in particular, and to achieve sustained regional development. Additionally, China's large market size, coupled with significant regional disparities in manufacturing development, makes it an ideal sample for empirical testing.

We pursue three objectives in this study. First, we will probe whether technological innovation drives manufacturing structure (MS) upgrading and rationalization in China. Second, to what extent market size impacts the MS optimization in China. Third, how does institutional innovation affect technological innovation and market size in China, thereby affecting the rationalization and advancement of MS?

Innovation and productivity have been recognized as the primary drivers of sustained economic growth, as well as the survival and success of individual businesses.[5,6] At the same time, sustainable economic growth requires the continued healthy industrial development and the upgrading of industrial structures.[6] The restructuring nature of innovation dates all the way back to Schumpeter's famous economic development theory, and the relationship has been studied extensively for a long period of time and can be classified into three categories. First, as supported by endogenous growth theory and creative destruction theory, technological progress aids in improving labor productivity, promoting the flow of production factors among industries, and optimizing production factors and resource allocation, which is referred to as rationalization of manufacturing.[7] Second, industrial structure upgrading refers to the continual transfer of input elements from low- to high-productivity sectors, which needs technological innovation in order to boost overall society's productivity which in turns supports long-term economic growth while optimizing industrial spatial structure and resource usage. Such transformations are inextricably linked to market size, which leads to market expansion and serves as the primary motivator for cultivating enterprises and industries to engage in technological innovation. The third type involves the interaction of technological innovation and industrial structure, that is they are highly correlated and have a multiplicative effect on economic growth.[8,9]

A large number of studies have been conducted in the context of China to examine the effect of technological change on productivity growth,[10] while others have shed light on China's industry structure. Several studies have been conducted to investigate the effect of technological advancements and industrial structure on carbon intensity. While some studies indicate that upgrading and optimizing industrial structures can help reduce carbon intensity in China, and technological advancement is the primary factor. Additionally, a small number of studies concluded that outsourcing plays a critical role in the development of China's manufacturing industry.

However, little attention has been paid in this diverse literature to the role of technological innovation and market size in MS optimization in China. To this end, we aim to fill the gap by making an inquiry about the impact of technological innovation and market size on MS optimization. In doing so, we developed a multiple regression model to empirically test the impact of technological innovation and market size on MS in China using Chinese provincial data from 2001 to 2016. Furthermore, we quantify the mediating effect of institutional innovation on the impact of technological innovation and market size on MS rationalization and advancement from two perspectives: the gradual establishment of the market institution and industry policy support.

Our study's findings indicate that technological innovation and market size both influence MS changes and facilitate MS advancement and rationalization. The technological innovation boosts productivity and causes the redistribution of production factors across industrial sectors, altering the industrial structure. The market size facilitates labor division, which increases productivity. In addition, we discovered that institutional innovation enhances both the effect of technological innovation on MS rationalization and the effect of market size on structural advancement and rationalization. However, institutional innovation does not enhance the role of technological innovation in advancing MS. A significant implication of the study's findings is that the Chinese government should accelerate the development of China's manufacturing industry through effective institutional reforms.

This study has a three-fold contribution to the existing literature. First, it proposes and explains that market size and technological innovation are important factors affecting MS changes. Second, it performed a comparative analysis to empirically ascertain the impact of technological innovation and market size on the MS. Finally, the difference in the influence of technological innovation and market size on the MS was further examined in the context of institutional innovation from two perspectives: the gradual establishment of the market institution and industry policy support.

The remainder of this study is organized as follows: Section 2 contains review of literature, and Section 3 outlines the study's hypothesis, which is based on theoretical analysis. Section 4 describes the research design, determines the model index variables and data sources, and develops a multiple regression model. Section 5 presents the main empirical results, and further goes into greater detail about the impact of technological innovation and market size on the structure of manufacturing in the context of institutional innovation. Finally, Section 6 concludes the study.

LITERATURE REVIEWE

Schumpeter pioneered the theoretical concept of technological innovation in his famous Schumpeter's economic development theory, arguing that the pattern of innovative activity is characterized by 'creative destruction' ,with technological ease of entry and a major role played by entrepreneurs and new firms in innovative activities.The creative destruction theory asserts that innovation is frequently accompanied by the renewal of old industries—that is, the optimization of industrial structure—demonstrating that there is a link between technological innovation and industrial structure. Besides, the labor division theory asserts that market size has an effect on the division of labor because market expansion leads to a deeper division of labor.As the market's size (i.e. the social division of labor) expands, the original industry fragments into more specialized new industries that continue to emerge in the production process, ultimately affecting the evolution of the industrial structure.[11,12]

There is a substantial amount of research available on the role of technological innovation and market size in the evolution of manufacturing structure. For example, a varied and diverse empirical attempt have been made to inquire the effect of technological innovation on industrial structure. Scholars have inquired the relationship between these two variables from different perspective, such as, Production cost,[13,14] leading industry,[15] innovation effect, [16] industrial form, [17]technological progress, [18,19] technology spillovers[20], and so forth. Kuznets[13] demonstrated that technological progress has a supply-side effect on the industrial structure. The underlying reason is that technological advancement reduces producers' production costs and enables resources to be allocated to more rationally, resulting in changes to the industrial structure. Arthur[14] believes that technology is critical to the industrial evolution process. Technological innovation has the potential to reduce business costs, improve product quality, expand the economic effects of the business, and generate increasing returns.

Furthermore, Antonnelli[17] documented that technological change affects the industrial form, which has then a strong impact on the economic structure system. It is primarily due to the fact that the economic sector's production progress rate varies, resulting in disproportional changes in production costs, which results in fluctuations in output, and ultimately, changes in the industrial structure.[18-20] Ngai and Pissarides[21] investigated the rate of technological progress and discovered that while technological advancement promotes industrial upgrading, difference in the rate of technological advancement results in an imbalance in the industrial structure. Luchese[22] found that differences in innovation opportunities and technological characteristics between industries account for differences in the changes in the industrial structure of various countries. What is more, other studies investigated the spillover effects of corporate technology innovation and found that the increasing corporate technology level not only promotes corporate transformation and upgrading, but also drives industry upgrading in which it is located.[20] In a recent study, Ningwu et al[23] discovered that higher levels of education and technological innovation would have a clear technology spillover effect on manufacturing structure optimization.

Besides, changes in industrial structure occur as a result of changes in the relative returns of production factors caused by differences in the efficiency of various industries, resulting in the flow and transfer of production factors within and between industries, thereby causing the expansion or contraction of different industrial sectors. Changes in industrial production efficiency are inextricably linked to social division of labor, which is determined by market size. In his book "The Wealth of Nations," Adam Smith proposed that the fineness of the social division of labor is determined by market size; the finer the social division of labor, the greater the economy of scale and the higher the production efficiency. This is known as the well-known "market scope". The market size expansion results in the deepening of the division of labor, which results in further market size expansion. According to Murphy et al.,[24] the size of market demand and the role of the backward economy in the process of escaping the "poverty trap" are critical due to the increasing return characteristics of modern industry.

In this light, the market size contributes to the industry's competitiveness by encouraging companies to invest heavily in large-scale production equipment, technology development, and productivity enhancement.[25]The market size, particularly the high-end market size, is the primary incentive for cultivating enterprises and industries to engage in technological innovation. Furthermore, the market size has a variety of "gravitational" effects on different production links along the manufacturing value chain, altering a country's position in the global value chain, and as a result, causing the value chain to rise. According to a UNCTAD survey and research on global value chains, market demand is the second most important factor (after factor endowment) affecting a country's participation in global value chains.[26]Likewise, relevant case studies revealed that numerous multinational companies are adjusting their global value chain layout strategies, relocating higher-end activities such as innovation to emerging market economies, and implementing a global strategy known as "reverse innovation".[27]

In summary, concerning the impact of technological innovation and market size on MS, existing research has focused on technological innovation as the core driving force that affects the changes in the MS. Relatively few studies have been conducted on structural impact, whereas more research has focused on market size. Market size is one of the many factors affecting the structural changes of the manufacturing industry, from an indirect perspective. At the same time, a few scholars tried attempted to link technological innovation and technological diffusion in order to study the common impact of the two on the industrial structure. There is a degree of correlation exists between technological diffusion and market size. However, technological diffusion is not proportional to market size and is difficult to quantify. Based on a review of the existing research, this study hypothesizes that technological innovation and market size are important factors affecting the MS evolution. Moreover, this study introduces the elements of institutional innovation through the development of a unified theoretical framework, and it examines the comparative influence of technological innovation and market size on the evolution of China's MS.

REAEARCH HYPOTHESIS

We begin by discussing the impact of technological innovation on the manufacturing industry's structure. Technological innovation encompasses the entire process of developing new product and process, from concept to research and development to initial commercialization.[28] The industrialization process in various countries demonstrates that enterprise technological innovation is the primary motivation and prerequisite for upgrading industrial structure, and it is critical for enterprise innovation institution to function effectively. As a micro-organization of the industry, the enterprise's technological innovation has a cascading effect on the industrial structure's upgrading. The industry's technological innovation is formed by the effective aggregation of enterprise technological innovation, which in turn promotes the industry's development and structural optimization.[29]

In terms of direct impact, technological innovation results in the transformation and innovation of traditional industries by facilitating the flow of production factors between them, resulting in the expansion or contraction of various industrial sectors and promoting the orderly development of the industrial structure. The indirect impact on MS upgrading is that technological innovation creates new market demand, and the new industries that meet the potential and higher-level needs in production and life, resulting in the expansion of new industries.[30] Thus, technological innovation has the potential to influence the demand, supply and trade structures by upgrading existing products, compensating for insufficient supply in bottleneck sectors, and catching up with developed countries in terms of technology.[31,32] Therefore, it indirectly affects changes in the industrial structure and promote industrial structure rationalization.

Therefore, this study proposes the first hypothesis:

Hypothesis 1: *Technological innovation can simultaneously promote the advancement and the rationalization of the manufacturing structure.*

Second, through industrial agglomeration and vertical specialization, market size has a significant indirect effect on the manufacturing industry's structure. The manufacturing industry benefits the most from economies of scale, and industrial agglomeration is triggered by the effect of market size.[33] Thus, industrial clusters promote complementary and related industries by deepening the division of labor and fostering inter- and intra-industry collaboration. At the same time, the technology diffusion effect generated by industrial agglomeration's technological relevance plays a key role in industrial upgrading.[34] Market size also serves as a catalyst for enterprises to specialize vertically. Moreover, vertical division of labor contributes to the improvement of industrial chain efficiency. This is beneficial for upgrading MS in developed countries, however, in case of developing countries it is likely to have a limited impact on the upgrading of MS. The underlying reason is that developed countries take the lead in occupying the high value-added links of the global value chain and mastering their production, effectively 'locking in' developing countries in low value-added industrial links, resulting in the sluggish technological progress and development in developing countries. Participation in vertical specialization of industries enables the country to achieve MS rationalization, but at the risk of losing the opportunity to establish its own MS.

Therefore, we propose the second hypothesis:

Hypothesis 2: *Market size can promote the rationalization but not the advancement of the manufacturing structure.*

The Role of Institutional Innovation on the Impact of Market Size

The growth of market size has boosted the demand for new institutional arrangements, and the combination of specific market sizes and specific institutional arrangements results in a variety of profits and costs associated with institutional adoption. As market size expands, new institutional arrangements are established more quickly, and market size exerts a greater influence on the manufacturing industry's structure. From the perspective of new institutional economics, both institutional and technological innovation are forms of innovation process that differ from one another. Institutional innovation focuses on lowering production transaction costs, whereas technological innovation focuses on lowering direct production costs. Institutional innovation benefits by lowering market transaction costs and industry entry costs, thereby increasing the proportion of enterprises that outsourced intermediate products. Thus, it improves vertical specialization level of enterprises, thereby promoting further market size expansion.

The Mediating Role of Institutional Innovation on Technological Innovation Effect

Davis and North[35] asserts that existing laws and institutional arrangements influence both the formation and 'pregnancy' of innovation. That is, if laws are amended or basic institutional arrangements are made prior to the adoption of innovation, the innovation 'pregnancy period' will be extended. There is manifestation that institutional innovation influences technological innovation, that advanced institutional choices promote technological innovation, and that lagging institutional design limits technological innovation or hinders the improvement of innovation efficiency.[36] The neo-classical school of technological innovation believes that technological innovation is similar to other commodities in that it involves public goods, innovation gains and non-exclusiveness, externalities and other market failures. Thus, both appropriate government and institutional innovation will have a significant impact on technological innovation.[37]

Technological innovation requires the support and assurance of institutional innovation during the course of industrial evolution. This is reflected in the following two aspects: First, an effective institutional arrangement can direct and stimulate technological innovation, effectively promotes technological innovation, application, and popularization; second, institutional innovation can define the scope of an enterprise's resources and environment choices, thereby reducing uncertainty associated with technological innovation.[38] In addition, technological innovation is a primary driver of industrial evolution, while institutional innovation lags behind but it is critical to industrial development. This shows that, at different stages of industrial development, technological and institutional innovation have different requirements, and may involve different modes of interaction and collaboration. In terms of their interaction, as the level of enterprise production technology improves, so does the enterprise production management system, and technological innovation also triggers institutional innovation. The advanced enterprise management institution ensures institutional innovation, and their interaction accelerates industrial structure upgrading.[39]

Therefore, this study puts forward the third hypothesis:

Hypothesis 3: *The impact of technological innovation on the MS is related to institutional innovation.*

The greater the degree of institutional innovation, the greater the impact of technological innovation on the MS. Moreover, the impact of market size on the MS is related to institutional innovation: the higher the institutional innovation, the more obvious the influence of market size on the structure of the manufacturing industry.

REAEARCH DESIGN AND DATA SOURCE

Model Setting

This study conducts regression analysis on the impact of technological innovation and market size on the rationalization and advancement of MS, as well as compares and analyses the difference in the impact of technological innovation and market size on MS optimization. We constructed an empirical regression model based on the existing analysis to test the impact of technological innovation and market size on the MS, as well as the factors that affect the optimization of the MS, including urbanization level, transportation infrastructure, and FDI. The advanced and rationalized MS represents distinct dimensions in the evolution of the MS; consequently, the corresponding influencing factors are distinct. As a result of the two terms' dissimilar connotations, this study selects the level of urbanization, transportation infrastructure, FDI and market. Moreover, the degree of openness is used as the control variable to analyze the influence of the advanced MS. Other control variables to analyze the MS rationalization includes the level of urbanization, transportation infrastructure, FDI, the development of the tertiary industry and the population size. The econometric model is constructed as follows, with models (1) and (2) investigating the impact of technological innovation on the advancement and rationalization of the MS, respectively, and models (3) and (4) investigating the impact of market size on the advancement and rationalization of the MS.

$$strh_{jt} = c_j + v_t + \alpha_1 \cdot tec_{jt} + \alpha_2 \cdot urban_{jt} + \alpha_3 \cdot open_{jt} + \alpha_4 \cdot \ln pgdp_{jt} + \alpha_5 \cdot trans_{jt} + \alpha_6 \cdot fdi_{jt} + \mu_{jt} \tag{1}$$

$$strc_{jt} = c_j + v_t + \beta_1 \cdot tec_{jt} + \beta_2 \cdot urban_{jt} + \beta_3 \cdot ser_{jt} + \beta_4 \cdot \ln pop_{jt} + \beta_5 \cdot trans_{jt} + \beta_6 \cdot fdi_{jt} + \mu_{jt} \tag{2}$$

$$strh_{jt} = c_j + v_t + \omega_1 \cdot scale_{jt} + \omega_2 \cdot urban_{jt} + \omega_3 \cdot open_{jt} + \omega_4 \cdot \ln pgdp_{jt} + \omega_5 \cdot trans_{jt} + \omega_6 \cdot fdi_{jt} + \mu_{jt} \tag{3}$$

$$strc_{jt} = c_j + v_t + \lambda_1 \cdot scale_{jt} + \lambda_2 \cdot urban_{jt} + \lambda_3 \cdot ser_{jt} + \lambda_4 \cdot \ln pop_{jt} + \lambda_5 \cdot trans_{jt} + \lambda_6 \cdot fdi_{jt} + \mu_{jt} \tag{4}$$

j is the j^{th} province, and t represents time in Year, α, β, ω and λ is the estimated parameter, c_j is the individual effect, v_t is the time effect and μ_{jt} is the error term.

Given that the impact of technological innovation and market size on the MS may be subject to institutional innovation, this study introduces the interaction between institutional innovation and technological innovation, as well as interaction between institutional innovation and market size.

The item examines the regulatory effect of institutional innovation on technological innovation and market size in relation to MS. The institutional environment influences both the driving effect of technological innovation and the pulling effect of market size on the MS. To compare the influence of technological innovation and market size on the MS under the condition of institutional innovation, we introduce the interaction term of institutional innovation and technological innovation（$tec_{jt} \cdot insti_{jt}$）in model (1) and model (2) to derive model (5) and model (6). Likewise, the interaction term of the institutional innovation and market size（$scale_{jt} \cdot insti_{jt}$）are introduced in models (3) and (4) to derive models (7) and (8).

Models (5) and (6) examine the impact of technological innovation under the conditions of institutional innovation on the advancement and rationalization of MS.

$$strh_{jt} = c_j + v_t + \alpha_1 \cdot tec_{jt} + \alpha_2 \cdot urban_{jt} + \alpha_3 \cdot open_{jt} + \alpha_4 \cdot \ln pgdp_{jt} + \alpha_5 \cdot trans_{jt} + \alpha_6 \cdot fdi_{jt} + \alpha_7 \cdot insti_{jt} + \alpha_8 \cdot (tec_{jt} \cdot insti_{jt}) + \mu_{jt} \tag{5}$$

$$strc_{jt} = c_j + v_t + \beta_1 \cdot tec_{jt} + \beta_2 \cdot urban_{jt} + \beta_3 \cdot ser_{jt} + \beta_4 \cdot \ln pop_{jt} + \beta_5 \cdot trans_{jt} + \beta_6 \cdot fdi_{jt} + \beta_7 \cdot insti_{jt} + \beta_8 \cdot (tec_{jt} \cdot insti_{jt}) + \mu_{jt} \tag{6}$$

Models (7) and (8) examine the impact of market size under the condition of institutional innovation on the advancement and rationalization of MS.

$$strh_{jt} = c_j + v_t + \omega_1 \cdot scale_{jt} + \omega_2 \cdot urban_{jt} + \omega_3 \cdot open_{jt} + \omega_4 \cdot \ln pgdp_{jt} + \omega_5 \cdot trans_{jt} + \omega_6 \cdot fdi_{jt} + \omega_7 \cdot insti_{jt} + \omega_8 \cdot (scale_{jt} \cdot insti_{jt}) + \mu_{jt} \tag{7}$$

$$strc_{jt} = c_j + v_t + \lambda_1 \cdot scale_{jt} + \lambda_2 \cdot urban_{jt} + \lambda_3 \cdot ser_{jt} + \lambda_4 \cdot \ln pop_{jt} + \lambda_5 \cdot trans_{jt} + \lambda_6 \cdot fdi_{jt} + \lambda_7 \cdot insti_{jt} + \lambda_8 \cdot (scale_{jt} \cdot insti_{jt}) + \mu_{jt} \quad (8)$$

Explained Variable

Advanced indicators of industrial structure

Industrial structure advancement can be measured by (1) intercepting different time points for vertical comparison and (2) selecting reference countries or regions for horizontal comparison. The main methods include the standard structure method, the similarity coefficient method, the high-tech industry proportion method, the softening degree judgement method, and the high-processing proportion method. This study chooses the high-tech industry proportion method based on data availability and the research characteristics to measure the evolution of the industrial structure. This study combines high-end and mid-to high-end technology industries based on the Organization for Economic Cooperation and Development's classification of manufacturing industries and R&D intensity data published by the National Bureau of Statistics of China.

Moreover, we categorize manufacturing industries as high-end, mid-end and low-end technology industries (see Table 1). Transportation, general equipment, special equipment, electrical machinery, electronic communications, instrumentation, chemical fiber and pharmaceutical manufacturing are all considered high-tech industries to measure the advanced structure of China's manufacturing industry. The advanced industrial structure is typically quantified using output value or value-added data. Due to insufficient output value and value-added data, industrial sales output value, to some extent, reflect the level of added value of industry products and the industry's status in the entire MS. This study replaces industrial sales output value with the output value to measure the advanced changes in the MS, which is calculated as follows:

strh = Industrial sales output value of high-end technology industries/Manufacturing industry sales output value (9)

where, *strh* represents the advancement of the industrial structure.

Table 1. Manufacturing industry classification.

High-end technology industry
General equipment, special equipment, transportation, electrical machinery and equipment, communication electronics
Instruments and metres, cultural office machinery, chemical and pharmaceutical industries
Mid- and low-end technology industry
Petrochemical, coking and nuclear fuel processing industries, rubber, plastics, non-metal products,
Ferrous metal smelting, non-ferrous metal smelting and metal products industries
Food processing and manufacturing, beverages, tobacco, textiles, clothing, leather, wood, furniture, study,
Printing and sports supplies and other manufacturing

Source: Compiled by the authors.

Indicators for rationalization of industrial structure

Different methods for measuring the rationalization of industrial structure have their own set of advantages and disadvantages. From the perspective of the connotation of industrial structure rationalization, it is more appropriate to measure industrial structure rationalization using the degree of industrial structure deviation, more specifically the Theil index. The term "rationalization of industrial structure" refers to an industrial structure that maintains the dynamic balance of each industry's ecological scale while maintaining a high degree of industrial coordination, structural aggregation quality and resource allocation. Therefore, the degree of structural deviation is used in this study to assess the level of industrial structure rationalization.

$$\text{strc} = \sum_i^n |(Q_i/L_i)/(Q/L) - 1| \quad (10)$$

where, *Strc* measures the degree of deviation of the MS, Q represents the industrial sales output value of the manufacturing industry, *L* represents the number of employees in the manufacturing industry, *i* represents the i-th industry and *n* represents the number of manufacturing industries. There is a negative correlation between the rationalization level of MS and the value of manufacturing deviation. What is more, when the economy is in a state of equilibrium, the production factors such as labor and capital have no essential difference and other production factors can flow freely. Moreover, there is no difference in labor productivity between industries; that is, the ratio of industry output value is equal to the industry employment ratio. The degree is 0, and the production factors among manufacturing industries are optimally allocated. However, due to the unique characteristics of capital and the long-term characteristics of labor skills, labor and capital cannot be completely exchanged, and thus the value cannot be zero; for countries with a low degree of marketization, factor mobility is low. Its value may be larger, and the problem of economic deviation from equilibrium will be more visible.

Explanatory Variables

Technical innovation indicators

The level of technological innovation can be measured from both input and output perspectives. R&D and patent data are commonly used metrics. R&D data measures enterprise innovation activities from the input side and its primary advantage is that data from enterprises is easy to obtain, and data is additive.[40]However, different industries and enterprises define and classify R&D activities differently. It is difficult to compare R&D data horizontally. Second, R&D data only records clearly defined formal R&D activities; it does not consider informal R&D and innovation. In contrast, patent data is a measure of technological innovation capability from the output side. Despite the possibility of errors, patent data can provide a relatively stable, objective and easy comparable metric for technological innovation activities.[41]As Griliches pointed out, ‘patent statistics provide the only source in the process of technological change’. No other data can compare to patents in terms of data quality, availability and detailed industry organizational and technical details.[42] In this light, this study selects the number of domestic patent applications granted to measure the level of technological innovation.

Market size indicators

The local market size in economics refers to the market capacity of a country or region. One of its fundamental characteristics is the country's (region's) population size and GDP scale.[43] The total population is frequently used in transnational empirical studies to represent the domestic market size, but this variable is not suitable for describing the regional market size of each province. The degree of urbanization and marketisation varies greatly across provinces due to significant differences in per capita income. Therefore, the total income (expressed in terms of gross regional product) is more reasonable to measure the market size.

Institutional innovation indicators

The foundation of industrial innovation and the premise of enterprise innovation is institutional innovation. A good institution can effectively stimulate the vitality of enterprise innovation. The most visible manifestation of institutional innovation is market performance, and it serves as a guarantee of technological innovation. Institutional innovation is a spontaneous activity undertaken by parties in economic activities in response to profit opportunities. The most intuitive manifestation of a region’s institutional innovation’s effectiveness is the region’s non-profit activity. The degree of activity in a country’s state-owned and non-state-owned economy is the primary driver of innovation. To some extent, the proportion of non-state-owned economy in a region’s total economic volume reflects regional difference in institutional innovation. In general, the greater the region's ownership of non-state economy, the greater the region's institutional innovation. In addition, during the transition period, the diversification of the property rights institution is mainly manifested in denationalization of macroeconomic components. The denationalization reform of the economic component is concentrated in the industrial field; therefore, this study measures institutional innovation using the proportion of non-state-owned industrial enterprises' main business income relative to all industrial enterprises in the region. The specific calculation method is as follows:

Institutional Innovation Index = 1 − (main business income of state-owned and state-controlled industrial enterprises/main business income of all industrial enterprises) (11)

As, there is no item of "main business income" in the statistical yearbook from 2000 to 2004, and therefore "product sales income" is used instead.

Sample Indicators and Data Sources

Table 2 lists the variables used in this paper, including their names and explanations. While a detailed description of control; variables is given in Appendix A. The third column of Table 2 details the numerical calculation of the variables.

Table 2. Index selection and numerical calculation.

Variable	Variable name and explanation	Numeral calculations
Explained variable	Advancement of MS（strh）	The sales output value of high-tech industry accounts for the proportion of the total sales output value of the manufacturing industry
	Rationalization of MS（strc）	The sum of the absolute value of the deviation between the per capita industrial sales output value of each industry and the whole industry
Explanatory variables	Technological innovation（tech）	Number of domestic patent applications granted (items)
	Market size（scale）	Regional gross national product (yuan)
	Institutional innovation（insti）	The proportion of the main business income of non-state-owned industrial enterprises in the main business income of all industrial enterprises
Control variable	Urbanisation level（urban）	The proportion of urban population in total population
	Transport infrastructure（trans）	Road mileage per square kilometre (km/km^2)
	Foreign direct investment（fdi）	Foreign capital of industrial enterprises above designated size (100 million yuan)
	Market openness（open）	The proportion of total import and export in GDP
	The level of economic development（pgdp）	Regional GDP per capita (100 million yuan)
	The development of the tertiary industry（ser）	The proportion of tertiary industry in GDP
	Population size（pop）	Total area population (person)

Source: Compiled by the authors.

The data sample of this study cover 26 provinces (cities) of Mainland China from 2001 to 2016, excluding Ningxia, Qinghai, Hainan, Tibet and Xinjiang. The original data is sourced from following databases: the National Bureau of Statistics of China, Historical ‘China Industrial Statistical Yearbook’, ‘China Statistical Yearbook’, and ‘China Demographic Yearbook’. As Ningxia, Qinghai, Hainan, and Tibet accounted for a negligible portion of the national industrial output value. While the data for Xinjiang Autonomous Region were incomplete in the majority of years. Therefore, these regions were excluded from the sample consideration.

EMPIRICAL ANALYSIS

Statistical analysis of indicator variables

Descriptive Analysis

Table 3. Descriptive analysis of main variables.

Var Name	Obs	Mean	SD	Min	Median	Max
strh	364	0.360	0.158	0.060	0.350	0.750
strc	364	28.020	47.838	3.280	13.640	454.900
*ln*tech	364	9.070	1.436	5.984	8.975	12.465
*ln*scale	364	9.240	0.897	7.026	9.303	11.300
insti	364	0.580	0.201	0.153	0.597	0.904
urban	364	0.490	0.174	0.149	0.476	0.896
trans	364	0.850	0.506	0.066	0.801	2.524
fdi	364	0.040	0.039	0.006	0.024	0.183
open	364	0.360	0.413	0.032	0.131	1.721
*ln*pgdp	364	0.870	0.800	1.204	0.959	2.469
ser	364	0.440	0.088	0.298	0.421	0.823
*ln*pop	364	2.120	0.065	1.933	2.125	2.231

Source: Calculated by the authors.

Table 3 reports the descriptive statistics for the study’s main variables. The average and median values of the MS advancement index (strh) are 0.360, and 0.350, respectively, indicating a relatively stable level of MS advancement in each province. The standard deviation is 0.16, indicating that MS advancement varies significantly across provinces and time periods. The average value of the MS rationalization index (strc) is 28.02, the median is 13.64 and the standard deviation is 47.84, indicating that the level of MS rationalization varies significantly across provinces. The result could be attributed to the large fluctuation in the output of individual industries (most notably petroleum processing, coking and nuclear fuel processing industries) in individual years caused by local government policies. However, the proportion of corresponding data is very small and has no effect on the overall analysis. In addition, the mean and median of technological innovation (lntech) and market size (lnscale) are close, their standard deviations are quite different. The standard deviation of technological innovation (lntech) is 1.436, whereas the standard deviation of market size (lnscale) is 0.897, indicating that market size fluctuation in each province is more significant than technological innovation fluctuation. The mean value of institutional innovation (insti) is 0.580, the median is 0.597 and the standard deviation is 0.201, indicating institutional innovation varies significantly across provinces.

MS advancement and rationalization across Chinese provinces (cities)

Figure 1 shows the manufacturing industry’s structural advancement index the by province. The comparison in the figure shows that the higher the manufacturing advanced index, the higher the economic aggregate and the faster the economic development of the provinces and cities. With few exceptions, the MS's high-level index has been increasing throughout the study period. This is closely related to Beijing’s—which serves as the country's political, economic, and technological hub—recent vigorous development of intelligent manufacturing and elimination of backward industries; Chongqing is an important growth engine in western China. In the case of Chongqing, continuous industrial structure optimization has steadily increased the proportion of high-end technology manufacturing in total manufacturing volume in recent years, which has contributed significantly to regional economic growth.

Meanwhile, Guangdong and Jiangsu are China's economic powerhouses, ranked first and second respectively. Moreover, Jiangsu's economic aggregate has grown faster than Guangdong in recent years; indicating a trend of outpacing. Jiangsu's high-level MS is steadily rising while Guangdong recorded a downward trend this year. Furthermore, the MS of Yunnan, Inner Mongolia, Gansu, Shanxi, Hebei, and other regions has been low in high-level China's economic growth, which highlights the regions' lack of economic growth to some extent. Notably, the manufacturing structural advancement index for Fujian, Shaanxi, Tianjin and Heilongjiang has declined significantly, reflecting the enormous differences in the industrial structure adjustment of various provinces in China.

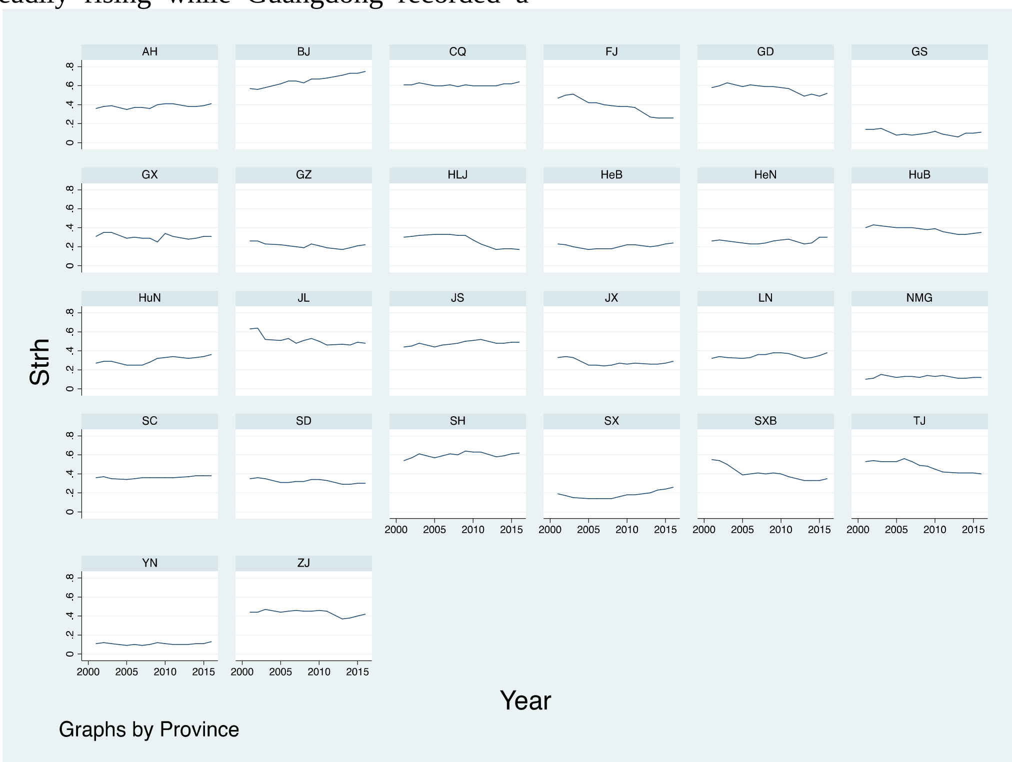

Fig 1. Advancement of the manufacturing structure at the provincial level in China.

Note: Abbreviations in figure, AH- Anhui, BJ- Beijing, CQ- Chongqing, FJ- Fujian, GD- Guangdong, GS- Gansu, GX- Guangxi, GZ- Guizhou, HLJ- Heilongjiang, HEB - Hebei, HEN - Henan, HUB - Hubei, HUN - Hunan, JL- Jilin, JS- Jiangsu, JX- Jiangxi, LN- Liaoning, NMG- Inner Mongolia, SC- Sichuan, SD- Shandong, SH- Shanghai, SX- Shanxi, SXB- Shaanxi, TJ- Tianjin, YN- Yunnan, ZJ- Zhejiang

The MS rationalization index for each Chinese province is depicted in Figure 2, which is calculated as the sum of each industry's deviations from the average manufacturing level. The deviation index of industrial structure varies greatly due to the distribution of manufacturing in different provinces. Overall, the degree of MS rationalization in each province decreased after 2010. That is, the internal adjustment of each province's MS began to speed up. Among them, Guangdong's MS adjustment is relatively modest, whereas Jiangsu's economic aggregate is second only to Guangdong's in terms of industrial structure differentiation. This also highlights the greater intensity of internal adjustment of Jiangsu's MS, followed by Chongqing, Beijing, Guizhou, Shandong and Tianjin. Since 2010, Zhejiang's MS has had significant internal differentiation, resulting in a significant increase in the MS deviation index.

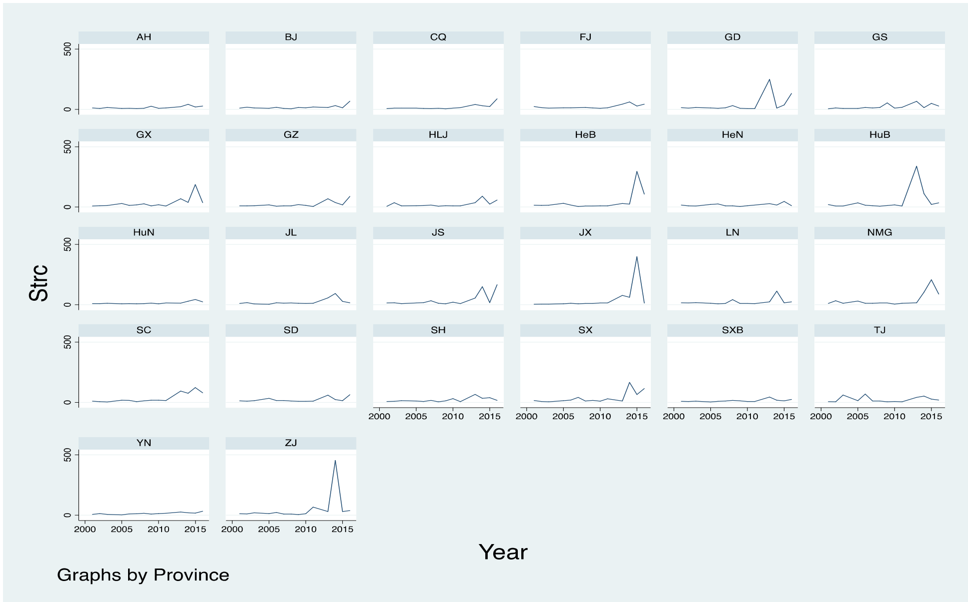

Fig 2. The rationalization of the manufacturing structure at the provincial level in China.

Estimation Results and Analysis

This study makes use of balanced short-panel data. First, the LSDV test determines the significance of the majority most individual dummy variables. Therefore, the null hypothesis of 'all individual dummy variables are '0' is rejected. That is, the sample has individual effects and should be selected using fixed-effect or random-effect model. The LM test strongly rejects the null hypothesis that there are no individual random effects; that is, random effect should be chosen over pooled OLS. Finally, the Hausman test result shows the fixed-effect model outperforms the random-effect model. Therefore, this study uses a fixed-effect regression model to estimate the impact of technological innovation and market size on the advancement and rationalization of MS, and results are given in Table 4 columns (1) and (2).

The results show that all scale coefficients are significantly positive at 1% level, implying that technological innovation and market size promote MS advancement. Subsequently, we added control variables, transportation infrastructure and FDI, (see Columns (3)–(4)) and discovered that the coefficients of technological innovation and market size on the advanced MS are still significantly positive. This demonstrates that technological innovation and market expansion are conducive to MS advancement, which is consistent with the assumptions in Hypothesis 1 and 2 that technological innovation and market size promotes the MS advancement. For other control variables, the extent to which a country open to the outside world plays a significant role in promoting MS advancement, indicating the positive role of foreign trade in promoting MS upgrade of developing countries.

Furthermore, the regression results show that the transportation infrastructure contributes to MS advancement as well. The comprehensive transportation infrastructure ensures the flow of production factors from middle- and low-end manufacturing with low production efficiency to high-end manufacturing with higher production efficiency, thereby promoting MS advancement. At the same time, FDI brings capital, advanced technology and other factors of production to the host country's manufacturing industry development, thereby contributing significantly to host country's higher-level MS; however, the process of urbanization has harmed the host country's higher-level MS due to the following reasons: (1) an increase in the labor force lowers labor costs, which promotes the development of low-end labor-intensive manufacturing, thereby reducing the proportion of high-end technology manufacturing in the entire manufacturing industry; and(2) the real estate industry is booming, resulting in a crowding-out effect on investment in high-end technology manufacturing.

Table 4. Basic model regression results (advancement)

	(1)	(2)	(3)	(4)
	strh	strh	strh	strh
*ln*tech	0.027***		0.023***	
	(4.25)		(3.73)	
*ln*scale		0.138***		0.196***
		(3.43)		(4.79)
urban	−0.118**	−0.140**	−0.119**	−0.143**
	(−2.08)	(−2.42)	(−2.09)	(−2.55)
open	0.081***	0.092***	0.049***	0.061***
	(4.50)	(4.83)	(2.68)	(3.29)
*ln*pgdp	−0.038***	−0.139***	−0.036***	−0.200***
	(−3.04)	(−3.35)	(−3.04)	(−4.83)
trans			0.032**	0.031**
			(2.48)	(2.44)
fdi			0.812***	1.083***
			(4.80)	(6.14)
cons	0.174***	−0.758**	0.153***	−1.306***
	(3.28)	(−2.27)	(2.89)	(−3.81)
Fixed effect	Yes	Yes	Yes	Yes
Adj R-squared	0.944	0.943	0.948	0.950
N	364	364	364	364

Note: The numbers in parentheses are T values and ***, ** and * are significant at the levels of 1%, 5% and 10%, respectively

Second, this study uses fixed-effect model to estimates the impact of technological innovation and market size on the MS rationalization, as shown in Table 5 in columns. The results indicate that technological innovation and market size both have significant positive coefficients at 1% and 5% levels, respectively, implying that that technological innovation and market size are both factors that promote MS rationalization. These results are consistent with the assumptions in Hypothesis 1 and 2 that technological innovation and market size promote the MS rationalization.

We then added additional control variables; for example, when FDI is included, the MS rationalization coefficients remain significant. For other control variables, the increasing share of the tertiary industry in the national economy contributes significantly to MS rationalization. The special producer service industry is closely related to the manufacturing industry in numerous ways, including finance, logistics and transportations as well as technical services. The development of the manufacturing industry provides intermediary service support, which greatly facilitates the free flow and reallocation of production factor resources among various industries within the manufacturing industry, and plays a key role in promoting MS rationalization. Simultaneously, the regression results show that transportation infrastructure constrains MS rationalization, which is related to the unbalanced development of industries in large countries' rapid economic development. The relatively large gap in the relative income between industries in the manufacturing industry results in the transfer of production factors and resources among various industries in the process of rapid economic development of large countries. Superior transportation infrastructure accelerates the transfer and redistribution of production factors between industries, causing differentiation of development and, ultimately, an imbalance between the manufacturing industries.

Table 5. Basic model regression results (rationalization).

	(1)	(2)	(3)	(4)
	strc	strc	strc	strc
*ln*tech	18.099***		21.888***	
	(3.18)		(3.69)	
*ln*scale		20.699**		25.011**
		(1.99)		(2.30)
urban	−15.375	4.750	33.055	40.935
	(−0.30)	(0.07)	(0.61)	(0.61)
ser	187.450**	245.183***	194.733**	257.131***
	(2.16)	(2.89)	(2.25)	(3.01)
*ln*pop	−517.008	−499.165	−424.075	−420.737
	(−1.41)	(−1.33)	(−1.07)	(−1.05)
trans			−37.267**	−28.929*
			(−2.32)	(−1.81)
fdi			−11.316	5.857
			(−0.05)	(0.03)
cons	886.406	786.586	660.158	581.795
	(1.17)	(1.02)	(0.80)	(0.69)
Fixed effect	Yes	Yes	Yes	Yes
Adj R-squared	0.153	0.138	0.162	0.141
N	364	364	364	364

Note: The numbers in parentheses are T values, and ***, **, and * are significant at the levels of 1%, 5% and 10%, respectively

Robustness Test

We conduct robustness tests on the following two aspects to ensure the reliability of the research findings. We modify the measurement of the main explanatory variables. To ensure the reliability of the results, we use the regional GDP calculated by the expenditure method rather than the regional GDP using production method to measure the regional market size. At the same time, we use the number of domestic utility model patent applications rather than the number of domestic patent applications to measure the level of technological innovation.

The fixed-effect model is used for model estimation, and the regression results are listed in columns (1) and (2) of Table 6 and columns (1) and (2) of Table 7. The technological innovation and market size coefficient are significantly positive for advancement (rationalization) at the 5% (1%) and 1% (5%) significance level, respectively. Even after adjusting the methodology for calculating technological innovation and market size, the study's hypothesis remains valid, namely that technological innovation and market size promote not only the MS advancement but also MS rationalization. This shows that the results of this study are robust. The explained variables were subjected to a 5% bilateral tailing. We discovered a significant difference between the maximum value and the minimum value of the explained variable in the original sample through additional observation (see Table 3). To avoid the impact of potential outliers, this study treated the explained variables with a 5% bilateral tailing treatment, and re-estimated them using a fixed-effect model. The regression results in columns (3) and (4) of Table 6 and columns (3) and (4) of Table 7 show that the significance of each variable and the sign of the coefficient have remained relatively stable and have not changed substantially. This confirms the robustness of the study's findings.

Table 6. Robustness test (advancement).

	(1)	(2)	(3)	(4)
	strh	strh	strh	strh
variable	change the measure of variable		bilateral tail reduction 5%	
*ln*tech	0.015**		0.017***	
	(2.50)		(2.89)	
*ln*scale		0.178***		0.085**
		(4.47)		(2.20)
urban	−0.122**	−0.141**	−0.113**	−0.125**
	(−2.13)	(−2.50)	(−2.14)	(−2.34)
open	0.048**	0.059***	0.064***	0.067***
	(2.57)	(3.16)	(3.76)	(3.80)
*ln*pgdp	−0.025**	−0.183***	−0.030***	−0.092**
	(−2.12)	(−4.51)	(−2.68)	(−2.35)
trans	0.036***	0.032**	0.032***	0.035***
	(2.71)	(2.50)	(2.59)	(2.84)
fdi	0.852***	1.049***	0.673***	0.791***
	(4.96)	(5.97)	(4.27)	(4.73)

cons	0.228***	−1.155***	0.204***	−0.379
	(4.77)	(−3.46)	(4.14)	(−1.17)
Fixed effect	Yes	Yes	Yes	Yes
Adj R-squared	0.947	0.949	0.952	0.952
N	364	364	364	364

Note: The numbers in parentheses are T values, and ***, **, and * are significant at the levels of 1%, 5% and 10%, respectively

Table 7. Robustness test (rationalization).

	(1)	(2)	(3)	(4)
	strc	strc	strc	strc
variable	change the measure of variable		bilateral tail reduction 5%	
*ln*tech	25.521***		13.120***	
	(4.44)		(5.05)	
*ln*scale		24.582**		21.710***
		(2.27)		(4.59)
urban	13.430	42.801	22.759	−4.421
	(0.25)	(0.64)	(0.95)	(−0.15)
ser	163.571*	257.918***	151.873***	170.561***
	(1.89)	(3.02)	(4.00)	(4.59)
*ln*pop	−512.983	−415.697	−295.239*	−319.151*
	(−1.30)	(−1.03)	(−1.70)	(−1.82)
trans	−40.346**	−28.861*	−21.265***	−18.432***
	(−2.54)	(−1.80)	(−3.03)	(−2.65)
fdi	63.484	3.708	27.290	62.859
	(0.30)	(0.02)	(0.30)	(0.67)
_cons	853.334	573.955	469.892	440.325
	(1.03)	(0.68)	(1.29)	(1.20)
Fixed effect	Yes	Yes	Yes	Yes
Adj R-squared	0.176	0.141	0.314	0.305

N	364	364	364	364

Note: The numbers in parentheses are T values, and ***, **, and * are significant at the levels of 1%, 5% and 10%, respectively

Mediating Effects of Institutional Innovation

The previous section looked at how technological innovation and market size effects on MS. Given that the impact of technological innovation and market size on the MS may be subject to institutional innovation, we introduce the interaction of institutional innovation with both technological innovation and market size. Columns (1) to (4) of Table 8 contain the regression results for the moderating effect. The interaction term of technological innovation and institutional innovation（$tec_{jt} \cdot insti_{jt}$） is added to formula (1), and formula (5) is constructed. The results are estimated using a fixed-effect model which are listed in column (1) of Table 8. The regression results show that neither the coefficient of technological innovation nor the coefficient of the interaction term between technological innovation and institutional innovation are significant, indicating that institutional innovation has had no effect on the effect of technological innovation on MS advancement. At the same time, formula (7) is constructed using formula (3), plus the interaction term of market size and institutional innovation（$tec_{jt} \cdot insti_{jt}$）, and the fixed-effect model is used for estimation. The estimated results are listed in column (2) of Table 8. The regression results show that the market size coefficient and the interaction term（$scale_{jt} \cdot insti_{jt}$） coefficient of the market size and institutional innovation are significantly positive at the 1% level, indicating that the institutional innovation has strengthened the market.

In addition, formula (6) adds the interaction term（$tec_{jt} \cdot insti_{jt}$） to formula (2) to construct the result, and estimates using the fixed-effect model to estimate. The estimated results are listed in column (3) of Table 8. The regression results show that the coefficient of technological innovation is positive but not significant, whereas the coefficient of technological innovation and institutional innovation is significantly positive at the 1% level, manifesting that institutional innovation has augmented the influence of technological innovation on the rational structure of the manufacturing industry. In formula (8), we add the interaction term（$scale_{jt} \cdot insti_{jt}$） of market size and institutional innovation to formula (4). Estimation is performed using the fixed-effect model, and results are listed in column (4) of Table 8. The regression results show that the market size coefficient is positive but not significant, whereas the market size and institutional innovation coefficient is significantly positive at 1% level, indicating that institutional innovation has strengthened the influence of market size on MS rationalization.

This study hypothesizes that institutional innovation can boost the effect of technological innovation on MS rationalization. There are two main aspects: (1) the gradual establishment of the market system; and (2) industry policy support. The dominant position of market allocation of resources has become increasingly prominent in China's transition from a planned economy to a market economy, effectively promoting the technology spillover effect caused by technological innovation and thereby narrowing the labor productivity gap between different manufacturing industries.

Table 8. The influence of technological innovation and market size on MS under the condition of institutional innovation.

	(1) strh	(3) strh	(2) strc	(4) strc
	Formula (5)	Formula (7)	Formula (6)	Formula (8)
*ln*tech	0.011		6.277	
	(0.92)		(0.67)	
*ln*scale		0.149***		11.262

		(3.41)		(0.75)
urban	−0.159***	−0.191***		
	(−2.64)	(−3.33)		
open	0.061***	0.076***		
	(3.19)	(4.02)		
lnpgdp	−0.006	−0.152***		
	(−0.32)	(−3.26)		
ser			175.972**	190.213**
			(2.03)	(2.19)
*ln*pop			−284.853	−515.518
			(−0.67)	(−1.16)
trans	0.033**	0.023*	−45.367***	−41.546**
	(2.45)	(1.77)	(−2.74)	(−2.53)
fdi	0.912***	1.191***	98.265	221.293
	(5.15)	(6.70)	(0.46)	(1.00)
insti	−0.166	−0.404***	−192.983**	−527.927***
	(−1.60)	(−3.17)	(−2.08)	(−3.33)
*ln*tech_insti	0.009		25.183**	
	(0.89)		(2.24)	
*ln*scale_insti		0.038***		56.516***
		(2.79)		(3.31)
cons	0.299***	−0.869**	488.241	958.506
	(2.89)	(−2.32)	(0.56)	(1.06)
Fixed effect	Yes	Yes	Yes	Yes
Adj R-squared	0.949	0.951	0.169	0.164
N	364	364	364	364

Note. The numbers in parentheses are T values, and ***, **, and * are significant at the levels of 1%, 5% and 10%, respectively.

The application and diffusion of technological innovation are inextricably linked to the government's industrial policy support. From a social welfare standpoint, the government has issued policies to support the backward industrial sectors, which helps to rationalize the MS. This study believes that institutional innovation can be explained from the perspective of transaction costs while strengthening the market size to advance and rationalize the MS. The expansion of the market size results in a further deepening of the manufacturing industry's labor division, which improves industrial production efficiency and strengthens industrial linkages. At the same time, it will also lead to an increase in transaction costs.

Institutional innovation will assist in lowering market transaction and industry entry costs, thereby promoting enterprise professional development and advancing and rationalizing the industrial structure. Regarding the failure of institutional innovation to amplify the impact of technological innovation on MS advancement, this study believes that one possible reason is the absence of intellectual property protection laws and policies. On the one hand, as emerging countries develop the property rights institution and regulations gradually improve, but institutional innovation lags behind, making advanced technological innovation insufficiently stimulated. On the other hand, in order to maximize the social welfare improvement brought by technological innovation and to promote the technological spillover effect of new technologies on multiple industries, property rights and patents enforcement are also more relaxed in developing countries.

CONCLUSIONS

The manufacturing industry's competitiveness and sustainable development are becoming increasingly important for a country's economic development in the global context of a new round of technological revolution and industrial transformation. The key to sustainable development, as well as the enhancement and possibility of manufacturing competitiveness, is the optimization and adjustment of the manufacturing structure (MS). This study examines the impact of technological innovation and market size on the optimization of MS using Chinese provincial data from 2001 to 2016. The findings reveal that technological innovation and market size are both important factors influencing MS changes. Technological innovation promotes the MS advancement and has a positive impact on its rationalization; market size has a similar effect on manufacturing. Moreover, both the advancement and rationalization of the industry structure are beneficial to promotion. This implies that market size and technological innovation are important drivers of MS optimization. The former encourages the division of labor in order to achieve production specialization, which then results in industrial changes, affecting the MS's optimization while the latter facilitates labor division, which boosts productivity and the factors of production are transferred between industries.

Furthermore, we discovered that institutional innovation boosted the effect of technological innovation on the rationalization but not on MS advancement. While, the institutional innovation boosted the effect of market size as well. This demonstrated the critical role of institutional innovation in optimizing MS of developing countries like China. In contrast to developed countries, developing countries will implement effective institutional reforms in response to economic development needs. This has also been the case throughout this century, and it has played a significant role in the rapid development of China's manufacturing industry. In addition, we re-tests the robustness of the research hypothesis by changing the measurement method of the core explanatory variables and the double-tailed regression method of the explained variables. The robustness check results confirm the validity the study's conclusions.

As the world's largest producer and seller of tobacco, China should inspire enterprise through innovation and expand the market to promote the development of manufacturing industry, as well as provide industry support for the development of tobacco industry. At the same time, China should implement corresponding system innovation to boost manufacturing industry's overall competitiveness in general and tobacco industry in particular.

This study contributes theoretically to the existing literature on the factors that influence MS optimization. It also serves as a theoretical reference for the developing countries' manufacturing industry's policies aimed at promoting development, which has both theoretical and practical implications. Despite its contributions, this study has several limitations. The research sample is small due to data availability, with only 16 years data for 26 Chinese provinces. Thus, the selection of typical cases in developing countries must be expanded in the future. More research and discussion in related fields, such as sample acquisition and changes in the manufacturing industry's internal structure.

Supplementary Materials: NA.

Funding

This research is not being funded by any tobacco-related organization.

Data Availability Statement

Data is available with corresponding and can be demanded on request.

Acknowledgments: NA.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

Control variables

The level of urbanization

The process of global urbanization has facilitated the division and reorganization of global industries, resulting in the acceleration of industrialization, and particularly coordinated agglomeration of modern emerging industries. A specialized labor division and agglomeration economy have increased the level of production technology complexity and innovation capabilities, thereby forming a strong driving force for industrial upgrading.[44] Simultaneously, urbanization promotes the rapid development and coordinated agglomeration of modern service industries, as well as industrial upgrading and also provide a broad space for industrial development. At the same time, urbanization requires continuous industrial support and promotion of organic integration, industrial structure adjustment, strategic emerging industry development and service industry upgrades. Therefore, we select the proportion of the urban population in the total population of the region to measure the amount of change in accordance with the practice of most literatures.

Transportation infrastructure

The status of industrial structure upgrading is dependents on whether a country's infrastructure has been improved. Infrastructure plays a critical role in the modernization of a country's industrial structure. A province benefits from convenient transportation, attracts significant external investment, and allows for the easy formation of industrial clusters, all of which contribute to the upgrading of the local industrial structure. The quality of a region's infrastructure can significantly reduce transportation costs, allowing industries with increasing returns to scale to grow more rapidly in the region.

Foreign direct investment

Foreign direct investment (FDI) improves the host country's investment structure by improving assets and resource governance. Simultaneously, technology spillovers and transfers are used to raise the technological level of the host country's manufacturing industry. Moreover, FDI contributes to increased labor remuneration, narrowing the income distribution gap and increasing per capita income, thereby altering the consumption structure to some extent.Here, we choose the actual use of foreign investment as a percentage of regional GDP to measure this variable.

Degree of opening to the outside world

The degree of openness to the outside world affects the MS in two ways. One is to promote the transformation and upgrading of domestic manufacturing production processes, as well as the development of emerging industries, through the import of advanced foreign production equipment and technologies; moreover, the MS advancement is promoted. The other is to expand export demand in order to better allocate production factor resources within the manufacturing industry, thereby achieving the MS upgradation. Therefore, we select the proportion of total import and export in regional GDP to measure this variable in accordance with the practice of most literatures.

The level of economic development

Along with technological progress, Chenery believes that economic development stage has a significant effect on manufacturing structure, and Kuznets uses per capita GDP to measure the level of economic development when comparing economic growth between countries. We chose per capita GDP to measure the level of economic development in accordance with the practice of most literatures.

The development of the tertiary industry

With the improvement of the manufacturing industry's service level, the tertiary industry, particularly the producer service industry, plays an important role in promoting the development of the manufacturing industry. To this end, this study uses the proportion of the tertiary industry in the regional GDP to gauge the development of the tertiary industry.

Population size

The optimization of the MS is a process of continuous replacement and development of factor-intensive industries. Countries and regions with abundant supply of labor resources prioritize the development of labor-intensive industries. This type of human resource endowment advantage, to some extent, promote the development of manufacturing scale. However, being locked in the low value-added industrial chain is easy, making the realization of the synchronized and coupled development of the industry difficult. Here, we choose the region's total population to measure the size of the regional population.

References

1. Fang, J. , K. Lee , and N. Sejpal . The China National Tobacco Corporation: From domestic to global dragon? Global Public Health, 2017; 12.3(4):315-334.
2. Han, Y. An analysis of tobacco industry's contribution to government revenue. China Tobacco. 2013. Retrieved from http://www.echinatobacco.com/zhongguoyancao/2013-09/01/content_416175.htm
3. Jun, Jungmi. Social Response to the FDA Authorization of Heated Tobacco Products (HTPs). Tobacco Regulatory Science, 2020; 6(1): 20-29.
4. Hiler, Marzena, et al. Are Urine Propylene Glycol or Vegetable Glycerin Markers of E-cigarette Use or Abstinence? Tobacco Regulatory Science, 2020; 6(4):235-241.
5. Sun Y, Li L, Shi H, Chong D. The transformation and upgrade of China's manufacturing industry in Industry 4.0 era. Systems Research and Behavioral Science. 2020 37(4):734-40.
6. Preissl B. The German Service Gap Or: Re-Organising The Manufacturing—Services Puzzle. Metroeconomica. 2007 58(3):457-78.
7. Romer PM. Endogenous technological change. Journal of political Economy. 1990;98(5, Part 2):S71-102.
8. Symeonidis, G. Innovation, Firm Size and Market Structure: Schumpeterian Hypotheses and Some New Themes. OECD Eco. Dept. Work. Pap, 1996.
9. Tsai KH, Wang JC. R&D productivity and the spillover effects of high-tech industry on the traditional manufacturing sector: the case of Taiwan. World Economy. 2004;27(10):1555-70.
10. Laurenceson J, O'Donnell C. New estimates and a decomposition of provincial productivity change in China. China Economic Review. 2014 1;30:86-97.
11. Murphy KM, Shleifer A, Vishny R. Income distribution, market size, and industrialization. The Quarterly Journal of Economics. 1989 Aug 1;104(3):537-64.
12. Amiti M, Khandelwal AK. Import competition and quality upgrading. Review of Economics and Statistics. 2013;95(2):476-90.
13. Kuznets, S.; & Murphy, J.T. Modern economic growth: Rate, structure, and spread. New Haven: Yale University Press, 1966; 33(3):475-476
14. Arthur WB. Competing technologies, increasing returns, and lock-in by historical events. The economic journal. 1989 Mar 1;99(394):116-31.
15. Rostow WW. The stages of economic growth: A non-communist manifesto. Cambridge university press; 1990.
16. Gerhard, Rosegger. The economics of production and innovation: an industrial perspective. Techn. and Cult., 1984; 25.
17. Antonelli C. Localized technological change and factor markets: Constraints and inducements to innovation. Structural Change and Economic Dynamics. 2006;17(2):224-47.
18. Acemoglu D, Guerrieri V. Capital deepening and nonbalanced economic growth. Journal of political Economy. 2008;116(3):467-98.
19. Susskind RE, Susskind D. The future of the professions: How technology will transform the work of human experts. Oxford University Press, USA; 2015.
20. Mrabet Z, Lanouar C. Trade liberalization, technology import and skill upgrading in Tunisian manufacturing industries: A dynamic estimation. African Journal of Economic and Management Studies. 2013.
21. Ngai LR, Pissarides CA. Structural change in a multisector model of growth. American economic review. 2007;97(1):429-43.
22. Lucchese M. Innovation, demand and structural change in Europe. 2011.
23. Ning, W. A., & Zkl, B. Higher education development, technological innovation and industrial structure upgrade. Tech. Forec. and Soc. Chang, 2021; 162: 120400
24. Murphy KM, Shleifer A, Vishny R. Income distribution, market size, and industrialization. The Quarterly Journal of Economics. 1989 Aug 1;104(3):537-64.
25. Porter, M. E. Competitive advantage of nations: creating and sustaining superior performance. Simon and Schuster, 2011.
26. UNCTAD. World Investment Report 2013： Global Value-Chains： Investment and Trade for Development. United Nations Conference on Trade and Development.
27. Jones CI. Intermediate goods and weak links in the theory of economic development. American Economic Journal: Macroeconomics. 2011;3(2):1-28.
28. Gürbüz E. Theory of new product development and its applications. Marketing. 2018 :57-75.
29. Zhao, Huifang.; Niu, Shanshan.; Xu, Sheng.; & Yang, Changhui. Industrial structure upgrading of China's manufacturing industry based on technological innovation. Journal of Hefei University of Technology Natural Science Edition, 2008; 31(9): 1485-1488.
30. Zhao, Yulin.; & Pei, Chengchen. Technological innovation, industrial convergence and manufacturing trans-formation and upgrading. Sci and Tech Pro and Count, 2019; 36(11): 70-76.
31. Jiang H, Zhao S, Zhang Y, Chen Y. The cooperative effect between technology standardization and industrial technology innovation based on Newtonian mechanics. Information Technology and Management. 2012 Dec;13(4):251-62.
32. Zhuang, W.; Gong, Y. Industrial Technology Innovation [M]. Oriental Publishing Center, 2005; 94
33. Krugman P. Scale economies, product differentiation, and the pattern of trade. The American Economic Review. 1980;70(5):950-9.

34. Boschma R. Relatedness as driver of regional diversification: A research agenda. Regional Studies. 2017;51(3):351-64.
35. Davis LE, North DC, Smorodin C. Institutional change and American economic growth. CUP Archive; 1971.
36. Zhao, Yue. Research on the Evolution of China's Furniture Industry Driven by Technological Innovation and Institu-tional Innovation. Northeast Forestry University, 2018.
37. Peng, J.L.; & Li, J.P. Research Progress and Development Trend of Technological Innovation Theory in China and Foreign Countries (Reform Dissertation), 2006.
38. Murmann, J. P. Knowledge and competitive advantage, 2003.
39. Jacobsson, S.; Oskarsson, C.; & Philipson, J. Indicators of technological activities—comparing educational, patent and R & D statistics in the case of Sweden. Research Policy, 1996; 25(4): 573-585.
40. Xu, Changsheng.; Wang, Jingjing.; Wang, Hai, et al. Competition degree, market size and innovation: An empirical study based on simultaneous equation model in China [J]. Journal of Huazhong University of Science and Technol-ogy (Social Science Edition), 2008; 22(4):59-64.
41. Griliches, Z. Patent statistics as economic indicators: a survey. In R&D and productivity: the econometric evidence. University of Chicago Press, 1998; 287-343.
42. Alesina, A.; Spolaore, E.; & Wacziarg, R. Trade, growth and the size of countries. In Handbook of economic growth, 2005; 1: 1499-1542. Elsevier.
43. Zhang, Songxin.; Gong, Jianli.; Wang, Feirong. An empirical analysis of the impact of industrial innovation on energy intensity: A case study of Zhejiang Province. Technological Economics and Management Research, 2006; 06:28-29.
44. Kolko, J. Urbanization, agglomeration, and co-agglomeration of service industries. In Agglomeration eco-nomics, University of Chicago Press, 2010; 151-180