Innovation, the Flying Geese Model, IPR Protection, and Sustainable Economic Development in China

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Abstract: China has achieved an “economic miracle” with 40 years of continual high-speed growth and the simultaneous realization of global innovation prowess. In this study, a large panel dataset from 1985 to 2017 was used in an effort to explore how innovation (at the enterprise level), the flying geese model (at the global and national level), and intellectual property rights (IPR) protection (at the governmental level) have facilitated China’s sustainable economic development (SED). We employed ridge regression to compensate for the obvious multicollinearity among independent variables. For control purposes, we included multiple variables, namely, population, the labor force, the exchange rate, human capital, and research and development (R&D) expenditures. The results show that all three factors have significant explanatory power for China’s SED. First, either Total domestic patent applications or Total domestic patent grants by Chinese enterprises have overtaken those by their foreign counterparts and become a powerful engine for China’s SED. However, we understand that patent applications as a measure of innovation could overestimate China’s innovation capability more than patent grants. Second, the flying geese model can explain not only China’s SED but also China’s innovation diffusion at the global and national levels. From 1985 to 1992, China’s industrialization and innovation were mainly driven endogenously; from 1993 to 2008, they were simultaneously driven exogenously and endogenously. Since 2009, they have gradually become predominantly endogenously driven. Third, China’s IPR protection has grown increasingly tighter at the governmental level, which has further facilitated China’s SED. About 98.5% (annually) of patent infringement disputes through the administrative protection system could be closed promptly between 2014 and 2017. Additionally, the proportion of infringed patent rights holders from foreign countries has been declining in recent years. The results significantly enrich the extant theories, and the analysis also has several key implications for actions that should be taken to maintain China’s sustainable economic growth; specifically, China should (1) keep its opening-up policy so as to continually expand exports and attract foreign direct investment (FDI); (2) encourage innovation activities from domestic enterprises since they have been the stimulus of China’s SED; (3) improve its IPR protection system, particularly its judicial protection system, so as to form a virtuous circle of innovation in China.

Keywords: flying geese model; innovation; intellectual property right (IPR); national governance; sustainable economic development (SED)

1. Introduction

In 1978, China initiated its reform toward a market-oriented economy and started opening up to foreign trade and investment. Since then, China has achieved an “economic miracle” [1,2], with its
real annual gross domestic product (GDP) at an average growth rate of 9.5% in 2018 [3]. The World Bank described China’s development as “the fastest sustained expansion by a major economy in history” [4,5]. In 1979, China’s GDP was 367.9 billion yuan (150 billion US dollars, 1.8% of the global GDP, and the 11th economy in the world). The GDP per capita was only 385 yuan (156.4 US dollars). Exports accounted for merely 0.8% of global exports of goods and services (EGS), and global foreign direct investment (FDI) was rare to none. In contrast, in 2018, its GDP had risen to 90,031 billion yuan (13,608 billion US dollars, 15.9% of the global GDP, the second-largest economy), with a per capita GDP of 59,660 yuan (9770.8 US dollars), exports accounting for 10.6% of global EGS (2655.6 billion US dollars), and FDI of 139 billion US dollars [6,7]. China has integrated into the global economy, particularly with China’s entering the WTO in 2001.

Today, China not only is recognized as the world’s factory but also bears the weight of international economic responsibility [8]. It has been “the largest single contributor to world growth” since the global financial crisis of 2008 [4,9], and its contribution accounted for 27.8% of global growth in 2017 [10]. Furthermore, China has consistently moved upward in the rankings of the Global Innovation Index (GII) (from 35th place in 2013 to 14th place in 2019) and has been the only middle-income economy in the top 20 [11]. Its innovation prowess is evident in diverse areas, such as global research and development (R&D) companies, importation of high-tech products, publication quality, and tertiary employment [12]. According to the World Intellectual Property Indicators (WIPI) [13], since 2011, China has been the premium powerhouse of patent applications for eight consecutive years. For example, the China National Intellectual Property Administration (CNIPA) received 1.60 million patent applications in 2018, which is about three times the number (606,956) received by the United States Patent and Trademark Office (USPTO). China’s shares of global patent filing activity rocketed to 44% in 2017 [13].

As the knowledge economy has become increasingly important, China has been ambitious in the development of an “innovation economy”, which has resulted in an increase in both patent applications and grants, as well as tighter IPR protection [14]. Conventional perceptions still hold many stereotypes about China. For example, China is notorious for its “widespread piracy” and poor ability to protect intellectual property rights, and China is thus characterized as “the world’s worst IPR infringer”. China has always been placed on the “Priority Watch List” in the annual special 301 report published by the Office of the United States Trade Representative (USTR) [15]. On 22 March 2018, the US President Donald Trump signed the Memorandum on Actions by the United States Related to the Section 301 Investigation of China’s Laws, Policies, Practices, or Actions Related to Technology Transfer, Intellectual Property, and Innovation, which stated that the US would impose tariffs on imports from China, and took actions to respond to China’s “theft of US intellectual property” [16]. After that, the Sino-US trade war inevitably broke out. The Chinese government denied the “theft” behavior. Although China has witnessed a huge rise in patent litigation in recent years, the majority of the cases are between Chinese partners [10,17]. Former American treasury secretary and economist Larry Summers also claimed that China’s technological progress was coming from “huge government investments in basic science” instead of “theft from the US” [18]. Chinese R&D expenditures formed 24% of the world’s total in 2017, up from a mere 2.6% in 1996. In 2017, R&D investments from the private sector in China accounted for 27% of the world’s total, up from only 2% in 1996 [19].

Economic growth is most commonly measured by gross domestic product (GDP). Affected by both China’s economic growth slowdown since 2012 and the Sino-US trade war, China’s economic growth fell to its slowest pace in the past three decades. It has dropped gradually from 9.54% in 2011, to 6.90 in 2017, and to 6.6% in 2018. Data from the National Bureau of Statistics of China (NBS) show that China’s GDP expanded by 6.3% in the first half of 2019 (6.4% in the first quarter and 6.2% in the second quarter) [7]. Western economists widely doubt “the veracity of the overall Chinese growth figure” because it shows “far more stability than comparable numbers from the United States and elsewhere” [20]. They also started to downgrade their forecasts for China’s economic growth in 2020 to below 6%, which is below “a level seen as necessary for the Communist Party to meet its own goals
in time for its centenary in 2021” [21]. Again, whether China’s economic growth is sustainable in the long run has become a major concern of scholars and academic researchers. In particular, The Coming Collapse of China has been prevailing for more than two decades [22,23]. Barbier [24] and Barbier and Markandya [25] stated that sustainable economic development (SED) has both narrower and wider interpretations: the former is concerned largely with “environmentally sustainable development”, and the latter pertains to “sustainable economic, ecological and social development”. Krongkaew and Zin [26] proposed that, in the future, SED should be characterized by “a reasonable rate” of economic growth, with indicators such as stable prices and satisfactory employment saturation.

Numerous scholars and academic researchers have put forward a long list of factors that may exert an influence on economic growth. As famously stated by Deng Xiaoping, “science and technology are the primary productive force” [27]. With the advent of the knowledge economy in the 21st century, innovation, science, and technology have become the driving force of economic growth. China has achieved great economic success for a prolonged period of time, but it has begun to suffer from an economic growth slowdown in recent years. Scholars have been seeking alternative explanations for China’s economic growth. This study focuses on the effect of innovation on China’s economic performance by using a large panel dataset from 1985 to 2017. Three factors that are closely related to innovation were taken into consideration: innovation factors, flying geese model factors, and IPR protection factors. For control purposes, we also included multiple variables, namely, population, the labor force, the exchange rate, human capital, and R&D expenditures. Answering these questions can help us to understand how China can maintain sustainable economic development. First, the innovative capabilities of China’s industries have gradually changed from imitation to innovation. Domestic patents in China have overwhelmed their foreign counterparts and become a powerful engine for China’s economic growth. Second, the flying geese model (FGM) has facilitated both China’s economic growth and innovation diffusion. In particular, the FGM has enhanced innovation diffusion not only from developed countries to China but also from the Eastern coast to Central and Western China. Third, China’s IPR protection has been increasingly tightened. These are other essential factors that have facilitated China’s sustainable economic development. These findings not only significantly enrich the extant theories but also are useful for other developing and transitional economies.

The rest of this paper is organized as follows: Section 2 is a literature review of related theories. Section 3 presents the research design and hypotheses development, and Section 4 explains our empirical findings. We provide an in-depth discussion in Section 5 and draw conclusions in Section 6.

2. Literature Review

Dillon and Morris [28] argued that “innovations that offer advantages perceived compatibility with existing practices and beliefs, low complexity, potential liability, and observability would have a more widespread and rapid rate of diffusion”. Given that technological change has been proved to be an essential factor of economic growth and that innovation gives rise to technological change, innovation has become “a major determinant” of economic growth and development [29]. The pioneers who suggested a theoretical linkage between innovation and economic growth include Adam Smith (who thought that innovation enhanced the efficiency of labor) [30], Karl Marx (who stressed the direct relationship between technological progress and capitalistic institutions) [31], and Allyn Young (who mentioned the critical role of technological change in economic growth) [32]. In the 1930s, Schumpeter [33–35] started to think of the relationship between industrial innovation and economic growth at a more macro level by emphasizing the “creative destruction” power of innovation and by insisting that economic growth was generated by the “endogenous” introduction of product or process innovations (or both) [29]. Solow [36,37] and Swan [38], however, argued that technical progress was entirely exogenous. They regarded technology and science as key factors of economic growth. On the basis of Schumpeter’s growth theory, Romer [39,40], Lucas [41], Grossman and Helpman [42], Aghion and Howitt [43], Howitt [44], and others developed endogenous growth theory in the 1990s, which regards endogenous technological change as the driving force of economic growth. Afterward,
an abundance of research efforts on endogenous growth theory sparked numerous empirical studies and explored how and to what degree innovation might contribute to economic growth [45].

The aforementioned theories and empirical studies are mainly derived from developed economies or countries. The flying geese model has become one of the theoretical frameworks for explaining “the catching-up process of industrialization in latecomer economies” [46–48]. Since World War II, East Asia has experienced extremely rapid economic development, which created the “East Asian Miracle” described by the World Bank [49–51]. The core of the “miracle” is foreign direct investment (FDI). For those East Asian countries and regions that were either newly industrializing economies (NIEs) or economically backward, the large-scale inflow of FDI exerted a dramatic influence on their economic growth and development. Furthermore, FDI has quickened their steps of modernization and enhanced the level of technology and organizational efficiency of receiving countries, as well [52].

2.1. The Flying Geese Model (FGM) and Sustainable Economic Development (SED) in China

The “East Asian Miracle” started with Japan. Following suit were the NIEs in the 2nd rank (Singapore, South Korea, Chinese Taiwan, and Hong Kong), then the Tiger Cub Economies (TCEs) in the 3rd rank (Malaysia, Indonesia, Thailand, and the Philippines), and Mainland China and Vietnam in the 4th rank [53]. The FGM regards the US as the “leader geese” at the global level and Japan as the leader in Asia, followed by the “follower geese” (in the 2nd, 3rd, and 4th ranks) that developed their economies by “taking on industries passed down from developed countries” [54].

With the launch of the Open Door policy, China’s central government granted power to Guangdong and Fujian provinces to take “special policies and flexible measures” in foreign trade activities for economic development [55]. China also established four special economic zones (SEZs) to attract overseas Chinese investors in 1979. The four SEZs include Zuhai, Shenzhen, Shantou and Xiamen, and they are located southeast coast in proximity to Chinese Macao, Hong Kong and Taiwan [56]. With the massive FDI and a mass influx of migrants from Mainland China, these SEZs achieved rapid economic growth. Therefore, China designated another 14 coastal cities as Economic and Technical Development Zones (ETDZs) in 1984. They are Dalian, Qinhuangdao, Tianjin, Qingdao, Lianyungang, Nantong, Shanghai, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang, and Beihai. In 1985, China opened the Yangtze River Delta, Pearl River Delta, and the Xiamen–Zhanjiang–Quanzhou triangle area in South Fujian, as well as the Bohai Economic Rim (Liaodong Peninsula and Jiaodong Peninsula), to foreign trade and investment. Then, Hainan Province (1988), Pudong New District in Shanghai (1990), Horgos and Kashgar in Xinjiang (2010) were opened in sequence [57].

Owing to the rapidly increasing FDI and international trade, China gradually became the “world’s factory”. Most of the products exported from China were actually made for American, European, Japanese, and Korean companies or produced according to original equipment manufacturer (OEM) agreements [58]. Furthermore, regional developments within China demonstrated the “ladder-step doctrine”. Industrial development transferred from the Eastern coastal region to the Central region and then to the Western region. In other words, China’s industrial upgrade followed the flying geese model [54]. Since 2008, economic growth in Central and Western China has accelerated and helped China effectively avoid the negative impact of the international financial crisis [59].

2.2. Innovation Diffusion (ID) and SED in China

According to the innovation diffusion theory (IDT), innovation diffusion (ID) is a process in which potential adopters imitate the action of adopters [60]. Rogers [61,62] defined innovation as “an idea, practice, or object that is perceived as new by an individual or another unit of adoption”, and it can provide an individual or organization with “a new alternative, as well as with new means for problem-solving”. Diffusion is defined as “the process by which an innovation is communicated through certain channels over time among the members of a social system”.

The conceptual notion of innovation can be applied “far more broadly to consider the spread of ideas and practices” [63]. It has been evidenced to be “a driver of regional economic development”,

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and innovation diffusion is strongly correlated to economic growth [64]. For the correlation between innovation diffusion (ID) and economic growth (EG), there are four hypotheses based on their Granger causality: (1) the supply-leading hypothesis claims that ID Granger causes EG, (2) the demand-following hypothesis holds that EG Granger causes ID, (3) the feedback hypothesis suggests that both ID and EG Granger cause each other, and (4) the neutrality hypothesis holds that both ID and EG are supported by mixed evidence. Some studies have provided mixed evidence and validated all four hypotheses [65].

For a long time, China was a backward agricultural economy with a huge population and a low per capita income. China’s Open Door policy has led China to a deep-level industrialization process by providing “both endogenous and exogenous driving mechanisms” [66]. There are two kinds of national industrialization mode, endogenous and exogenous industrialization. The former relies on “domestic economic growth factors” to drive industrialization, such as entrepreneurial talent, independent technology and free capital accumulation; while the latter relies on “supplies of foreign factors” to drive industrialization, such as FDI [66]. On the one hand, through market-oriented economic reforms and institutional innovations, the traditional socialist planned system was gradually loosened. Diversified domestic driving forces were cultivated, such as the fully released factors of private sectors and the fully mobilized resource of the traditional state-owned system. On the other hand, China also attracted huge amounts of FDI and imported advanced technologies and managerial knowledge by setting up SEZs and ETDZs and joining the World Trade Organization (WTO), among other actions. Supported by a “peaceful and stable” development environment, “unlimited supplies” of low-wage laborers, and a good supporting “productive capacity”, China has developed into an important country for international trade and FDI inflow in the world [66].

2.3. Intellectual Property Rights (IPR) Protection and SED in China

Previously, China had neither a conceptual notion of intellectual property rights (IPR) nor a system for protecting them [67,68]. When China plunged headlong into international trade in 1978, it was the net import country of innovation, technology, intellectual property (IP), and IPR-intensive goods, while the US was the net export country. The US (or the Western countries), which had a well-developed legal system for protecting IPR, accused China of not respecting their IPR and coerced and persuaded China to establish better protection of patents, copyrights, and trademarks [69]. China was compelled to take a series of actions, such as enacting its Trademark Law (passed in 1982, promulgated in 1983), Patent Law (passed in 1984, promulgated in 1985), and Copyright Law (passed in 1990, promulgated in 1991) [70]. From a lack of experience in protecting IPR, China was continually criticized for maintaining poor IPR protection to encourage low-cost imitation [71,72].

A genuine change occurred when China was essentially forced to significantly raise its IPR protection standards so as to join the WTO in 2001. China amended its trademark, patent, and copyright laws in order to comply with the WTO’s Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) [73]. China adjusted its IPR legislation to more closely match the tough minimum standards on protection and enforcement that were accepted by the world’s major trading partners [74]. Since 2008, China has been ambitious in building an “innovation economy” and wanted to transition from manufacturing-based to knowledge-based production [75]. China regarded IPR as a powerful engine for economic growth; thus, it started to morph from passive into active protection and enforcement of IPR [76]. China’s Patent Law was revised in 2008, which signaled its strong desire to enforce IPR protection.

There have always been disputes over IPR issues in developing countries with technological disadvantages. A major argument is that stronger IPR protection stimulates economic growth by protecting innovators from being imitated. Thus, IPR protection enhances innovation capacity and encourages economic growth. In particular, it is vitally important for developing countries to learn foreign technologies, attract FDI, and develop international trade [77]. Conversely, others have argued that strong IPR protection exerted too early does not help developing nations improve their IPR protection levels. Tighter IPR protection is “a necessary but not a sufficient condition” for improving
technological innovation and economic development [78] because costless imitation does not necessarily enhance economic growth in an endogenous growth model. Therefore, “stronger is always better” is not always correct [79].

3. Research Design and Hypotheses Development

This paper aims to provide an in-depth understanding of how innovation and its closely related factors explain China’s sustainable economic development. CNIPA was established and accepted as a World Intellectual Property Organization (WIPO) member in 1980. It initiated the first patent application and grant in 1985 when China’s Patent Law came into force. Given the availability of data, this research examined the period from 1985 to 2017. As the dependent variable, we evaluated China’s sustainable economic development by means of “China’s GDP”. Because it is a scale variable, we applied ordinary least squares (OLS) regression for the purpose of analysis. On the basis of the literature review in Section 2, we selected three groups of explanatory variables for the model: innovation factors, FGM factors, and IPR protection factors. For the purpose of control, we included population, the labor force, the exchange rate, human capital, and R&D expenditures.

With regard to innovation factors, we used items that are highly relevant to innovation prowess, namely, patents. Patents are used to protect inventions, and their quantity is recognized as “a measure of innovative activity” [80]. WIPO [12,19,80] stated that “A ‘patent’ is a set of exclusive rights granted by law to applicants for inventions that are new, non-obvious, and commercially applicable. A patent is valid for a limited period of time (generally 20 years), during which patent holders can commercially exploit their inventions on an exclusive basis. In return, applicants are obliged to disclose their inventions to the public in a manner that enables others, skilled in the art, to replicate the invention. The patent system is designed to encourage innovation by providing innovators with time-limited exclusive legal rights, thus enabling them to appropriate the returns from their innovative activity”. It is the national or regional patent offices that grant patents. The validity of patents is limited to the jurisdiction of the issuing authority [81].

China’s Patent Law recognizes three types of patent rights: inventions, utility models, and industrial designs [69]. The annual China Patent Statistics Yearbook released by CNIPA reports “applications of patents” and “grants of patents” from 1985 to 2017 [82]. Thus, we simply adopted Total patent applications and Total patent grants as the measure of China’s innovative activity. We expect that China’s innovative activity significantly and positively facilitates China’s SED. Additionally, Total patent applications consists of Total domestic patent applications and Total foreign patent applications. Total patent grants is composed of Total domestic patent grants and Total foreign patent grants. Therefore, we developed two hypotheses (H1 and H2) and four sub-hypotheses (H1a, H1b, H2a, and H2b).

Hypothesis 1 (H1): “Total Patent Applications” has a significantly positive association with China’s GDP.

Hypothesis 1a (H1a): “Total Domestic Patent Applications” has a significantly positive association with China’s GDP.

Hypothesis 1b (H1b): “Total Foreign Patent Applications” has a significantly positive association with China’s GDP.

Hypothesis 2 (H2): “Total Patent Grants” has a significantly positive association with China’s GDP.

Hypothesis 2a (H2a): “Total Domestic Patent Grants” has a significantly positive association with China’s GDP.

Hypothesis 2b (H2b): “Total Foreign Patent Grants” has a significantly positive association with China’s GDP.
According to the flying geese model (FGM), “a group of economies advance together because of mutual interactions between countries through demonstration effects, learning and emulation, with the transmission mechanism being flows of people, trade in goods and services, flows of FDI, technology and other TNC-related assets” [83]. In this context, transnational companies (TNCs) play an increasingly important role through non-equity arrangements, joint ventures, or direct investments [84]. FDI may raise the level of industrialization, and an upgraded industrial structure further enhances rapid economic development [85]. Therefore, we expect that the FGM factors are positively associated with China’s SED. These factors include “International trade of goods”, “International trade of services”, and “Foreign direct investment”. We expect that these items all have a significantly positive association with China’s sustainable economic development.

Hypothesis 3a (H3a): “International Trade of Goods” has a significantly positive association with China’s GDP.

Hypothesis 3b (H3b): “International Trade of Services” has a significantly positive association with China’s GDP.

Hypothesis 3c (H3c): “Foreign Direct Investment” has a significantly positive association with China’s GDP.

With respect to IPR protection factors, Rapp and Rozek [86] found a close correlation between economic development and “patent protection”: countries with a tighter patent system undergo much faster economic development. Shen [87] regarded “patent protection” as a measure of China’s IPR protection and found that China’s IPR protection had a significantly positive impact on regional economic growth. Nevertheless, too strong an IPR protection mechanism is not conducive to either higher innovative capability or regional economic growth [87].

In contrast to Western countries’ one-track judicial protection, China’s patent protection has adopted a distinctive “dual-track” system at both administrative and judicial levels [88]. Enterprises are able to select either “judicial protection” or “administrative protection” to protect their own rights [88]. However, the administrative protection system (APS) is more important than the judicial protection system (JPS) because of the former system’s convenience, high efficiency, and time-saving and money-saving characteristics. Administrative protection of IP refers to “the administrative enforcement of law by IP administrative organs when dealing with IP disputes and punishing infringements” [89]. First, through the APS, cases can be filed, prosecuted, and investigated promptly, and their penalty decision could be made within several days, whereas the litigation time through the JPS is long. Second, in China, a patent rights holder may have to deal with hundreds of infringers at the same time, and suing all those infringers through the JPS is rather a heavy burden. The process can be much simpler through the APS, and administrative officers can deal with those disputes in a more flexible manner. Third, judicial punishment for patent rights infringement only provides limited compensation to the owners of those rights. Therefore, many patent rights holders complain that they “win the lawsuit, but lose money”, and “the winner (the rights holder) never wins, the loser (infringer) never loses, and the infringement action is never stopped by punishment” [90].

In 2017, China’s People’s Courts accepted merely 5913 patent infringement cases through the JPS, whereas CNIPA accepted 27,305 patent infringement cases by means of the APS [91,92]. Therefore, we adopted administrative patent protection as an indicator of China’s IPR protection. The “Patent Enforcement of the Administrative Authorities for Patent Affairs” in the annual China Patent Statistics Yearbook recorded both the “Entertained patent infringement disputes” and the “Closed patent infringement disputes” [82]. The two variables are strongly correlated (the correlation efficiency is 0.923). Finally, we chose “Closed patent infringement disputes” as a measure of China’s IPR protection. We expect that China’s IPR protection factors are significantly and positively associated with China’s sustainable economic development.
Hypothesis 4 (H4): “Closed Patent Infringement Disputes” has a significantly positive association with China’s GDP.

The control variables are Population, Total employed persons, Nominal exchange rate, Tertiary education (%), and R&D expenditures (%). First, both classical and neoclassical economic growth theories emphasize the importance of capital and labor [30,36,37]. Howitt [44] found that the long-term economic growth rate is an increasing function of the population growth rate. China has the largest population in the world, with 1.39 billion people at the end of 2018, growing from 1.05 billion in 1985 [7]. Its huge population provides China with a massive number of low-cost laborers, who fuel China’s SED. China also possesses huge numbers of employed laborers. We adopted Total employed persons as a proxy for the labor force, and we expect that both Population and Total employed persons are significantly and positively associated with China’s SED.

Hypothesis 5 (H5): “Population” has a significantly positive association with China’s GDP.

Hypothesis 6 (H6): “Total Employed Persons” has a significantly positive association with China’s GDP.

Second, there are many studies on the relationship between the exchange rate (both real and nominal) and economic growth. The nominal exchange rate can be expressed in bilateral and multilateral term; and the Real exchange rate volatility means the short term fluctuation of the real exchange rate [93]. Theoretically, the exchange rate (either devaluation or depreciation) can enhance economic growth. However, there are controversial views on their relations. He [94] found that the fixed exchange rate policy in China promotes its long-term economic growth. Tang [95] argued that China’s economic growth is stimulated by the expansion of exports and the inflow of FDI; thus, China’s economic growth has not benefited from the depreciation of RMB. We chose Nominal exchange rate as a proxy for the exchange rate, and we expect that Nominal exchange rate is unrelated to China’s SED.

Hypothesis 7 (H7): “Nominal Exchange Rate” (RMB per USD) has no significant impact on China’s GDP.

Third, Zhang and Zhuang [96] examined the effect of human capital on economic growth in China and found that tertiary education plays a more important role than primary and secondary education in China’s economic growth. We selected Tertiary education (%) as a proxy of human capital. This factor represents the net enrolment ration of tertiary education for undergraduates in regular higher education institutions (HEIs), including both normal courses and short-cycle courses. We expect that Tertiary education (%) has a significant and positive impact on China’s GDP.

Hypothesis 8 (H8): “Tertiary Education (%)” has a significantly positive association with China’s GDP.

Finally, R&D provides an impetus for science and technology [52]. Birdsall [97] found a positive correlation between R&D expenditures and economic growth in the Organization for Economic Co-operation and Development (OECD) countries, but no significant correlation was identified between the two variables in developing countries. Goel and Ram [98] found that the effect of R&D expenditures on economic growth appeared “positive and numerically large”, but the statistical significance of the estimate was low. This paper defines R&D expenditures (%) as the ratio between R&D expenditures and GDP. We expect that R&D expenditures (%) has no significant impact on China’s GDP.

Hypothesis 9 (H9): “R&D Expenditures (%)” has no significant impact on China’s GDP.

The detailed information on each variable and their data sources are provided in Appendix A (see Table A1).
4. Empirical Findings

4.1. Descriptive Statistics

Table 1 summarizes the means, standard deviations (SD), and the minimum (Min) and maximum (Max) values of each variable.

<table>
<thead>
<tr>
<th>Abb.</th>
<th>Variables</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>China’s GDP (unit: 10 billion RMB)</td>
<td>33</td>
<td>2280.1</td>
<td>2479.0</td>
<td>91.0</td>
<td>8271.2</td>
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<tr>
<td>TPA</td>
<td>Total patent application (unit: thousand)</td>
<td>33</td>
<td>770.9</td>
<td>1069.6</td>
<td>14.4</td>
<td>3697.8</td>
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<tr>
<td>TDPA</td>
<td>Total domestic patent application (unit: thousand)</td>
<td>33</td>
<td>707.8</td>
<td>1018.3</td>
<td>9.4</td>
<td>3536.3</td>
</tr>
<tr>
<td>TFPA</td>
<td>Total foreign patent application (unit: thousand)</td>
<td>33</td>
<td>63.0</td>
<td>57.7</td>
<td>4.4</td>
<td>161.5</td>
</tr>
<tr>
<td>TPG</td>
<td>Total patent grants (unit: thousand)</td>
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<td>425.4</td>
<td>583.7</td>
<td>0.1</td>
<td>1836.4</td>
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<tr>
<td>TDPG</td>
<td>Total domestic patent grants (unit: thousand)</td>
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<td>388.3</td>
<td>544.6</td>
<td>0.1</td>
<td>1720.8</td>
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<tr>
<td>TFPG</td>
<td>Total foreign patent grants (unit: thousand)</td>
<td>33</td>
<td>37.1</td>
<td>41.0</td>
<td>0.0</td>
<td>124.9</td>
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<tr>
<td>CPID</td>
<td>Closed patent infringement disputes (unit: thousand)</td>
<td>33</td>
<td>2.7</td>
<td>6.0</td>
<td>0.3</td>
<td>27.0</td>
</tr>
<tr>
<td>ITG</td>
<td>International trade of goods (unit: billion USD)</td>
<td>33</td>
<td>1433.3</td>
<td>1541.8</td>
<td>69.6</td>
<td>4301.5</td>
</tr>
<tr>
<td>ITS</td>
<td>International trade of services (unit: billion USD)</td>
<td>33</td>
<td>201.4</td>
<td>228.9</td>
<td>5.2</td>
<td>695.7</td>
</tr>
<tr>
<td>FDI</td>
<td>Foreign direct investment (unit: billion USD)</td>
<td>33</td>
<td>63.2</td>
<td>40.6</td>
<td>4.8</td>
<td>131.0</td>
</tr>
<tr>
<td>POP</td>
<td>Population (unit: million)</td>
<td>33</td>
<td>1250.6</td>
<td>98.7</td>
<td>1051.0</td>
<td>1386.0</td>
</tr>
<tr>
<td>TEP</td>
<td>Total employed persons (unit: million)</td>
<td>33</td>
<td>699.3</td>
<td>85.5</td>
<td>498.7</td>
<td>780.0</td>
</tr>
<tr>
<td>NER</td>
<td>Nominal exchange rate (RMB per USD)</td>
<td>33</td>
<td>6.9</td>
<td>1.5</td>
<td>2.9</td>
<td>8.6</td>
</tr>
<tr>
<td>TE</td>
<td>Tertiary Education (%)</td>
<td>33</td>
<td>16.9</td>
<td>12.9</td>
<td>2.9</td>
<td>45.7</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>R&amp;D Expenditures (%)</td>
<td>33</td>
<td>1.2</td>
<td>0.5</td>
<td>0.6</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Table 2 shows the Pearson correlation matrix of all variables in this study. Apart from the variable Nominal exchange rate, China’s GDP is strongly correlated with the other independent variables. Their correlation coefficients range from 0.677 to 0.996. The correlation coefficients between some independent variables are quite high as well, which implies that multicollinearity must exist among some variables.
Table 2. The Pearson correlations between the variables.

<table>
<thead>
<tr>
<th>No.</th>
<th>Variables</th>
<th>GDP</th>
<th>TPA</th>
<th>TDPA</th>
<th>TFFPA</th>
<th>TPG</th>
<th>TDPG</th>
<th>TFPG</th>
<th>CPID</th>
<th>ITG</th>
<th>ITS</th>
<th>FDI</th>
<th>POP</th>
<th>TEP</th>
<th>NER</th>
<th>TE</th>
<th>R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China's GDP</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Total patent application</td>
<td>0.983 ***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Total domestic patent application</td>
<td>0.979 ***</td>
<td>0.993 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Total foreign patent application</td>
<td>0.953 ***</td>
<td>0.896 ***</td>
<td>0.885 ***</td>
<td>0.986 ***</td>
<td>0.938 ***</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Total patent grants</td>
<td>0.986 ***</td>
<td>0.993 ***</td>
<td>0.992 ***</td>
<td>0.904 ***</td>
<td>0.978 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Total domestic patent grants</td>
<td>0.983 ***</td>
<td>0.993 ***</td>
<td>0.993 ***</td>
<td>0.895 ***</td>
<td>0.978 ***</td>
<td>0.993 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Total foreign patent grants</td>
<td>0.978 ***</td>
<td>0.946 ***</td>
<td>0.939 ***</td>
<td>0.973 ***</td>
<td>0.950 ***</td>
<td>0.956 ***</td>
<td>0.950 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>8</td>
<td>Closed patent infringement disputes</td>
<td>0.772 ***</td>
<td>0.850 ***</td>
<td>0.857 ***</td>
<td>0.624 ***</td>
<td>0.806 ***</td>
<td>0.810 ***</td>
<td>0.712 ***</td>
<td>0.712 ***</td>
<td>0.976 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>9</td>
<td>International trade of goods</td>
<td>0.972 ***</td>
<td>0.926 ***</td>
<td>0.917 ***</td>
<td>0.914 ***</td>
<td>0.941 ***</td>
<td>0.936 ***</td>
<td>0.967 ***</td>
<td>0.617 ***</td>
<td>0.967 ***</td>
<td>0.617 ***</td>
<td>1.000 ***</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>International trade of services</td>
<td>0.996 ***</td>
<td>0.974 ***</td>
<td>0.969 ***</td>
<td>0.959 ***</td>
<td>0.980 ***</td>
<td>0.977 ***</td>
<td>0.978 ***</td>
<td>0.745 ***</td>
<td>0.981 ***</td>
<td>0.745 ***</td>
<td>0.981 ***</td>
<td>1.000 ***</td>
<td></td>
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</tr>
<tr>
<td>11</td>
<td>Foreign direct investment</td>
<td>0.927 ***</td>
<td>0.861 ***</td>
<td>0.851 ***</td>
<td>0.941 ***</td>
<td>0.876 ***</td>
<td>0.869 ***</td>
<td>0.920 ***</td>
<td>0.590 ***</td>
<td>0.931 ***</td>
<td>0.590 ***</td>
<td>0.931 ***</td>
<td>0.925 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Population</td>
<td>0.825 ***</td>
<td>0.740 ***</td>
<td>0.727 ***</td>
<td>0.708 ***</td>
<td>0.760 ***</td>
<td>0.748 ***</td>
<td>0.846 ***</td>
<td>0.486 ***</td>
<td>0.836 ***</td>
<td>0.820 ***</td>
<td>0.946 ***</td>
<td>0.946 ***</td>
<td>0.946 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Total employed persons</td>
<td>0.677 ***</td>
<td>0.579 ***</td>
<td>0.564 ***</td>
<td>0.588 ***</td>
<td>0.577 ***</td>
<td>0.711 ***</td>
<td>0.353 ***</td>
<td>0.698 ***</td>
<td>0.673 ***</td>
<td>0.852 ***</td>
<td>0.963 ***</td>
<td>0.963 ***</td>
<td>0.963 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Nominal exchange rate</td>
<td>−0.004</td>
<td>−0.076</td>
<td>−0.085</td>
<td>−0.083</td>
<td>−0.089</td>
<td>0.004</td>
<td>−0.039</td>
<td>−0.021</td>
<td>−0.022</td>
<td>0.296</td>
<td>0.495 ***</td>
<td>0.647 ***</td>
<td>0.647 ***</td>
<td>1.000 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Tertiary Education (%)</td>
<td>0.976 ***</td>
<td>0.940 ***</td>
<td>0.932 ***</td>
<td>0.982 ***</td>
<td>0.939 ***</td>
<td>0.933 ***</td>
<td>0.977 ***</td>
<td>0.734 ***</td>
<td>0.957 ***</td>
<td>0.973 ***</td>
<td>0.947 ***</td>
<td>0.947 ***</td>
<td>0.947 ***</td>
<td>0.773 ***</td>
<td>0.128</td>
<td>1.000 ***</td>
</tr>
<tr>
<td>16</td>
<td>R&amp;D Expenditures (%)</td>
<td>0.922 ***</td>
<td>0.880 ***</td>
<td>0.871 ***</td>
<td>0.944 ***</td>
<td>0.891 ***</td>
<td>0.884 ***</td>
<td>0.944 ***</td>
<td>0.611 ***</td>
<td>0.939 ***</td>
<td>0.925 ***</td>
<td>0.854 ***</td>
<td>0.777 ***</td>
<td>0.628 ***</td>
<td>−0.113</td>
<td>0.929 ***</td>
<td></td>
</tr>
</tbody>
</table>

Level of Significance: * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001.
4.2. Regression Results

Three groups of variables in the innovation factors are strongly correlated. The correlation efficiency between total patent applications and total patent grants is 0.993, that between Total domestic patent applications and Total domestic patent grants is 0.993, and that between Total foreign patent applications and Total foreign patent grants is 0.972. Therefore, we established four OLS regression models: in M1, Total patent applications is used as a measure of China’s innovation capability; for M2, we chose total patent grants to represent innovation; in M3, the innovation factors consist of Total domestic patent applications and Total foreign patent applications; in M4, the innovation factors include Total domestic patent grants and Total foreign patent grants. Apart from the items in the innovation factors, we selected the same groups of independent and dependent variables in the four models. The variables Population, Total employed persons, Nominal exchange rate, Tertiary Education (%), and R&D Expenditures (%) were controlled.

The variance inflation factors (VIFs) of the four OLS models show that all VIFs of the variables in each model are above 10, which illustrates that multicollinearity among variables is a serious issue in the OLS regression model (the results of the four OLS regressions are shown in Appendix A Table A2). We consider the standard OLS model matrix form for multiple linear regression to be \( Y = X\beta + \epsilon \), and the estimate of \( \beta \) is given by \( \hat{\beta} = (X'X)^{-1}X'Y \) [99]. The multicollinearity among independent variables can cause \( |X'X| \approx 0 \), which may lead to weak estimates [100]. Then, the estimated value \( \hat{\beta} \) of the variance matrix \( D(\hat{\beta}) = \sigma^2(X'X)^{-1} \) with the diagonal elements becomes abnormally large and unstable [101]. Hoerl and Kennard [102] put forward ridge regression to reduce the standard errors by adding a degree of bias to the regression estimates, using \( \hat{\beta}(k) = (X'X + kI)^{-1}X'Y \) instead of \( \hat{\beta} = (X'X)^{-1}X'Y \) for the estimation of the coefficients of a regression model [103], where \( k \) is called the tuning/biasing/ridge parameter [104]. Since \( X'X + kI \) is far less than \( X'X \) in the singular degree, the variance of the estimated value \( \hat{\beta} \) becomes narrow, forming a more stable and reliable estimated result [101]. We can see that when \( k = 0 \), the parameter estimate value \( \hat{\beta}(0) \) is the OLS estimation [105–108]. Thus, we reran the above four models by means of ridge regression. We set the ridge regression parameter, lambda, to range from 0 to 150, and we set its step to 0.01. The ridge tracks (Figure 1) show that the coefficients of the independent variables in each model become stable when lambda is above 100.

Strong correlations between the dependent variable and independent variables are indicated by an R-squared value of around 0.999 in each regression model. In particular, the correlation coefficient between China’s GDP and Total patent application is 0.983; that between China’s GDP and Total patent grants is 0.986; that between China’s GDP and International trade of goods is 0.972; that between China’s GDP and International trade of services is 0.996; that between China’s GDP and Foreign direct investment is 0.927; that between China’s GDP and Population is 0.825; that between China’s GDP and Tertiary Education (%) is 0.976; and that between China’s GDP and R&D Expenditures (%) is 0.922 (see Table 2). The figure of the dependent variable and independent variables from 1985 to 2017 is shown in Figure 2.

The best estimations of the ridge regressions of the four models are reported in Table 3.
Strong correlations between the dependent variable and independent variables are indicated by an R-squared value of around 0.999 in each regression model. In particular, the correlation coefficient between China’s GDP and Total patent application is 0.983; that between China’s GDP and Total patent grants is 0.986; that between China’s GDP and International trade of goods is 0.972; that between China’s GDP and International trade of services is 0.996; that between China’s GDP and Foreign direct investment is 0.927; that between China’s GDP and Population is 0.825; that between China’s GDP and Tertiary Education (%) is 0.976; and that between China’s GDP and R&D Expenditures (%) is 0.922 (see Table 2).

The figure of the dependent variable and independent variables from 1985 to 2017 is shown in Figure 2.

Figure 1. Ridge Tracks: (a) the ridge track of M1, (b) the ridge track of M2, (c) the ridge track of M3, (d) the ridge track of M4.

Figure 2. The dependent variable and independent variables from 1985 to 2017. China’s GDP (unit: 10 billion RMB) corresponds to the black axis; Closed patent infringement disputes (unit: thousand) and Nominal exchange rate (RMB per USD) correspond to the green axis; Tertiary Education (%) and R&D Expenditures (%) correspond to the blue axis; the rest of the variables correspond to the red axis.
Table 3. Ridge regressions of China’s gross domestic product (GDP).

<table>
<thead>
<tr>
<th></th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef. (SE) p-Value</td>
<td>Coef. (SE) p-Value</td>
<td>Coef. (SE) p-Value</td>
<td>Coef. (SE) p-Value</td>
</tr>
<tr>
<td>(constant)</td>
<td>−1716.8</td>
<td>−1582.2</td>
<td>−1901.5</td>
<td>−1558</td>
</tr>
<tr>
<td><strong>Innovation Factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total patent application</td>
<td>0.68 (325.37) *** 0.000</td>
<td>0.68 (3918.47) *** 0.000</td>
<td>0.68 (3918.47) *** 0.000</td>
<td>0.68 (3918.47) *** 0.000</td>
</tr>
<tr>
<td>Total foreign patent application</td>
<td>−1.02 (−333.26) 0.215</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Total patent grants</td>
<td>1.07 (3553.21) *** 0.000</td>
<td>1.1 (3387.74) *** 0.000</td>
<td>1.1 (3387.74) *** 0.000</td>
<td>1.1 (3387.74) *** 0.000</td>
</tr>
<tr>
<td><strong>Flying Geese Model (FGM) Factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>International trade of goods</td>
<td>0.3 (2587.05) *** 0.000</td>
<td>0.33 (2919.98) *** 0.000</td>
<td>0.31 (2738.93) *** 0.000</td>
<td>0.33 (2914.73) *** 0.000</td>
</tr>
<tr>
<td>International trade of services</td>
<td>2.13 (2758.62) *** 0.000</td>
<td>1.98 (2559.4) *** 0.000</td>
<td>2.11 (2728.9) *** 0.000</td>
<td>1.92 (2480.33) *** 0.000</td>
</tr>
<tr>
<td>Foreign direct investment</td>
<td>10.23 (2347.98) *** 0.000</td>
<td>9.32 (2138.77) *** 0.000</td>
<td>10.02 (2300.94) *** 0.000</td>
<td>9.17 (2105.82) *** 0.000</td>
</tr>
<tr>
<td>Intel</td>
<td><strong>lectual Property Rights (IPR) Protection Factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed patent infringement disputes</td>
<td>35.66 (1211.82) *** 0.000</td>
<td>51.77 (1759.2) *** 0.000</td>
<td>34.28 (1164.85) *** 0.000</td>
<td>50.91 (1729.98) *** 0.000</td>
</tr>
<tr>
<td><strong>Control Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>1.81 (1008.56) *** 0.001</td>
<td>1.61 (900.32) ** 0.006</td>
<td>1.91 (1064.57) *** 0.000</td>
<td>1.61 (900.19) * 0.010</td>
</tr>
<tr>
<td>Total employed persons</td>
<td>0.17 (83) 0.757</td>
<td>0.26 (123.56) 0.679</td>
<td>0.27 (131.53) 0.586</td>
<td>0.2 (95.66) 0.761</td>
</tr>
<tr>
<td>Nominal exchange rate</td>
<td>−100.01 (−465.95) *** 0.000</td>
<td>−93.04 (−405.57) *** 0.000</td>
<td>−102.7 (−889.25) *** 0.000</td>
<td>−88.88 (−769.55) ** 0.002</td>
</tr>
<tr>
<td>Tertiary education (%)</td>
<td>7.72 (564.92) + 0.070</td>
<td>11.55 (845.17) * 0.014</td>
<td>12.28 (898.7) *** 0.000</td>
<td>10.71 (783.89) * 0.028</td>
</tr>
<tr>
<td>Research and Development (R&amp;D) expenditures (%)</td>
<td>43.33 (131.89) 0.588</td>
<td>38.78 (118.03) 0.664</td>
<td>70.33 (214.07) 0.349</td>
<td>30.85 (93.9) 0.743</td>
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<td><strong>Regression information</strong></td>
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<tr>
<td>R-squared</td>
<td>0.999 ***</td>
<td>0.999 ***</td>
<td>0.999 ***</td>
<td>0.999 ***</td>
</tr>
<tr>
<td>N</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
</tbody>
</table>

Note: (1) Level of Significance: + p ≤ 0.1, * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001. (2) Entries are unstandardized beta coefficients. Figures in parentheses are standard errors.
With regard to innovation factors, **Total patent applications** is significantly and positively associated with China’s GDP, as we expected (H1) in the first model (M1). This is also the case for **Total patent grants** in the second model (M2), which is consistent with hypothesis 2. In the third model (M3), **Total domestic patent applications** is significantly and positively associated with China’s GDP; thus, H1a is confirmed. However, **Total foreign patent applications** is not, and H1b fails to be accepted. In the fourth model (M4), **Total domestic patent grants** has a significantly positive association with China’s GDP, and H2a is confirmed, but **Total foreign patent grants** is not, and H2b fails to be accepted. Generally, the innovation factors have significant explanatory power for China’s sustainable economic development, although foreign patents (both application and grants) contribute non-significantly to China’s SED.

In terms of the flying geese model (FGM) factors, all the items significantly explain China’s SED. **International trade of goods**, **International trade of services**, and **Foreign direct investment** all have a significantly positive association with China’s GDP in the four models, which meet our expectations (H3a–c). With respect to IPR protection factors, as we expected, **Closed patent infringement disputes** is significantly and positively associated with China’s GDP. Therefore, H4 is accepted in the four models.

The control variables **Population** and **Tertiary Education (%)** are significantly and positively associated with China’s GDP in the four models. Thus, H5 and H8 are confirmed. **Nominal exchange rate** (RMB per USD) is significantly and negatively associated with China’s GDP, which is not our expectation. Higher **Nominal exchange rate** (RMB per USD) means the depreciation of RMB; on the contrary, lower **Nominal exchange rate** (RMB per USD) means the appreciation of RMB. Thus, our findings indicate that the depreciation of RMB has a significant and negative effect on China’s SED. These findings are not consistent with the extant empirical findings, and H7 fails to be accepted. **Total employed persons** and **R&D Expenditures (%)** have no significant explanatory power for China’s SED; thus, H6 fails to be accepted, and H9 is confirmed.

In sum, the innovation factors, FGM factors, and IPR protection factors all have significant explanatory power for China’s sustainable economic development, and the FGM factors and IPR protection factors’ explanatory power are robust in the four models. Because we adopted different items to represent innovation factors, some subtle findings are not among our expectations. For instance, either **Total patent applications** (M1) or **Total patent grants** (M2) have a significantly positive association with China’s GDP. However, when we split patent applications/grants into domestic applications/grants and foreign applications/grants, we find that while both **Total domestic patent applications** (M3) and **Total domestic patent grants** (M4) have significantly positive associations with China’s GDP, neither **Total foreign patent applications** (M3) nor **Total foreign patent grants** (M4) is significantly relevant to China’s GDP. That means that domestic patent applications/grants are a powerful engine for China’s economic development, whereas foreign patent applications/grants are not.

### 5. Discussion

#### 5.1. Domestic Patents Facilitate China’s Sustainable Economic Development

Generally, as illustrated in Figure 3, patents in China have experienced rapid growth. **Total patent applications** increased from 14,372 in 1985 to 3,697,845 in 2017; **Total patent grants** increased from 138 in 1985 to 1,836,434 in 2017. The number of both domestic and foreign patents have drastically increased. However, domestic patents increased more rapidly than foreign patents. During the period of 1996–2006, the share of **Total foreign patent applications** was about 20%. After that period, it gradually dropped to 4.2% in 2017. From 1992 to 2000, the share of **Total foreign patent grants** remained below 10%, then it increased to about 20% in 2005, and then it gradually declined to 6.3% in 2017. Conversely, the share of **Total domestic patent applications** and **Total domestic patent grants** climbed from about 80% in 2005 to 95.8% and 93.7%, respectively, in 2017.

China’s **Patent Law** recognizes three categories of patent rights: inventions, utility models, and industrial designs. These three kinds of patents are diametrically different in nature, and they represent different technological novelties [57,109]. As Figure 4 indicates, **Total foreign patent applications** (in
Figure 4a) and Total foreign patent grants (in Figure 4b) primarily belong to the category of inventions. The share of foreign innovation applications accounted for about 15% of the total between 1996 and 2005, but it dropped to only 4% in 2017. The share of foreign invention grants once reached 16.4% in 2004, but it declined to 6% in 2017.

**Figure 3.** Patent applications and grants in China from 1985 to 2017. The figure shows Total domestic patent applications (TDPA) and Total foreign patent applications (TFPA), Total domestic patent grants (TDPG) and Total foreign patent grants (TFPG), and the share of Total foreign patent applications (TFPA) and the share of Total foreign patent grants (TFPG).

China’s Patent Law recognizes three categories of patent rights: inventions, utility models, and industrial designs. These three kinds of patents are diametrically different in nature, and they represent different technological novelties [57,109]. As Figure 4 indicates, Total foreign patent applications (in Figure 4a) and Total foreign patent grants (in Figure 4b) primarily belong to the category of inventions. The share of foreign innovation applications accounted for about 15% of the total between 1996 and 2005, but it dropped to only 4% in 2017. The share of foreign invention grants once reached 16.4% in 2004, but it declined to 6% in 2017.

**Figure 4.** The share of patent applications and grants of each category and their granted rate. (a) The share of patent applications of domestic (foreign) inventions, utility models, industrial designs; (b) the share of patent grants of domestic (foreign) inventions, utility models, industrial designs; (c) the domestic patent granted rate of inventions, utility models, industrial designs; (d) the foreign patent granted rate of inventions, utility models, industrial designs.

Total domestic patent applications (in Figure 4a) and Total domestic patent grants (in Figure 4b) mainly consist of utility model patents. The share of domestic utility model applications once accounted
for 84.7% of the total in 1988, and it declined to 42% in 2017. The share of domestic utility model grants was 88% in 1988, and it decreased to 53% in 2017. In contrast, the share of domestic invention applications gradually climbed from 2% in 1986 to 34% in 2017; the share of domestic invention grants gradually climbed from 2% in 1986 to 18% in 2017, as well. Since 2010, the share of domestic invention grants has overtaken foreign invention grants, and their gap quickly enlarged to 13% in 2017.

We measured the patent granted rate (PGR) using patent applications divided by patent grants (patent grants/patent applications). The domestic PGR (in Figure 4c) is lower than the foreign PGR (in Figure 4d). In particular, the PGR of domestic inventions is only about 20.7% on average, while the PGR of foreign inventions is about 45.6% on average. Although the domestic PGR is a little bit lower, domestic companies and individuals still hold their enthusiasm for innovation. Undoubtedly, China’s innovation capability has become progressively stronger.

The watershed moment of China’s innovation occurred in 2010. Before 2010, foreign enterprises had more innovative and technological advantages than their Chinese counterparts. Foreign enterprises relied on quality and “long-term competitiveness”. They protected the core technologies of their inventions more than they sought after marginal innovations, which were represented by utility models or industrial designs [110]. Domestic enterprises were quantity-oriented and marginally innovation-oriented because core technologies were more costly and difficult to develop. However, since 2010, Chinese companies have reversed this situation. There have been huge amounts of governmental R&D investment and private sector R&D investment in science and technology [19]. Domestic inventions increased rapidly, which indicates that Chinese companies have become more innovative compared with their foreign counterparts in China.

5.2. FGM and Innovation Diffusion Facilitate China’s Sustainable Economic Development

The flying geese model can significantly explain China’s sustainable economic development. Since China’s reform and opening up, three historical events have exerted massive influence on China’s economic growth: Deng Xiaoping’s Southern China tour in 1992 [111], China’s entering the WTO in 2001, and the global financial crisis of 2008. Furthermore, China’s regional development strategy shifted, step by step, from Eastern to Central and then to Western China. China not only experienced the flying geese migration globally in Asia but also witnessed the flying geese migration domestically in Mainland China, which effectively prevented China from suffering the impact of the international financial crisis [54].

Simultaneously, China has faced greater pressure to meet the tough minimum standards of protection and enforcement that have been accepted by the world’s major trading partners. China also pursues its great ambition to build an “innovation economy”. China’s patent strategies are targeted more toward the diffusion of technology [111], and its Patent Law experienced three revisions (1992, 2001, and 2008). Thus, we used these three critical moments to categorize 1985–2017 into four stages: the first stage (1985–1992), second stage (1993–2001), third stage (2002–2008), and fourth stage (2009–2017). We calculated the Total domestic patent grants and the total foreign patent grants in each stage. Furthermore, we calculated the Total domestic patent grants by province/automatic region/municipality directly under the central government (PAMs), and the total foreign patent grants were calculated by countries and regions in each stage. Finally, we drew the geographic distribution of China’s patent grants according to the countries/region/PAMs (see Figure 5).

Encouraged by the instant success and rapid economic growth of the four SEZs since 1978, China designated another 14 coastal cities as the ETDZs in 1984. In the first stage (1985–1992), on the one hand, most of the foreign investors were still carefully watching. We set the automaker industry as an example, Volkswagen (VW) invested in China in 1984. Whereas General Motor (GE) invested in China till 1998, Toyota till 2001, etc. On the other hand, China’s Open Door policy fully released verified limitation. China’s comparative advantage lay in its labor-intensive industries, with a lower level of economic development and abundant low-cost labor [54]. During this period, China’s innovation was endogenously driven, and it mainly relied on the fully mobilized resource of the traditional state-owned
system, as did China’s industrialization. As China’s technology center in this stage, Beijing was
granted 12,334 patents, followed by Liaoning (9223), Jiangsu (7699), Shandong (7381), Hunan (6397),
Shanghai (5827), Zhejiang (5610), and Sichuan (5602). As the frontier of China’s reform and opening up,
Guangdong was granted merely 5268 patents. Taiwan was granted 2184 patents. The gap of innovation
capability among China’s PAMs was quite narrow (as seen in Figure 5a). The foreign countries that
had the largest number of patents granted were Japan (4164), the US (2981), and Germany (1226).

Figure 5. Geographical distribution of China’s patent grants by countries/regions/province/automatic
region/municipality directly under the central government (PAMs) (a) in the first stage (1985–1992),
(b) in the second stage (1993–2002), (c) in the third stage (2003–2008), (d) in the fourth stage (2009–2017).

In 1990, Taiwan announced “Measures on Indirect Investment and Technical Cooperation with the
Mainland”, which removed the ban on Taiwan’s investment in Mainland China. In the meantime, Deng
Xiaoping’s publicized visit to the SEZ of Shenzhen in 1992 indicated that China wanted to maintain its
opening-up policy. Taiwanese Investment in Mainland China (TIMC) has surged since then [112], and
Taiwan’s accumulated patent grants in Mainland China rocketed to 52,408 pieces (ranked the 2nd) in the
second stage (1993–2001). Two major economic powers—Japan (21,135) and the US (13,711)—secured the
largest number of Total foreign patent grants in China. Because of “first-mover advantages”, Guangdong
started to boom in its innovation power. With 83,845 patents granted, it held the most innovation
prowess in Mainland China, followed by the Eastern coastal regions, such as Beijing (42,147, the 3rd),
Zhejiang (40,030, the 4th), Shandong (39,414, the 5th), Jiangsu (36,666, the 6th), Liaoning (32,191, the
7th), and Shanghai (23,952, the 8th). Foreign patents with Hong Kong–Macao–Taiwan (HMT for short)
accounted for 17.5% of the total. In the third stage (2002–2008), foreign patents with HMT accounted for
21.6%. The top 5 foreign patentees in China were Japan (122,388), the US (55,156), South Korea (24,386),
Germany (24,128), and France (10,503). The top 5 domestic patentees were Guangdong (282,334),
Zhejiang (185,176), Jiangsu (137,905), Shanghai (112,145), and Shandong (102,282), whereas Taiwan was
granted only 90,833 patents and ranked the 6th. From 1993 to 2008, TIMC and FDI facilitated China’s
innovation to a certain degree, and the exogenous driving mechanism took effect and played a vitally
important role in China’s innovation system [113]. Additionally, state-owned, collective-owned, and
non-state-owned Chinese industries all contributed significantly to China’s innovation capability [114].

In the fourth stage (2009–2017), the top 5 foreign patentees in China were still Japan (313,375),
the US (197,334), Germany (88,154), South Korea (72,682), and France (32,168). Chinese Taiwan was
granted 141,875 patents, and the foreign patents with HMT accounted for 8.7% of the total, while
their contribution to China’s innovation activities became marginal. Jiangsu alone was granted 1,843,602 patents, followed by Guangdong (1,668,214), Zhejiang (1,574,457), Shandong (666,852), Beijing (586,730), Shanghai (479,421), Sichuan (387,992), Anhui (376,133), Fujian (354,138), Henan (289,178), Hubei (256,243), Tianjin (222,129), and Hunan (218,530). Patentees in China were highly clustered into two regions: the Yangtze River Delta (Jiangsu–Zhejiang–Shanghai, with 3.9 million patent grants in total) and the Pearl River Delta (Guangdong, with about 1.7 million patent grants). China’s innovation was dominated by an endogenous driving mechanism. Overall, the development pattern of China’s innovation can be explained by the flying geese model, as well. The Yangtze River Delta and Pearl River Delta were the two “leader geese” of innovation in China, followed by the “follower geese” in other regions along the Eastern coast and Central and Western China. The innovative capabilities of China’s industries have changed gradually from imitation to innovation [115].

5.3. IPR Protection Contributed to China’s Sustainable Economic Development

China used to be acknowledged for its well-written intellectual property laws and criticized for its problematic enforcement [73]. China has done much to improve this situation since 2001 when China entered into WTO. However, with limited experience and rapid technological development, there are still legislative and executive problems [116]. In 2008, China’s State Council released Outlines on the National Strategy of Intellectual Property Rights with the purpose of “enhancing IPR protection” and “promoting IPR innovation” [117]; in 2014, China made the fourth amendment to its Patent Law in order to strengthen China’s IPR protection and protect the patentee’s rights [69]. As a matter of fact, China’s IPR protection has become increasingly tighter.

First, we applied the Closed ratio of patent infringement disputes (Closed ratio) to measure the capability of China’s IPR protection, which is equal to Entertained patent infringement disputes divided by Closed patent infringement disputes (Closed ratio = Entertained patent infringement disputes/Closed patent infringement disputes). The Closed ratio means the proportion of patent infringement disputes closed annually by the administrative officers. If the Closed ratio is equal to or approximately one, then all or a majority of the patent infringement disputes could be closed promptly (annually), and the IPR litigation system is highly effective and efficient. The results show that the Closed ratio between 2014 and 2017 was 98.5% on average (ranging from 96.7% to 99.6%); it was 73.3% on average from 2006 to 2013 (ranging from 58.2% to 79.1%); and it was 75.8% on average during the period of 1985–2005 (ranging from 61.4% to 82.2%). The higher Closed ratio in recent years clearly illustrates that China’s IPR protection has greatly improved.

Second, CNIPA recorded the infringed patentees by countries and regions (see Figure 6). In 2007, 85.6% of infringed patentees were from Mainland China, 6.9% were from Chinese HMT, and 7.6% of them were from foreign countries (0.9% from the US, 3% from Japan, etc.). Since then, the patent infringement disputes involving Chinese HMT and foreign counties have dramatically declined. In 2017, 96% of infringed patentees were from Mainland China, 0.2% were from Chinese HMT, and merely 3.8% of them were from foreign countries (0.3% from the US, 0.47% from Japan, etc.). Although there has been a huge rise in patent litigation, the majority of them have been between Chinese partners [10,17]. This is also evidence that China’s IPR protection of patentees from Chinese HMT and foreign countries is stronger than before [118,119].
Over the past 40 years, China has experienced fast and consistent economic growth, and it has been the second-largest economy since 2010. Since 2011, China has also been the premium powerhouse of patent applications in the world for eight consecutive years.

The results in this paper show that part of the controlled variables (Population, Total employed persons, Nominal exchange rate, Tertiary education (%), and R&D expenditures (%)), innovation (at the enterprise level), the flying geese model (at the global and national level), and China’s IPR protection (at the governmental level) all play an important role in China’s sustainable economic development. Patent applications and grants from enterprises are significantly and positively associated with China’s economic development. Because about half of the patent applications did not become validly granted patents, the term "patent applications" could overestimate China’s innovation capability to some degree. Furthermore, we find that domestic patents are a powerful engine for China’s economic growth, and their number exceeds that of foreign patents. Since 1985, both domestic and foreign patents have grown dramatically in China, yet domestic patents have increased more rapidly than foreign patents. The watershed moment of China’s innovation occurred in 2010. Before 2010, foreign enterprises were much more innovative than domestic ones. They concentrated more on the “core” technological inventions than the “marginal” innovations (utility models, industrial designs). Since 2010, domestic patents have overtaken foreign innovations, and their gaps enlarged to 13% in 2017.

Both China’s sustainable economic development and innovation diffusion follow the flying geese model. We used three critical and historical moments (1992, 2001, and 2008) to categorize the period of 1985–2017 into four stages. In the first stage (1985–1992), foreign investors kept a careful watch. Both China’s industrialization and innovation were “endogenously driven” and at the lower level of labor-intensive industries. The top three domestic patentees (Beijing, Liaoning, and Jiangsu) were more innovative than the top three foreign patentees (Japan, the US, and Germany).

In the second and third stages (1993–2008), encouraged by Deng Xiaoping’s Southern China tour (1992) and China’s entry into WTO (2001), Taiwanese investment in Mainland China and foreign indirect investment poured into China, and those investments played an important role in China’s sustainable economic development. China’s industrialization and innovation were driven by both exogenous and endogenous mechanisms. Total foreign patent grants with Hong Kong–Macao–Taiwan accounted for approximately 20% of the total. Because of its “first-mover advantages”, the coastal region became more innovative. From 1993 to 2008, Guangdong was granted 366,179 patents and
ranked 1st, followed by Zhejiang (225,206, the 2nd), Jiangsu (174,571, the 3rd), Taiwan (143,241, the 4th), Shandong (141,696, the 5th), Shanghai (136,097, the 6th), and Beijing (119,784, the 7th). The top four foreign patentees were Japan (143,523), the US (68,867), Germany (28,956), and South Korea (27,504).

In the fourth stage (2009–2017), the Yangtze River Delta (granted 3.9 million patents) and Pearl River Delta (granted 1.7 million patents) were the two “leader geese” in economic growth, industrialization, and innovation diffusion in Mainland China, followed by the “following geese” in other regions along the Eastern coast or in Central and Western China. Total foreign patent grants with HMT accounted for 8.7% (about one million). In 2017, both R&D expenditures and R&D investments in private sectors from China took up about one-fourth of the world’s total. The innovative capabilities of Chinese industries have changed gradually from imitation to innovation.

China’s IPR protection has become increasingly tighter and contributed to its sustainable economic development. China used to be notorious for “widespread piracy” and poor ability to implement IPR protection. However, China has done much to improve this condition since 2001. In 2008, China released the “Outlines on the National Strategy of IPR” with the aim of enhancing IPR protection and promoting IPR innovation. Since then, China’s IPR administrative protection has become increasingly tighter. We applied the closed ratio to measure the capability of China’s IPR administrative protection. We find that it was 98.5% on average between 2014 and 2017, and it was 73.3% on average from 2006 to 2013. This clearly illustrates that China’s IPR administrative protection has greatly improved; 98.5% of patent infringement disputes could be closed annually in recent years. Moreover, 96% of infringed patentees in 2017 were from Mainland China, 0.2% were from Chinese HMT, and merely 3.8% of them were from foreign countries (0.3% from the US, 0.47% from Japan, etc.). In contrast, in 2007, 85.6% of infringed patentees were from Mainland China, 6.9% were from Chinese HMT, and 7.6% of them were foreigners (0.9% from the US, 3% from Japan, etc.). This also means that China’s IPR administrative protection and enforcement have improved dramatically.

6.2. Implications

Both the economic slowdown and the Sino-US trade war have persuaded Western economists to hold pessimistic expectations of the future of China’s sustainable economic growth. This study, however, illustrates that although China has suffered from the Sino-US trade war, there are still a series of measures that maintain its sustainable economic growth, particularly through innovation and the innovation economy.

First, China should aim to keep its opening-up policy, expand exports of both goods and services and attract foreign direct investment. As a matter of fact, China has frequently realized these goals. For instance, the US electric vehicle industry leader Tesla set up a wholly owned super factory in Shanghai after the Sino-US trade war started [120]. The number of China’s Pilot Free Trade Zones (FTZs) increased to 18 in August 2019. The Chinese government promised to “continue to work hard to create a more stable, fair, transparent and predictable investment environment” [20].

Second, China should encourage domestic enterprises’ innovation activities. Domestic patents in China have overwhelmed their foreign counterparts and have become a powerful engine for China’s economic growth. Since 2018, when the US government announced a ban on the export of US semiconductor products or production equipment to ZTE, Huawei, Fujian Jinhua, and others, the transfer of IP (either as a virtual good or embedded in a product or solution) has been subject to deeper US government scrutiny [20]. Therefore, it is necessary that China encourages innovation activities from domestic enterprises.

Third, China should improve its IPR protection system. Although China’s IPR protection has improved dramatically, there is still room for improvement. China’s IPR protection, to a great extent, relies on the administrative protection system because its judicial protection system (JPS) is relatively weak. However, Western countries have only the judicial protection system. This has led Westerners to regard China as engaging in “widespread piracy” and as having a poor ability to protect IPR, and they have characterized China as “the world’s worst IPR infringer”, among other accusations. China should
improve its IPR protection system so that innovative firms can protect their patents and innovation from being pirated and imitated. When an innovating firm can “behave monopolistic to market a new product”, the prospect of monopoly profits will encourage it to produce new, better, and creative products [29,43]. After that, there will gradually be a virtuous circle of innovation in China.

6.3. Limitations and Future Research

This study is not without limitations. The long-term sustainability of economic growth has been a focal point of scholars, academic researchers, and policymakers. They have provided a long list of factors that may have an impact on economic growth. This paper focuses on innovation and its relevant factors, such as the flying geese model and IPR protection factors. For control purposes, we included population, the labor force, the exchange rate, human capital, and R&D expenditures. However, these factors and variables are still limited. In our future research, we should consider more factors, such as fixed-asset investment (which includes the state budget, domestic loans, foreign investment, and self-raising funds) and consumption.

Author Contributions: Conceptualization, J.X. and Y.C.; data curation, Y.C.; formal analysis, Y.C.; funding acquisition, J.X.; investigation, J.X. and Y.C; methodology, Y.C.; supervision, J.X.; writing—original draft, J.X. and Y.C.; writing—review and editing, J.X. and Y.C.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Variables’ definitions and data sources of variables.

<table>
<thead>
<tr>
<th>Abb.</th>
<th>Variable</th>
<th>Definition</th>
<th>Data Source</th>
</tr>
</thead>
</table>
| GDP  | China’s GDP | Gross domestic product. | China Statistical Yearbook *
| TPA  | Total patent applications | Total number of patent applications: the accumulated number of applications of inventions, utility models, and industrial designs. | China National Intellectual Property Administration b |
| TDP A | Total domestic patent applications | Total number of domestic patent applications. | China National Intellectual Property Administration b |
| TFPA | Total foreign patent applications | Total number of foreign patent applications. | China National Intellectual Property Administration b |
| TPG  | Total patent grants | Total number of patent grants: the accumulated number of grants of inventions, utility models, and industrial designs. | China National Intellectual Property Administration b |
| TDPG | Total domestic patent grants | Total number of domestic patent grants. | China National Intellectual Property Administration b |
| TFPG | Total foreign patent grants | Total number of foreign patent grants. | China National Intellectual Property Administration b |
| CPID | Closed patent infringement disputes | Total number of closed patent infringement disputes by the patent enforcement of the administrative authorities for patent affairs. | China National Intellectual Property Administration b |
| ITG  | International trade of goods | Total value of imports and exports of goods. | China Statistical Yearbook *
| ITS  | International trade of services | Total value of imports and exports of services. | China Statistical Yearbook *
| FXR  | Foreign direct investment | Total amount of foreign direct investment. | China Statistical Yearbook *
| POP  | Population | Total number of people in Mainland China. | China Statistical Yearbook *
| TEP  | Total Employed Persons | Total number of employed persons. | China Statistical Yearbook *
| NER  | Nominal exchange rate | Nominal exchange rate, Yuan per US Dollar (period average). | Annual Statistics of The People’s Bank of China *
| TE   | Tertiary Education (%) | Net enrolment ratio of tertiary education for undergraduates in regular higher-education institutions (HEIs), including both normal courses and short-cycle courses. | Educational Statistics Yearbook of China *
| R&D  | R&D Expenditures (%) | Ratio of expenditures on research and development (R&D) to GDP. | China Statistical Yearbook *

Table A2. Ordinary least squares (OLS) regressions of China’s GDP, and the variance inflation factor (VIFs).

<table>
<thead>
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<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Coef. (SE)  p-Value  VIF</td>
<td>Coef. (SE)  p-Value  VIF</td>
<td>Coef. (SE)  p-Value  VIF</td>
<td>Coef. (SE)  p-Value  VIF</td>
</tr>
<tr>
<td>(constant)</td>
<td>−4633 (1526.7) **  0.006</td>
<td>−3679.7 (1931.6) + 0.070</td>
<td>−3894.4 (1386.8) * 0.011</td>
<td>−3619.7 (1977.8) + 0.081</td>
</tr>
<tr>
<td>Innovation Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total patent applications</td>
<td>0.84 (0.1) ***  0.000</td>
<td>77.933</td>
<td></td>
<td></td>
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<tr>
<td>Total domestic patent applications</td>
<td>0.75 (0.1) ***  0.000</td>
<td>81.879</td>
<td></td>
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<tr>
<td>Total foreign patent applications</td>
<td>−5.39 (2.39) * 0.035</td>
<td>160.486</td>
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<tr>
<td>Total patent grants</td>
<td>1.13 (0.19) ***  0.000</td>
<td>50.561</td>
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<tr>
<td>Total domestic patent grants</td>
<td>1.16 (0.21) ***  0.000</td>
<td>52.664</td>
<td></td>
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<tr>
<td>Total foreign patent grants unit</td>
<td>0.14 (2.74) 0.961</td>
<td>52.084</td>
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<tr>
<td>FGM Factors</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>International trade of goods</td>
<td>0.27 (0.1) * 0.012</td>
<td>148.477</td>
<td>0.44 (0.12) *** 0.001</td>
<td>138.895</td>
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<tr>
<td>International trade of services</td>
<td>2.62 (0.83) ** 0.005</td>
<td>242.474</td>
<td>1.82 (1.11) 0.115</td>
<td>275.686</td>
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<td>Foreign direct investment</td>
<td>8.17 (2.15) ** 0.007</td>
<td>50.972</td>
<td>7.93 (2.69) ** 0.007</td>
<td>50.960</td>
</tr>
<tr>
<td>IPR Protection Factors</td>
<td></td>
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<tr>
<td>Closed patent infringement disputes</td>
<td>31 (10.65) ** 0.008</td>
<td>27.497</td>
<td>61.94 (11.07) *** 0.000</td>
<td>18.979</td>
</tr>
<tr>
<td>Control Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>5.33 (1.89) ** 0.010</td>
<td>233.883</td>
<td>4.21 (2.4) + 0.093</td>
<td>240.142</td>
</tr>
<tr>
<td>Total employed persons</td>
<td>−1.41 (1.14) 0.228</td>
<td>63.160</td>
<td>−1.02 (1.44) 0.485</td>
<td>64.762</td>
</tr>
<tr>
<td>Nominal exchange rate</td>
<td>−99.79 (33.04) ** 0.006</td>
<td>17.118</td>
<td>−87.31 (41.23) * 0.046</td>
<td>17.050</td>
</tr>
<tr>
<td>Tertiary education (%)</td>
<td>−19.27 (13.69) 0.173</td>
<td>209.871</td>
<td>−11.16 (17.58) 0.531</td>
<td>221.224</td>
</tr>
<tr>
<td>R&amp;D expenditures (%)</td>
<td>72.18 (105.15) 0.500</td>
<td>21.437</td>
<td>37.06 (132.49) 0.782</td>
<td>21.759</td>
</tr>
<tr>
<td>Regression information</td>
<td>R-squared 0.999 ***</td>
<td>0.999 ***</td>
<td>0.999 ***</td>
<td>0.999 ***</td>
</tr>
<tr>
<td></td>
<td>N 33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
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</table>

Note: (1) Level of Significance: + p ≤ 0.1, * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001. (2) Entries are unstandardized beta coefficients. Figures in parentheses are standard errors. (3) VIF is the variance inflation factor of independent variables in each model.
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