China's innovation boom : miracle or mirage?

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China's Innovation Boom: Miracle or Mirage?

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Abstract

Is China's innovation boom a miracle or mirage? As a comprehensive national innovation development strategy, China's National Technology Zone (NTZ) pilot provides an excellent natural experiment for the analysis of this phenomenon multidimensionally. Using unique Chinese Patent Census Database and matching it with Chinese Industrial Firm Census Database, this paper shows that the establishment of NTZs has promoted firm innovation, as well as innovation in high-tech industries and indigenous innovation, measured by both the quantity and the quality of invention patents. In this sense, China is creating an innovation miracle in general. More evidence from our results shows that both firm–academia collaboration and FDI inflows play significantly positive roles in China's achievement of this miracle. However, there are also two types of innovation mirages: 1) there is no significant impact of NTZs on the quality of patents after the financial crisis of 2008, which might be attributed to the relatively radical macro planning; 2) the establishment of NTZs has brought enhancement of patent quality for state-owned enterprises (SOEs) but not for non-SOEs, which might be ascribed to the imperfect market institution. Finally, we provide some policy suggestions on the basis of our analysis.

Keywords: China's innovation boom, patent quality, indigenous innovation, patent citation, innovation development strategy

JEL classification: L25, O38, R15

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China's Innovation Boom: Miracle or Mirage?

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Abstract (longer version): Over the past few decades, the Chinese government has adopted a series of national innovation development strategies, which have begotten the rapid growth of Chinese patenting. However, the views expressed by the international community regarding this patent boom are split right down the middle, with some seeing it as an *innovation miracle* and others dismissing it as an *innovation mirage*. The one-dimensional nature of the existing patent growth hypotheses makes it difficult to explain many important aspects of the so-called "China's innovation boom". As a comprehensive national innovation development strategy, China's National Technology Zone (NTZ) pilot provides an excellent natural experiment for the analysis of this phenomenon multidimensionally. Using unique Chinese Patent Census Database and matching it with Chinese Industrial Firm Census Database, this paper shows that the establishment of NTZs has promoted firm innovation, as well as innovation in high-tech industries and indigenous innovation, measured by both the quantity and the quality of invention patents. In this sense, China is creating an innovation miracle in general. More evidence from our results shows that both firm–academia collaboration and FDI inflows play significantly positive roles in China's achievement of this miracle. However, there are also two types of innovation mirages: 1) there is no significant impact of NTZs on the quality of patents after the financial crisis of 2008, which might be attributed to the relatively radical macro planning; 2) the establishment of NTZs has brought enhancement of patent quality for state-owned enterprises (SOEs) but not for non-SOEs, which might be ascribed to the imperfect market institution. Finally, we provide some policy suggestions on the basis of our analysis.

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1 Introduction

Since the turn of this century, patents in China have been increasing rapidly. The ratio of invention patent applications in China and Patent Cooperation Treaty (hereinafter "PCT") filings from China to the global total increased from 3.79% and 0.84 % in 2000 to 46.36% and 21.11% in 2018, respectively. Furthermore, both invention patent applications by residents and PCT applications have been soaring since 2009 although there has been little growth for nonresident patents since then (see Figure 1). With the boom of patents in China, two distinct positions have emerged. Some (e.g., Keane, 2007; Yusuf, 2012; Campbell, 2013; Beinhart, 2018; Atkinson and Foote, 2019) assert that China is creating an *innovation miracle* with the help of the national innovation development strategy and is experiencing an innovation catch-up with advanced economies. Others (e.g., Prud'homme, 2012; Waldmeir, 2013; The Economist, 2014; Chen, 2018) call into question the quality of Chinese patents and argue that China is making an *innovation mirage*.

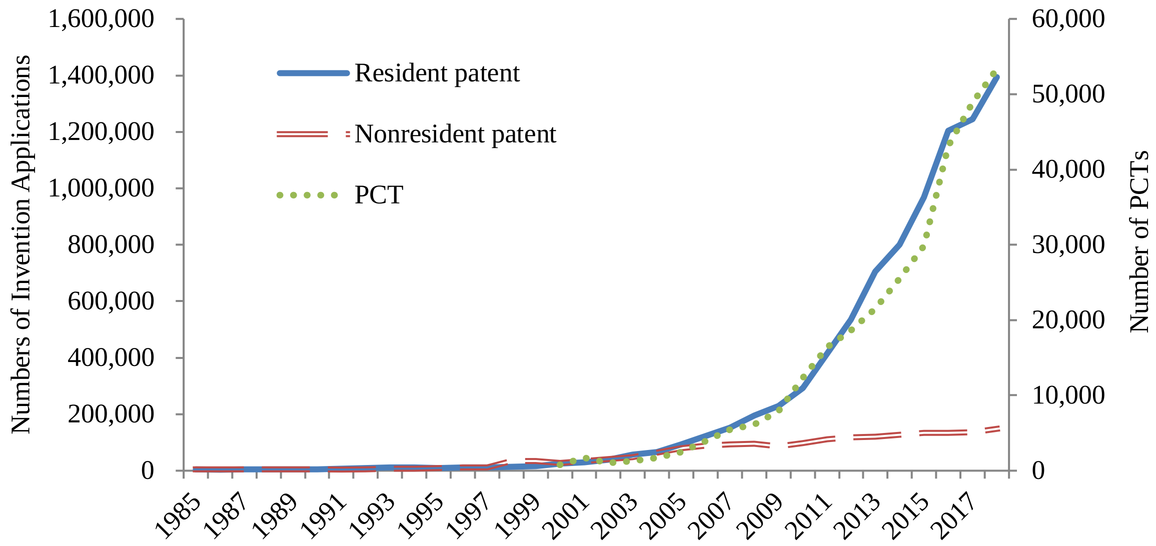

Figure 1 Number of Invention Applications in China and PCTs from China (1985-2018)

Source: World Intellectual Property Organization (WIPO) website: https://www3.wipo.int/ipstats/keyindex.htm.

Is China creating an innovation miracle or an innovation mirage? To date, despite widespread discussions on the issue of China's innovation boom, strict and normative empirical studies are scarce. There are at least two challenges to answering the above question. The first concerns the identification of patent quality to obtain a better proxy for innovation instead of solely using patent quantity as most existing research does on China's innovation. The second challenge is to choose a comprehensive national innovation development strategy that explains the behavior of the Chinese government multidimensionally rather than choosing one that focuses on one dimension (for example, a certain institution or policy) as existing hypotheses do.

We overcome the first challenge by identifying the patent quality with unique Chinese Patent Census Database that contains over 22.13 million patents. Patents have long been employed as an innovation indicator in both macro and micro studies, which was reviewed by Griliches (1990). Patents are important carriers of technical knowledge, the core of technological innovation when compared with other innovation indicators (See Appendix II for details). We use patents for two additional reasons. First, patents are significant indicators for evaluating the achievements of NTZs. Second, the Chinese Patent Census Database used in this study include abundant information, such as backward citations, forward citations, number of claims, etc., which allows us to identify patent quality and thus measure innovation, and even indigenous innovation, more accurately. To our best knowledge, no previous studies have incorporated these important indicators (e.g., Xie and Zhang, 2014; Dang and Motohashi, 2015; He et al., 2017, 2018; Cai et al., 2018). In addition, the micro-level Chinese Patent Census Database have been updated to 2018, which enables us to analyze China's surge in patents post-2009. Existing studies, however, are based on data up to 2014 at the latest (e.g., Cai et al., 2018), which can only be analyzed up until 2009 if the commonly used 5-year forward citation were to be employed as innovation indicator. Furthermore, given the fact that firms as the most important market entities and innovators were responsible for 67.60% of all patent publications in China from 1991 to 2018 (the rest were from universities, scientific research institutions, individuals, and others; see Figure A1 in Appendix I), this paper focuses on firms' innovation activities by consistently matching Chinese Patent Census Database with Chinese Industrial Firm Census Database.

Regarding the second challenge, different hypotheses on the patent growth have been analyzed. 1) Patent subsidy hypothesis. Both Li (2012) and Dang and Motohashi (2015) have found the patent subsidy policy to have resulted in an increase in the number of patents. However, the patent subsidy policy basically covered all provinces in the country by 2007, and the amount of the patent subsidy has barely increased ever since, except in Gansu Province, where the policy commenced in 2015. Thus, it is difficult to explain the acceleration in the number of patent applications after 2009.
2) R&D subsidy hypothesis. From 2004 to 2017, the annual growth rate of government R&D expenditure and total R&D expenditure in China was 12.76% and 15.35%, respectively, which is far lower than the average annual growth rate of the number of patents (19.91%).[1] However, several studies (e.g., Cincera, 1997; Hausman et al., 1984; Hu and Jefferson, 2004, 2009; Li, 2008) have found that the R&D elasticity of patents is less than 1, indicating a large proportion of the growth in the number of patents as not being explainable by the increase in R&D expenditure.
3) Technology transfer policy hypothesis. China's foreign direct investment (FDI) grew much faster in the period 2000–2009 (average annual growth rate of 6.67%) than it did in the period 2010–2018 (average annual growth rate of 0.96%). Thus, it is difficult to explain the acceleration in the number of patent applications after 2009.
4) the Friendly Court Hypothesis, which was first put forth by Kortum and Lerner (1989), further supported by evidence from Hall (2005) and Song (2006). It holds that a better intellectual property protection system is conducive to increasing the number of patent applications. However, reform of China's patent system mainly took place in 2000,[2] and thus, it remains difficult to explain the acceleration in the number of patent applications after 2009. In addition, the reform of China's patent system fails to explain the accelerated growth in the number of PCT applications because the enhancement of domestic intellectual property protection is not directly related to international patent applications. Furthermore, the reform of China's patent system cannot explain the slowing down of the growth of Chinese patents applied for by nonresidents either.

In short, the above four hypotheses have explained some parts but no other important aspects of China's patent growth such as the accelerated growth in the number of patent applications and PCT applications by resident after 2009, and the relative slowing down of patent applications by nonresidents after 2009. The rationale would be that these hypotheses are only analyzed from one dimension, whereas China's national innovation development strategy has multidimensional tools, including a range of institutions, policies, and macro planning.

To better answer the above question, we need to start with a comprehensive strategy. China's National Technology Zones (NTZs) meet the standard:
1) The NTZs are place-based programs, which include a package of property rights institution, tax policy and land use policy (Wang, 2013). In fact, NTZs are important vehicles and experimental fields for the national innovation development strategy, including patent system reform, patent subsidy policy, technology transfer policy, macro planning etc.

[1] *Source:* Data on R&D expenditure are taken from the *2018 China Statistical Yearbook on Science and Technology*. R&D expenditure has been adjusted using the consumer price index (CPI), which is based on the *2018 China Price Statistical Yearbook*. The average annual growth rate of patent counts is calculated based on data from the WIPO website.

[2] In preparation for China's accession to the WTO, China's patent law underwent significant revision in 2000, which greatly improved the protection of patent holders and basically complied with the principles of the internationally accepted TRIPS agreement. No major revisions have been made since then. As part of the Chinese version of the "Bayh–Dole Act", China's Ministry of Science and Technology issued *Several Opinions on Strengthening the Protection and Management of Intellectual Property Rights Related to Science and Technology* in 2000, which, for the first time, attribute the rights of intellectual property from implementing national science and technology projects to the undertaking units, rather than the government.

2) The establishment of NTZs is a pilot project in itself, thereby providing a good opportunity for policy evaluation.
3) The direct and main goal of NTZs is to spur technological innovation. The NTZs in China include national economic and technical development zones (hereinafter "National Econ-Tech Zones") and national high-tech industrial development zones (hereinafter "National High-Tech Zones"), both of which aim at promoting innovation. Until now, most related articles do not focus directly on the NTZs but on the Special Economic Zones (SEZ), studying SEZs in China (e.g., Wang, 2013; Alder et al., 2013; Moberg, 2015; Zheng et al., 2016); Russia (Sosnovskikh, 2017); the Philippines (Ortega et al., 2015); Tanzania (Farole, 2011); or in Europe (Liptáka et al., 2015). SEZs include more than NTZs, such as trade zones, tourism zones, etc., which directly aim at promoting trade, tourism, FDI, etc.

Our study is intended to empirically investigate the effects of the establishment of NTZs on firm innovation. This paper aims to enrich the existing body of research in the following two ways. First, in contrast to previous studies on SEZs, which take R&D (e.g., Cao, 2004) and productivity (e.g., Wang, 2013; Alder et al., 2013) as innovation indicators, this study is the first, to our knowledge, to conduct analysis by regarding both the quantity and quality of patents as innovation indicators for China. Second, we provide strong evidence on whether and the extent to which China is creating an innovation miracle or mirage, thus deepening the understanding of China's innovation boom.

The remainder of this paper is organized as follows. Section 2 introduces data matching and the staggered difference-in-differences (DID) regression model. Section 3 presents an empirical analysis on the effect of the establishment of NTZs on the overall level of innovation. We also conduct dynamic analysis and a series of robustness tests, particularly endogeneity analysis, using the connections of local officials in the central government as instrumental variables (IVs). Section 4 lays out the effects of NTZs on high-quality innovation by studying the effects of NTZs on innovation of high-tech industries and that on indigenous innovation. Section 5 investigates the innovation mirages in two ways: before and after the financial crisis; among firms with different ownerships. Section 6 attempts to uncover the mechanisms between the establishment of NTZs and the innovation growth by both reviewing the NTZ literature and technology catch-up literature. Section 7 concludes and discusses policy implications.

2 Data and Model

2.1 NTZs and Chinese Industrial Firm Census Database

Since the establishment of the first National Econ-Tech Zone in 1984 and the first National High-Tech Zone in 1988, numerous NTZs have been established in China. Technology Zones are a type of China's SEZs. By the end of 2018, SEZs in China included: five Special Economic Areas, 16 coastal Open Cities, and various development zones, which further encompass Technology Zones, Special Customs Supervision Zones, Cross-border Economic Cooperation Zones, and Tourism Development Zones. According to the *China Development Zone Audit Announcement Catalogue (2018 Edition)*, there are 219 National Econ-Tech Zones and 156 National High-Tech Zones in China (see Figure A2 in Appendix I). The provincial distribution of NTZs is shown in Figure A3 in Appendix I.

This study focuses on NTZs for the following three reasons. First, we only analyze Technology Zones rather than other special economic zones because one of the main goals of the former is to propel technological innovation, while other special economic zones mainly target exports, FDI, or tourism. Second, we only analyze the National Technology Zones rather than Local (Provincial or Municipal) Technology Zones because the establishment of Local Technology Zones is likely to be the result of "political games" between the central government and local governments and may not accurately reflect the intentions of the national innovation development strategy.[3] In addition, when

[3] In 2003, the National Development and Reform Commission of China issued *Specific Standards and Policy Boundaries for Cleaning up and Overhauling the Existing Development Zones* (No. 2343 [2003]), which is the most powerful rectification in the history of the development zones, and the number of provincial development zones established in the following 2 years fell sharply.

compared with National Development Zones, Local Development Zones are obviously weaker in terms of management authority and preferential tax policies. Third, we simultaneously analyze the National Econ-Tech Zones and the National High-Tech Zones. Both are important components of the national innovation development strategy and are aimed at promoting technological innovation in industries such as electronic information, new materials, biomedicine, energy conservation, environmental protection, and equipment manufacturing. Previously, the National Econ-Tech Zones were meant to import foreign technology, while the National High-Tech Zones were aimed at taking advantage of domestic intellectual resources such as scientific research institutions and universities. However, the original difference has been fading over time. Apart from that, considering the diversified distribution of the two types of NTZs (only six out of 216 treatment municipalities have set up the two types of NTZs in the same year), we are able to obtain more treatment groups. In brief, simultaneous analysis of the two types of zones is conducive to a more comprehensive understanding of the national innovation development strategy. Later, we will also distinguish between the two types of NTZs in terms of their effects on innovation.

We employ Chinese Industrial Firm Census Database for the period 1995–2013, which are annually collected by the National Bureau of Statistics (NBS). The dataset covers all above-scale firms[4] in industries such as mining and manufacturing as well as public utilities. The database includes various input/output indicators and financial indicators, with annual sample sizes in the range of 160,000–430,000. Previous studies mostly used 1998–2007 data (e.g., Brandt et al., 2012), excluding 2008–2013 data because the variable of value added is absent. However, this does not present a problem in this study because we do not need to calculate productivity. There are also some recent articles that employed the data up to 2013 (e.g., Chen and Chen, 2017; Tan et al., 2017).

Given the change in industry classifications in 2002 and 2011, this study reconciles the four-digit industry codes based on the N*ational Economic Industry Classification* (GB-T4754-2002). To test the representativeness of our sample, we pick up the total assets in 2004, 2008, and 2013 and compare them with total assets in the *First Economic Census* in 2004, the *Second Economic Census* in 2008, and the *Third Economic Census* in 2013, which include all industrial firms. Results show that the ratio of total assets in our data to those in the *Economic Census* data is approximately 90% in 2004; 85% in 2008; and 79% in 2013. We have also made comparisons at the two-digit industry level, and the results also indicate that our data are highly representative. The only drawback is that the database does not include non-above-scale firms, meaning that the conclusion should be cautiously arrived at when it is extended to all industrial firms.

In addition, the number of above-scale firms annually released by the NBS is also like that in our data, with the only exception being that about a fourth of the sample in 2010 is missing (approximately 110,000 firms). While Chen and Chen (2017) keep the data in 2010, Tan et al. (2017) simply drop them. We think that dropping the 2010 data would create a more serious impact on the panel regression. Therefore, we conservatively retain the data in 2010. The descriptive statistics for the major variables in 2010 is actually not very abnormal when compared with those in other years. Hence, this might have some, although not likely decisive, influence on our conclusion.

Finally, we identify the municipality that each NTZ is located in, with the help of a search engine, and then, we match NTZ data with Chinese Industrial Firm Census Database with municipality and year as the linking variables.

2.2 Matching Chinese Patent Census Database with Chinese Industrial Firm Census Database

To our knowledge, this study is the first to employ the Chinese Full Sample Micro-level Patent Database (hereinafter referred to as "Chinese Patent Census Database") up to 2018, which contains

However, the number of provincial development zones peaked in 2006 when the rectification was over and even exceeded the total established before that.

[4] The above-scale firms in Chinese Industrial Firm Census Database used here refer to the enterprises above designated size. Prior to 2006, the data covers non-SOEs with annual sales of more than RMB 5 million and all state-owned enterprises (SOEs). From 2007 to 2010, it includes all firms with annual sales of at least RMB 5 million. After 2011, it includes all firms with annual sales of at least RMB 20 million.

over 22.13 million patents, including 8.94 million invention patents, 8.23 million utility models, and 4.96 million industrial designs.[5] The processing of patent data is effort-intensive (Xie and Zhang, 2014; Lerner and Seru, 2017), particularly considering the large sample size and that the text documents are generally not machine-readable. To verify the representativeness of our data, we compare the numbers of the three types of patents in our database with those released in the *Patent Statistics Annual Report*. The numbers of patents from the two sources are almost equal for the three types of patents (See Figure A4 in Appendix III). The provincial distribution of invention applications is shown in Figure A5 in Appendix III.

When compared with the Chinese Patent Census Database used in previous studies (Xie and Zhang, 2014; Dang and Motohashi, 2015; He et al., 2017, 2018; Cai et al., 2018), our data have two significant advantages. First, our data encompass abundant information, including backward citations, forward citations, number of claims, etc., which helps better identify patent quality. Previous versions, however, include only basic information on patent quantity. Second, the time span is longer. Our data extend to the year 2018, while previous ones only covered the period up to 2014 at the latest (e.g., Cai et al., 2018).

We first divide applicants into five groups on the basis of their name: firms, universities, scientific research institutions, individuals, and others. Generally, firms are applicants with "company," "factory," "design institute," etc. in their names. Universities are applicants with "university," "school," "college," etc. in their names. Scientific research institutions are applicants with "research laboratory," "academy of sciences," "research center," etc. in their names. Individuals are applicants with a person's name. Others include associations, foundations, promotion associations, etc. To avoid double counting, if an applicant's name contains terms related to both firms and other groups, it is classified simply as a firm. For example, both "the ** company of the ** university" and "the ** research laboratory of the ** company" are classified as firms. In addition, we reclassify some applicants as firms if their names are matched with the firm name in the Chinese Industrial Firm Census Database. About 7.36% of invention patents are applied for by more than one applicant. Generally, the first applicant is the one that contributed the most. If we concentrate only on the first applicant, our data sample shows that firms, universities, scientific research institutions, individuals, and others account for 67.60%, 14.62%, 1.97%, 15.16%, and 0.64% of the total invention patents, respectively.

Then we match the name of patent applicants with the firm name in the Chinese Industrial Firm Census Database. To improve the matching accuracy, we make some adjustments to the names prior to matching. For example, we deleted the terms "limited company," "limited liability company," "company," "factory," "province," "city," and "county" from firm names, as well as all spaces and punctuation marks. The matching results are shown in Table 1. We observe that in the period 1995–2013, only 4.64% of above-scale industrial firms had patent applications but that 44.07% of domestic firm patents were applied for by above-scale industrial firms.[6] That is to say, a very small proportion of above-scale industrial firms are responsible for nearly half of all patent applications by domestic firms. We identify whether the firm is domestic or foreign on the basis of its address in Chinese Patent Census Database.

Apart from that, by matching the 2008 China patent database with the 2008 Economic Census data, we find that patent applications by non-above-scale industrial firms are only about 8.47% of those by all domestic firms. The remaining patents are mostly applied for by the service sector. Therefore, we have analyzed most patents (83.88%) by the industrial sector, which has greater learning capacity and more learning externalities than do other sectors (Stiglitz and Greenwald, 2014).

[5] The data is from the State Intellectual Property Office of China (hereinafter "SIPO"), and provided by Shenzhen Degaohang Intellectual Property Data Technology Co., Ltd.

[6] This result is lower than the figure (58.80%) obtained by Xie and Zhang (2014) on the basis of 1998–2009 data because they have not considered the entry and exit of firms during the sample period and have only used the firm name for matching instead of using both the firm name and year. We repeated the matching using only the firm name for data from 1995 to 2013 and obtained a figure of 56.80%, which is very close to the result obtained by them.

Table 1 Matching Chinese Patent Census Database with Chinese Industrial Firm Census Database

	Invention (Ungranted)	Invention (Granted)	Utility Model	Industrial Design	In total
Proportion of Above-scale Industrial Firms with Patents					
Number of Above-scale Industrial Firms with Patent Applications	67,381	79,245	156,620	65,151	225,705
Number of Above-scale Industrial Firms	4,859,810	4,859,810	4,859,810	4,859,810	4,859,810
Proportion of Above-scale Industrial Firms with Patent Applications	1.39%	1.63%	3.22%	1.34%	**4.64%**
Proportion of Patent Applications by Above-scale Industrial Firms					
Number of Patent Applications by Above-scale Industrial Firms	288,121	351,951	853,481	570,775	2,064,328
Number of Patent Applications by Domestic Firms	767,626	770,111	1,882,998	1,263,528	4,684,263
Proportion of Patent Applications by Above-scale Industrial Firms	37.53%	45.70%	45.33%	45.17%	**44.07%**

Source: Author calculations based on our matching data.

To verify the validity of our matching, we compare the matching results with macro data released by the government. The SIPO (State Intellectual Property Office of China) issued the *Report on Patent Activities and Economic Performances of Above-scale Industrial Firms in China* (2012 and 2013), which released data on the proportion of above-scale industrial firms with patent applications in 2008 and 2011–2013 (see (1b) in Table 2). On the basis of patent applications by above-scale industrial firms obtained from the NBS website and the total patent applications released in *Patent Statistics Annual Report*, we can reckon the proportion of patent applications by above-scale industrial firms in total patent applications (see (2b) in Table 2). In general, our matching is in line with the official data.

Table 2 Our Matching V.S. Official Data

Year	Proportion of Above-scale Industrial Firms with Patent Applications		Proportion of Patent Applications by Above-scale Industrial Firms in Total Patent Applications	
	(1a) Our Matching	(1b) Official Data	(2a) Our Matching	(2b) Official Data
2013	12.11%	13.10%	26.20%	25.21%
2012	11.68%	12.20%	24.92%	25.39%
2011	9.88%	10.30%	24.06%	25.08%
2008	4.05%	4.20%	19.84%	20.95%

Source: "Our Matching" represents the matching between Chinese Patent Census Database and Chinese Industrial Firm Census Database. "Official Data" is from the *Report on Patent Activities and Economic Performances of Above-scale Industrial Firms in China*, the National Bureau of Statistics website, and *Patent Statistics Annual Report*.

2.3 Model Specification and Descriptive Statistics

Difference-in-differences (DID) is one of the major methods employed in policy evaluation because it alleviates the endogeneity problem to some extent with two differences: one between periods, which is the difference between the periods before and after the policy intervention, and the other between groups, which is the difference between the treatment group and the control group. The traditional DID method is used for a one-off policy shock. However, the National Technology Zone pilot is a kind of staggered policy. Therefore, we use the staggered DID method for our estimations. The basic regression model is as follows:

$$y_{it} = \beta_0 + A_i + B_t + \gamma did_i + \sum \delta X_{it} + \varepsilon_{it} \tag{1}$$

where y_{it} represents the innovation of firm i in year t. The innovation indicator can be patent quantity, average patent quality, and innovation (quantity multiplied by average quality). β_0 is the intercept term; A_i is the firm fixed effect; B_t is the time fixed effect; and ε_{it} is the random error term. did_i is the core explanatory variable, the coefficient of which tells the impact of the establishment of NTZs on firm innovation. If the municipality was granted an NTZ in year t, then we set did_i at 1 for the municipality in and after year *t*, and 0 otherwise. If the municipality was granted the second NTZ in year t + m, then we would set did_i at 2 for the municipality in and after year t + m, and so on. More than one NTZ being authorized in one municipality in the same year is considered to be one NTZ in the basic regression model. We will later consider the number and the area of NTZs granted in one municipality in the same year.

$\sum \delta X_{it}$ represents a set of control variables that might affect firm innovation. On the basis of the existing literature and the variables in the Chinese Industrial Firm Census Database, we choose the following firm control variables:

① Scale – this is measured by the number of employees. According to Schumpeter's (1934) hypothesis, larger firms are more innovative;

② Export – this is measured by the real value of exports. According to the demand-pull hypothesis on innovation first put forth by Schmookler (1966), demand in larger markets benefits innovation. Therefore, exports might promote innovation by increasing market demand;

③ Capital intensity (Kintensity) – this is measured by the ratio of total assets to the number of employees. In general, capital-intensive industries, such as information and communication, have more patents than labor-intensive industries such as food and textiles do;

④ Age – this is measured by the period between the current year and the year that the firm first occurs in the sample. Schumpeter's (1934) "creative destruction" theory states that older innovations are gradually replaced by new innovations, which are usually created by young firms;

⑤ Administrative subordination (subordination): there are 10 levels of administrative subordination (with code in parentheses) in Chinese Industrial Firm Census Database: the central government (10); provinces (20); municipalities (40); counties (50); streets (61); towns (62); townships (63); neighborhood committees (71); village committees (72); and others (90). These codes are set by the NBS of China and are basically based on the administrative power of the authority. This is the variable with Chinese characteristics. Firms with higher-level administrative subordination obtain more government resources. Whether these resources benefit innovation depends on how firms use them;

⑥ Ownership – this can be divided into six types. They are as follows (with code in parentheses): state-owned enterprises (SOEs) (1); collective firms (2); Hong Kong-, Macao-, and Taiwan-based firms (3); foreign firms (4); legal-person firms (5); and private firms (6). This is also a variable with Chinese characteristics. China's economic transition has resulted in the many various types of firm ownership.

To alleviate the problem of abnormal value, we winsorize by 0.01 the following variables: Scale, Export, Kintensity, and Age, and then, we take the logarithm of these variables. To better alleviate the problem of missing variables, we use a two-way fixed effects model, in which the firm fixed effect and the time fixed effect are simultaneously controlled for. In addition, considering the huge gaps in innovation among provinces, we also add the dummy variable of province. Even though we have included firm fixed effect, the province dummy variable further controls the impact of firm mobility among provinces. We use standard errors that explain the clustering of firms to obtain more stable results. The descriptive statistics of variables in the basic regressions is shown in Table 3. Some control variables have missing values, and thus their observations are less than the total observation.

Table 3 Descriptive Statistics of Variables in the Basic Regressions

	Variable	Obs	Mean	Std.Dev.	Min	Max
Quantity Indicators	Patent	4,859,810	7.606	39.62	0	985.5
	Invention	4,859,810	2.905	21.93	0	903.9
	Invention (granted)	4,859,810	1.824	16.45	0	849.5
	Invention (ungranted)	4,859,810	1.589	15.61	0	817.1
	Utility Model	4,859,810	4.680	28.99	0	923.8
	Industrial Design	4,859,810	2.061	20.88	0	704.9
Quality Indicators	Invention	4,859,810	2.035	17.08	0	447.7
	Invention (granted)	4,859,810	1.517	15.12	0	499.7
	Invention (ungranted)	4,859,810	1.052	12.08	0	420.5
Innovation Indicators	Invention	4,859,810	4.500	32.95	0	1033
	Invention (granted)	4,859,810	2.992	26.37	0	1004
	Invention (ungranted)	4,859,810	2.386	22.82	0	897.5
DID	DID	4,859,810	0.286	0.605	0	4
Control Variables	Scale	4,828,657	4.853	1.166	1.386	7.883
	Export	4,859,810	2.043	4.007	0	12.59
	Kintensity	4,779,103	3.775	1.379	0.070	7.386
	Age	4,780,459	2.038	0.873	0	3.951
	Subordination	4,859,809	73.86	21.96	10	90
	Ownership	4,859,384	4.421	1.776	1	6

3 Effects of NTZs on the Overall Level of Innovation

3.1 Effects of NTZs on Patent Quantity

We first consider only patent quantity. We analyze all types of patents, including invention patents, utility models, and industrial designs. Invention patents can be further divided into granted inventions and ungranted inventions. Empirical results with the quantum of these types of patents as dependent variables are shown in Table 4. The DID coefficients in the six equations without control variables are significantly positive (see Panel A). After the control variables are added, the goodness of fit increases, and the six DID coefficients are still significantly positive (see Panel B). In addition, the values of these coefficients are relatively robust. Hence, the establishment of NTZs has resulted in growth in the numbers of all types of patents.

Now we come to an analysis of the coefficients of each control variable. The coefficients of Scale are all significantly positive, consistent with Schumpeter's hypothesis. The coefficients of Export are all significantly positive, supporting Schmookler's demand-pull hypothesis. This also suggests that to some extent, the recent rise of new protectionism may harm innovation. The coefficients of Kintensity are all significantly positive; capital-intensive industries contribute more to innovation than labor-intensive industries do. The declining demographic dividend in the past decade in China makes it increasingly difficult for China to obtain a comparative advantage through cheap labor. China is undergoing the important historical process of changing from labor-intensive to capital-intensive industries. In other words, the decline in demographic dividend is likely to force China to focus on innovation (Wei et al., 2017). The coefficients of Age are all significantly negative, indicating that younger firms might be more innovative, which, to some extent, benefits from China's long-term market-oriented reform. The coefficients of subordination are not highly significant in the equations related to inventions; however, they are significantly negative in the equations related to utility models and industrial designs. This suggests that increased government resources might only bring more low-quality patents related to utility models and industrial designs but not more low-quality patents related to inventions. The coefficient of ownership is significantly negative in the equation related to granted invention but insignificant in the equation relating to ungranted invention.

This, to some extent, indicates that SOEs have certain advantages over non-SOEs in granted invention applications, which are of higher quality than ungranted ones.

Table 4 The Impact of the Establishment of NTZs on Patent Quantity

Dependent Variable	Patent	Invention	Invention Granted	Invention Ungranted	Utility Model	Industrial Design
			Panel A：Without Controls			
DID	2.2643***	1.0520***	0.3763***	0.8595***	1.3299***	0.5613***
	(0.1051)	(0.0646)	(0.0480)	(0.0484)	(0.0774)	(0.0568)
R square	0.0362	0.0259	0.0181	0.0159	0.0319	0.0036
Obs	4859810	4859810	4859810	4859810	4859810	4859810
			Panel B：With Controls			
DID	2.3064***	1.0760***	0.3898***	0.8762***	1.3577***	0.5652***
	(0.1063)	(0.0654)	(0.0487)	(0.0492)	(0.0783)	(0.0578)
Scale	2.1303***	0.6439***	0.3512***	0.3387***	1.1260***	0.8067***
	(0.0694)	(0.0432)	(0.0341)	(0.0307)	(0.0521)	(0.0356)
Export	0.6183***	0.3064***	0.2109***	0.1740***	0.4294***	0.1584***
	(0.0145)	(0.0089)	(0.0069)	(0.0065)	(0.0108)	(0.0077)
Kintensity	1.8749***	0.8436***	0.5514***	0.4791***	1.2297***	0.5120***
	(0.0367)	(0.0221)	(0.0165)	(0.0161)	(0.0275)	(0.0185)
Age	-1.2058***	-0.8122***	-0.5566***	-0.4835***	-0.9194***	-0.1050***
	(0.0690)	(0.0421)	(0.0322)	(0.0293)	(0.0514)	(0.0341)
Subordination	-0.0080***	-0.0029	-0.0031*	-0.0016	-0.0061***	-0.0029**
	(0.0031)	(0.0021)	(0.0017)	(0.0015)	(0.0023)	(0.0015)
Ownership	-0.0971**	-0.0569**	-0.0638***	-0.0217	-0.0941***	-0.0575***
	(0.0434)	(0.0269)	(0.0208)	(0.0184)	(0.0325)	(0.0203)
R square	0.0403	0.0288	0.0203	0.0175	0.0353	0.0045
Obs	4701365	4701365	4701365	4701365	4701365	4701365

Note: Patent here includes invention, utility model and industrial design. *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses. Panel A includes regressions without control variables. Panel B includes regressions with all the six control variables mentioned above.

3.2 Effects of NTZs on Patent Quality and Innovation

The results presented in Table 4 have shown that the establishment of NTZs has significantly increased patent quantity, which, however, cannot reflect innovation well. In fact, there might be many low-quality patents, which do not necessarily represent innovation. This is one of the major reasons for which some people argue that China is making an innovation mirage. Therefore, the quality of patents must be seriously considered.

Forward citation is the most used indicator of patent quality, which first appears in bibliometrics studies (e.g., Campbell and Nieves, 1979; Carpenter et al., 1981; Carpenter and Narin, 1983). Trajtenberg (1990) was the first to apply the number of forward citations to economic research, and it has been widely used as an innovation indicator ever since. The most common way is to add up the number of patents with the number of forward citations as the weight to represent innovation (e.g., Arora et al., 2001; Harhoff et al., 2003; Hsu et al., 2014).

The biggest issue of using forward citations is truncation; that is to say, the number of citations after the last year of the data can never be known, and patents disclosed later face more serious truncation issues than those disclosed earlier. Because of this, following Aghion et al. (2019), we use the number of forward citations within 5 years since the patent's publishing, to measure patent quality. In fact, the number of invention patent citations within 5 years is as high as 76.20% of all citations by the end of 2018. In addition, the gap between the last year of Chinese Patent Census Database and that of Chinese Industrial Firm Census Database is 5 years, which allows us to use this indicator. Thus, unless otherwise specified, patent quality is measured by the number of forward citations within 5 years. We analyze only invention patents when considering patent quality because there are few forward citations for utility models and industrial designs. Unless otherwise specified, it is only invention patents that are referred to by "patents" in the following part.

We first use only average patent quality as the dependent variable. The results are shown in Columns 2–4 of Table 5. Then, we simultaneously consider the quantity and quality of patents. Following Aghion et al. (2019), we multiply the number of patents by the average quality of patents to obtain an innovation index. Innovation = Patent Quantity × (Average Patent Quality + 1). Here we use "Average Patent Quality + 1" rather than "Average Patent Quality" so that even if the number of citations is zero, the patent is still considered to be of some value because the patent data that we use have already been examined and published, although perhaps not yet granted, by SIPO. In so doing, there would also be fewer zero observations in our regression.

We use the new index of innovation as the dependent variable, and the regression results are shown in Columns 5–7 of Table 5. The DID coefficients are all significantly positive, whether we add the control variables or not. After adding the control variables, the DID coefficients are slightly higher and the goodness of fit is improved. Besides, the sign and significance of the coefficients of control variables are basically the same as those shown in Table 4. Therefore, we can conclude that the establishment of NTZs has improved the quality of patents. Even if we consider both the quantity and quality of patents, the establishment of NTZs still has improved innovation. In other words, China is not making an innovation mirage.

Table 5 The Impact of the Establishment of NTZs on Patent Quality

Dependent Variable	Average Patent Quality			Innovation		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
			Panel A：Without Controls			
DID	0.1630***	0.1012***	0.1240***	1.1903***	0.4531***	0.9599***
	(0.0351)	(0.0317)	(0.0260)	(0.0852)	(0.0671)	(0.0626)
R square	0.0086	0.0064	0.0052	0.0206	0.0138	0.0128
Obs	4859810	4859810	4859810	4859810	4859810	4859810
			Panel B：With Controls			
DID	0.1699***	0.1074***	0.1295***	1.2208***	0.4721***	0.9815***
	(0.0357)	(0.0323)	(0.0265)	(0.0863)	(0.0680)	(0.0636)
Scale	0.8086***	0.5947***	0.4429***	1.2885***	0.8149***	0.6779***
	(0.0278)	(0.0252)	(0.0206)	(0.0615)	(0.0508)	(0.0434)
Export	0.1529***	0.1243***	0.0954***	0.4325***	0.3105***	0.2482***
	(0.0060)	(0.0054)	(0.0043)	(0.0129)	(0.0105)	(0.0091)
Kintensity	0.4702***	0.3637***	0.2815***	1.2253***	0.8404***	0.6957***
	(0.0152)	(0.0135)	(0.0110)	(0.0320)	(0.0255)	(0.0228)
Age	-0.3426***	-0.2999***	-0.2088***	-1.1002***	-0.7980***	-0.6506***
	(0.0277)	(0.0248)	(0.0191)	(0.0613)	(0.0497)	(0.0416)
Subordination	-0.0008	-0.0013	-0.0016	-0.0040	-0.0045*	-0.0029
	(0.0014)	(0.0013)	(0.0010)	(0.0030)	(0.0025)	(0.0021)
Ownership	-0.0302	-0.0437***	-0.0094	-0.0847**	-0.1007***	-0.0301
	(0.0192)	(0.0169)	(0.0135)	(0.0402)	(0.0326)	(0.0270)
R square	0.0098	0.0073	0.0059	0.0231	0.0156	0.0143
Obs	4701365	4701365	4701365	4701365	4701365	4701365

Note: Patent here refers to invention only. Patent quality is measured by five-year forward citations *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses. Panel A includes regressions without control variables. Panel B includes regressions with all the six control variables mentioned above. Innovation = Patent Quantity × (Average Patent Quality+1).

3.3 Dynamic Effects of the Establishment of NTZs

The above empirical results have identified the positive effects of the establishment of NTZs on innovation. However, the dynamic effects remain to be investigated. Hence, we replace the DID variable with a series of year dummy variables $\sum_{T=-10,\ T\neq-1}^{10} D_i^T$. D_i^T means the Tth year before or after the establishment of NTZs in municipality i. If $\text{year} - \text{year}_{i0} = \text{T}$, then $D_i^T = 1$, and 0 otherwise, where year refers to the current year, and year_{i0} is the year when municipality i is granted NTZs.

In line with existing studies (e.g., Beck et al., 2010; Wang, 2013), we only consider the 10-year period before and after the establishment of NTZs. If $\text{year} - \text{year}_{i0} \leq -10$, then $D_i^{-10} = 1$, and zero otherwise. Similarly, if $\text{year} - \text{year}_{i0} \geq 10$, then $D_i^{10} = 1$, and 0 otherwise. We ignore the dummy variable D_i^{-1}, and thus, the coefficients of all other dummy variables are relative to the effect of the year right before the establishment of NTZs.

Because the establishment of different NTZs took place in different years for a given municipality, we take the principle of proximity when defining year_{i0}. Assuming that municipality A has been granted an NTZ in 2000, 2005, and 2009, then year_{i0} equals 2000 for the period 1995–2004; 2005 for the period 2005–2008; and 2009 for the period 2009–2013.

Figure 2 provides the coefficient and 95% confidence interval of each dummy variable. The innovation effect is positive right after the establishment of NTZs. Furthermore, the positive effect is strengthened over time, which might be attributed to the increasingly mature state–market relationship with the ongoing process of trial and error. However, prior to the establishment of NTZs, the coefficient of each dummy variable is insignificantly different from 0, and without obvious trend. This, to a certain extent, indicates that the endogeneity problem related to the staggered DID regression is not very serious.

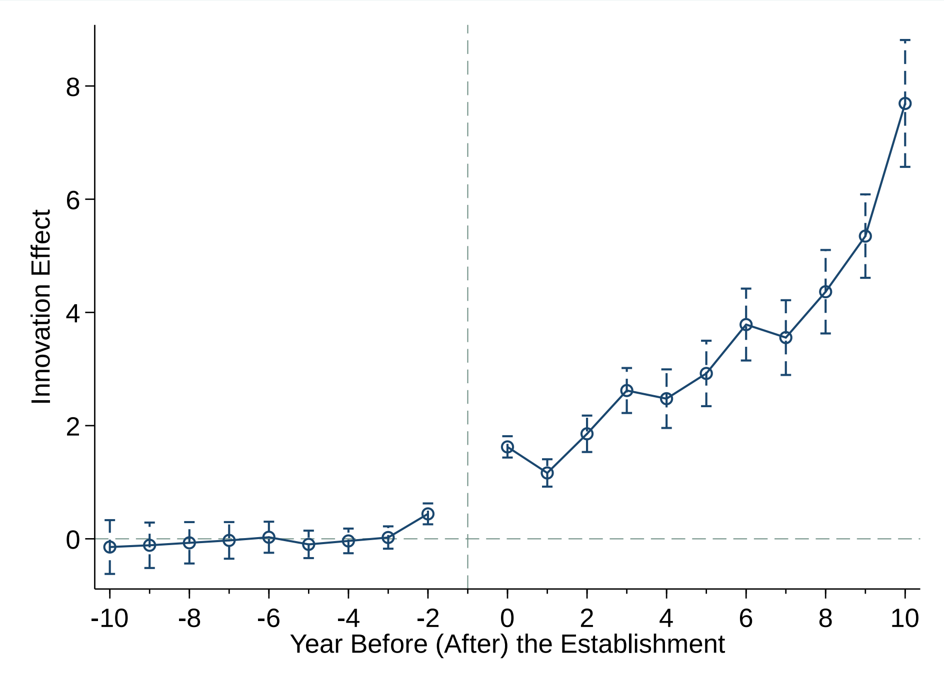

Figure 2 Dynamic Effects of the Establishment of NTZs on Innovation

3.4 Robustness Analysis

To verify whether our results are robust, we conduct a series of robustness analyses (See Appendix III for details).

First, we employ two alternative indicators of patent quality: one-year forward citation and the number of claims, in the event that 5-year forward citation is not good enough. Second, we consider the number and area of NTZs, which might also significantly influence innovation. Third, we analyze the effects of National Econ-Tech Zones and National High-Tech Zones on innovation separately in order to test whether both have positive effects as the NTZs do. Fourth, we investigate the influence of firm mobility among municipalities on innovation, considering the possible spillover effects or beggar-thy-neighbor effects. Fifth, we come to study the endogeneity issues by drawing the scatter plot between the year that a city is authorized the first NTZ and the innovation rank 2 years prior to the NTZ being authorized and also by conducting 2SLS regression with the connections of local officials in the central government as the IVs. Sixth, we drop the sample in the municipalities that had been authorized NTZs before 1995, in order to obtain a new control group.

We redo these regressions and all the results are robust, providing strong evidence for our basic conclusion that the establishment of NTZs does exert positive effects on the overall level of innovation.

4 Effects of NTZs on High-quality Innovation

The preceding analysis shows the promotional effects of the establishment of NTZs on the overall level of innovation. In order to provide further evidence as to the innovation miracle, we investigate the effects of NTZs on high-quality innovation, which we refer to as innovation in high-tech industries and indigenous innovation.

High-tech industries in China have experienced great development since the *National High Technology Research and Development Program* (*"863" plan*) in 1986, and both the value added and export of high-tech industries of China has surpassed those of the US. However, the ratio of the labor productivity of high-tech industries in China to that in the US only increased slightly from 8.36% in 2000 to 8.66% in 2013,[7] indicating that the innovation of high-tech industries in China still lagged far behind that in the US. Rather than utilizing labor productivity, we use patent as innovation indicator to re-examine the innovation of high-tech industries.

In addition, the classical models on trade and innovation (e.g., Krugman, 1979; Grossman and Helpman, 1991a, 1991b) all assume indigenous innovation as coming from developed countries, with developing countries only carrying out imitative innovation. As a developing country, China is behind in indigenous innovation, and its core technologies are heavily dependent on developed countries, which can be seen from the US sanctions on chips of Huawei and ZTE since 2018. Now we use patent data to review the effects of innovation strategy on indigenous innovation.

4.1 Effects of NTZs on High-tech Industries

To identify the innovation promotion effect on high-tech industries, we set a new dummy variable: medium- and low-tech industry (hereinafter "*Medium-Low*"), which takes a value of 1 if the firm belongs to the medium- and low-tech industries, and 0 if it belongs to high-tech industries. Subsequently, we incorporate the interaction term between *Medium-Low* and *DID* into regression model (1), leaving all other variables unchanged. The classification of high-tech industries springs from the *Catalogue of Statistical Classifications of High-tech Industries*. To harmonize different editions of classification, we drop the "nuclear fuel processing" industry.

The results are shown in Table 6. Because of space limitation, we have not listed the regression results with patent quantity or average patent quality as dependent variables, which are like the results with innovation as the dependent variable. The coefficients of the interaction item are all significantly negative, which indicate that the innovation effects of the establishment of NTZs on high-tech industries are larger than those on medium- and low-tech industries. Both the DID coefficient and the coefficient of interaction item are significant, and the sum of the two coefficients is positive, which means that the establishment of NTZs has also promoted innovation of medium- and low-tech industries. However, the sum of the two coefficients is much smaller than the corresponding DID coefficient in Table 5. This indicates that the innovation effect of the establishment of NTZs on medium- and low-tech industries is still very limited. The reason for this would be that the main goal of NTZs is to promote the innovation of high-tech industries; however, the innovation spillovers from high-tech industries to medium- and low-tech industries are far from adequate.

In summary, the establishment of NTZs has significantly promoted the innovation of high-tech industries.

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[7] The value added of high-tech industries in China and the U.S. is from the National Science Foundation of the U.S (in current US dollars). Employment of high-tech industries in China is from *China Statistics Yearbook on High Technology Industry*, and Employment of high-tech industries in the U.S. is from the National Science Foundation of the US.

Table 6 Innovation Effects of the Establishment of NTZs on High-tech Industries

	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
DID	6.4153***	4.3130***	4.0328***	6.3147***	4.2455***	3.9674***
	(0.3161)	(0.2565)	(0.2355)	(0.3179)	(0.2588)	(0.2372)
Medium-Low *DID	-5.7399***	-4.2403***	-3.3758***	-5.6009***	-4.1489***	-3.2831***
	(0.3165)	(0.2565)	(0.2359)	(0.3184)	(0.2589)	(0.2378)
Controls	No	No	No	Yes	Yes	Yes
R square	0.0214	0.0145	0.0133	0.0238	0.0163	0.0148
Obs	4859810	4859810	4859810	4701365	4701365	4701365

Note: Patent here refers to invention only. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

4.2 Effects of NTZs on Indigenous Innovation

Research abounds on indigenous innovation, and various indicators have been used to measure indigenous innovation. However, indicators utilized to measure indigenous innovation in China are still based on patent quantity. Li et al. (2016) directly employ the number of patent applications as a proxy for indigenous innovation. Wu and Liu (2013) go even further and measure indigenous innovation in terms of the number of invention grants. Obviously, invention grants are of higher quality when compared with invention applications.

However, all the above indicators are limited to patent quantity, without identifying the quality. The quantity of patents, whether patent applications or grants, is very limited in representing indigenous innovation. There are still large amounts of invention grants that are in actuality imitative innovation, particularly for developing countries. Therefore, we use the indicator of science relation to measure indigenous innovation. What we have used above as patent quality indicator is based on forward citations. Now we come to backward citations, which include not just patents but also scientific documents (e.g., research reports and academic papers). Science relation refers to the ratio of the number of scientific documents to all the backward citations, which have been used in many papers (e.g., Albert et al., 1991; Trajtenberg et al., 1997). Our data shows that the ratio of firms with science relation larger than zero to all firms is approximately 0.89%, but that to firms with patents is approximately 39.20%. We first calculate the science relation of each patent, and then, we calculate the average science relation of all patents for each firm, that is, the *average indigenous innovation*. We obtain *indigenous innovation* by multiplying average indigenous innovation by patent quantity.[8] The results are shown in Table 7.

We mainly focus on Columns 5–7, where indigenous innovation is the dependent variable. All the DID coefficients are significantly positive, which indicates that the establishment of NTZs has promoted indigenous innovation. If we come to Columns 2–4, where average indigenous innovation is the dependent variable, we would find an interesting story. The DID coefficient for granted patents is significantly positive, but it is insignificant for ungranted patents. This means that the establishment of NTZs might have encouraged the application of patents with relatively low quality; however, the SIPO is very strict when authorizing patents, which makes the granted patents of relatively higher quality.

In addition, some patent citations are self-citations, which have little to do with indigenous innovation. Therefore, we first calculate the number of self-citations by identifying whether the patents in the backward citations are being applied for by the same applicants. When calculating self-citations, we consider all the applicants rather than the first applicants as Trajtenberg et al. (1997) do. Then we subtract the self-citations from the total backward citations, on the basis of which we obtain a new indicator of science relation, and then, we obtain the new indicator of average indigenous innovation and that of indigenous innovation. We redo the regressions by replacing the old dependent

[8] To note that unlike the calculation of *innovation*, the formula of *indigenous innovation* is a little bit different: Indigenous Innovation = Patent Quantity × Average Indigenous Innovation. We do not use "Average Indigenous Innovation+1" here because the requirement for indigenous innovation is much higher than that for innovation. In other words, patent being published mean would mean innovation but don't necessarily mean indigenous innovation.

variables with the new ones, and the results are basically the same. These results are not listed because of space limitations.

In sum, the establishment of NTZs has promoted indigenous innovation.

Table 7 The Impact of the Establishment of NTZs on Indigenous Innovation

Dependent Variable	Average Indigenous Innovation			Indigenous Innovation		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
DID	0.1832***	0.1461**	0.0805	0.4069***	0.1854**	0.2182***
	(0.0700)	(0.0622)	(0.0522)	(0.1043)	(0.0867)	(0.0713)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0070	0.0053	0.0037	0.0092	0.0067	0.0044
Obs	4701365	4701365	4701365	4701365	4701365	4701365

Note: Patent here refers to invention only. Indigenous Innovation = Patent Quantity × Average Indigenous Innovation. *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

5 The Establishment of NTZs and Innovation Mirage

5.1 Innovation Effects before and after the Financial Crisis

Previous relevant studies (e.g., Wang, 2013; Moberg, 2015; Zheng et al., 2016) have not conducted comparative analyses of innovation effects of the establishment of NTZs before and after the financial crisis. In fact, both economic development and innovation strategy have experienced great changes. Following the 2008 financial crisis, China's economic growth has slowed down significantly, and the old engine of development, cheap labor, has been declining. The average wage in China is higher than that in most non-OECD countries and three times higher than that in India (Wei et al., 2017). Technological innovation has become the new key engine of development for China in the new era. Following the financial crisis, China has issued a series of national innovation development strategies, and the establishment of NTZs has also experienced a highpoint. During 2009–2013, there were 156 National Econ-Tech Zones (71.23% of the total) and 60 National High-Tech Zones (38.46% of the total) being established (see Figure A2 in Appendix I). Therefore, we divide the period into two stages: pre-financial crisis (1995–2008) and post-financial crisis (2009–2013). Considering the possible impact of the municipalities that had been authorized NTZs during 1995–2008, we drop these municipalities when studying the situation after the financial crisis.

The results in Panel C of Table 8 show that the DID coefficients are all significantly positive, meaning that NTZs established in both periods have promoted firm innovation. The DID coefficients are also significantly positive for patent quantity in both periods (see Panel A). However, when it comes to patent quality (Panel B), the DID coefficients are significantly positive before the financial crisis but insignificant thereafter. This means that NTZs established before the financial crisis did promote patent quality but that those established after the crisis failed.

The explanation is that NTZs were granted sporadically before the financial crisis, which seemed to be demand-driven, and thus, they generally met the needs of economic development. However, the massive NTZs granted after the financial crisis seemed to be supply-driven and might have exceeded the needs of economic development at least in the short run.

Furthermore, quantified goals for patent growth have been put forward in the macro planning after the financial crisis, which aggravate the innovation effect of NTZs. The *12th* five-year plan made by the central government of China in 2010 incorporated the quantified goal for patent growth into the five-year plan for the first time. The *National Patent Development Strategy (2011–2020)* further highlighted the quantified goal for PCT growth. While the perfection of competitive market system and patent system reform, which indicates a stronger market hand, is likely to attract nonresidents to apply for patents in China, macro planning, which indicates stronger government hand, might not. This would explain the relative slowdown of patent applications by nonresidents after 2009. Li and Zhou (2005) provide a promotion tournament hypothesis to explain China's miracle. The hypothesis claims that, with the incentive role of personnel control, the central government can realize its quantified goal for GDP (gross domestic product) growth without spending additional economic resources. When it comes to its quantified goal for patent growth, the incentive role of personnel control works in a similar way, which brings a boost in the number of patents (and PCTs) after 2009. However, the quantified goal for patent growth involves only patent quantity, instead of patent quality. This relatively radical macro planning would, to a large extent, help explain the innovation mirage after the financial crisis.

Of course, the time frame that can be used to analyze the effect of the establishment of NTZs after the financial crisis is no more than 5 years, which might have influenced the results. However, as shown in Figure 2, the establishment of NTZs takes effect instantly, and thus, time frame would not be a major factor influencing the outcome. Therefore, it would be safe to conclude that the establishment of NTZs after the financial crisis is relatively irrational and fails to promote patent quality at least in the short run. In other words, it is making an innovation mirage, that is, rapid but relatively low-quality patent growth.

Table 8 Innovation effects of the establishment of NTZs Before and after the financial crisis

Dependent Variable	1995-2008			2009-2013		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
			Panel A：Patent Quantity			
DID	1.1644***	0.7150***	0.6543***	0.8899***	0.3474***	0.7265***
	(0.1146)	(0.0883)	(0.0766)	(0.0773)	(0.0530)	(0.0650)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0110	0.0081	0.0062	0.0080	0.0050	0.0052
Obs	3019015	3019015	3019015	1487114	1487114	1487114
			Panel B: Average Patent Quality			
DID	1.0367***	0.7263***	0.6121***	0.0488	0.0454	0.0524
	(0.0940)	(0.0819)	(0.0638)	(0.0526)	(0.0478)	(0.0417)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0078	0.0058	0.0045	0.0007	0.0004	0.0006
Obs	3019015	3019015	3019015	1487114	1487114	1487114
			Panel C: Innovation			
DID	1.9749***	1.2714***	1.1125***	0.9491***	0.3990***	0.7732***
	(0.1833)	(0.1484)	(0.1201)	(0.1047)	(0.0793)	(0.0862)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0112	0.0081	0.0064	0.0031	0.0014	0.0026
Obs	3019015	3019015	3019015	1487114	1487114	1487114

Note: Patent here refers to invention only. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

5.2 Innovation Effects on Firms with Different Ownerships

We divided firms into three categories on the basis of ownership: SOEs, privately-owned enterprises (POEs), and foreign-owned enterprises (FOEs).[9] The results are shown in Table 9. We first concentrate on Panel C. All the DID coefficients are significantly positive, meaning that the establishment of NTZs has promoted innovation for all types of firms.

Now we look at Panel A and Panel B. All the DID coefficients are significantly positive in Panel A. When it comes to patent quality (Panel B), however, only the DID coefficients for SOEs are all significantly positive. The DID coefficient for granted patents of POEs is insignificant, and the three DID coefficients for FOEs are all insignificant, which, to some extent, argues against the aforementioned technology transfer hypothesis. That is to say, the positive effects of the establishment of NTZs on average patent quality for POEs and FOEs are inferior to those for SOEs. The reason for

[9] To better control the heterogeneity of firms with different ownerships, we have divided firms into six categories in previous parts. Now, we divide firms into three categories to better investigate the implications of different ownerships. SOEs include SOEs and collective firms. FOEs include Hong Kong-, Macao-, and Taiwan-based firms and foreign firms. POEs include legal-person firms and private firms.

this would be that fair competition between SOEs and non-SOEs is still limited in China. In fact, it was not until 2019 that the central government of China put forth the principle of "Neutral Competition", mainly referring to fair competition between SOEs and non-SOEs.

Figure 3 shows the annual invention applications by firms with different ownerships. The (descending) order of the number of invention applications is POE, FOE, and SOE, respectively. After the financial crisis, the growth of invention applications by all types of firms has accelerated, and that by POE is much faster. Therefore, the relatively limited effect of the establishment of NTZs on the quality of patent applications by POEs and FOEs would indicate a certain innovation mirage in total.

In sum, the establishment of NTZs has brought patent quality enhancement for SOEs but not for non-SOEs (particularly FOEs), which might be ascribed to the imperfect market institution. In fact, it was not until 2019 that the central government of China proposed to unify the treatment of domestic and foreign investment, and put forward the principle of neutral competition between SOE and non-SOE.

Table 9 Innovation Effects of the Establishment of NTZs on Firms with Different Ownerships

	SOEs			POEs			FOEs		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
Panel A：Patent Quantity									
DID	1.4950***	0.9615***	0.8281***	1.1836***	0.3418***	1.0550***	0.6285***	0.2533**	0.4852***
	(0.2217)	(0.1782)	(0.1550)	(0.0776)	(0.0544)	(0.0610)	(0.1351)	(0.1062)	(0.0981)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0287	0.0224	0.0192	0.0272	0.0186	0.0168	0.0262	0.0195	0.0149
Obs	937542	937542	937542	2888567	2888567	2888567	875256	875256	875256
Panel B: Average Patent Quality									
DID	0.6172***	0.5117***	0.2647***	0.1238***	0.0630	0.1320***	0.0984	0.0579	0.0726
	(0.1251)	(0.1157)	(0.0885)	(0.0457)	(0.0413)	(0.0344)	(0.0679)	(0.0618)	(0.0496)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0096	0.0083	0.0063	0.0085	0.0062	0.0052	0.0094	0.0071	0.0054
Obs	937542	937542	937542	2888567	2888567	2888567	875256	875256	875256
Panel C: Innovation									
DID	1.9904***	1.3715***	1.0282***	1.2981***	0.3918***	1.1687***	0.7141***	0.2987**	0.5424***
	(0.3051)	(0.2578)	(0.2089)	(0.1037)	(0.0792)	(0.0794)	(0.1738)	(0.1419)	(0.1244)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0225	0.0175	0.0149	0.0211	0.0137	0.0133	0.0215	0.0154	0.0124
Obs	937542	937542	937542	2888567	2888567	2888567	875256	875256	875256

Note: Patent here refers to invention only. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

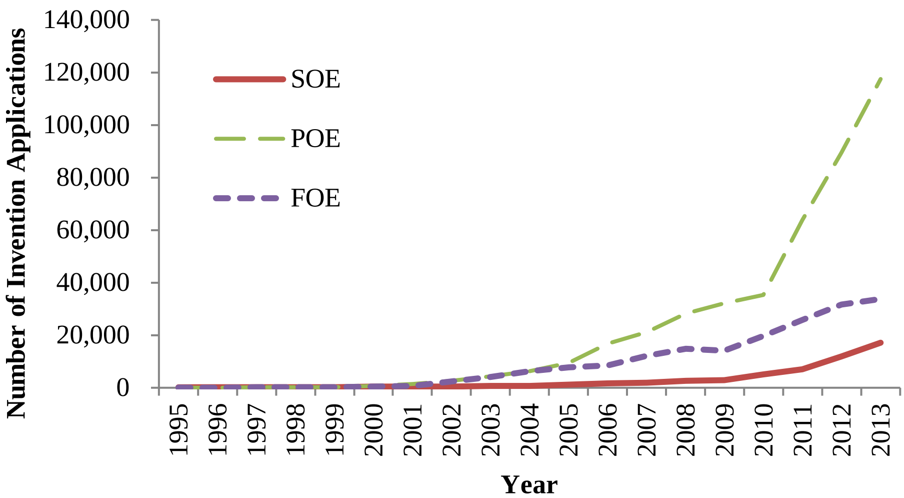

Figure 3 Annual Invention Applications by firms with Different Ownerships

6 Mechanisms of the Innovation Effects

There are some articles investigating the mechanisms of the effect of NTZs on firm innovation based on case studies. Wang and Wang (1998) study the technological learning of Zhongguancun, an NTZ in Beijing. They find that domestic institutes (universities, research institutions, and domestic firms) are playing an increasingly important role when compared with foreign firms in the learning process and claim that the self-sustained innovativeness is critical for domestic firms to avoid reliance on foreign technologies. Lu (2001) investigates the information technology industry in Zhongguancun and finds local technological knowledge to be critical for the rise of technology firms. Zhou and Xin (2003) further investigate the innovation interaction between domestic firms and multinational firms in Zhongguancun. They also find that domestic research institutes (universities and research institutions) are increasingly important when compared with foreign firms in promoting learning capability and thus innovation of local firms. Liefner et al. (2006) regard both foreign firms and domestic research institutes as helping promote the innovation of firms in Zhongguancun and argue that firms without the necessary learning capability might not be able to absorb foreign technologies.

The above literature concentrates on two mechanisms: firm–academia collaboration and FDI inflows, which correspond to the two major channels mentioned in China's official documents on developing NTZs as mentioned in Section 2. In addition, they are also in line with the two major sources of technological learning (learning by doing domestically and learning by importing foreign technologies) as mentioned in the technology catch-up literature (e.g., Kim, 1997; Shen, 1999; Fu et al., 2011). As for learning by doing domestically, different articles use different words to express similar meaning, such as independent approach (Kim, 1997), indigenous technological development (Shen, 1999), indigenous innovation (Fu et al., 2011). Learning by doing here includes not merely the learning by producing or investing as mentioned in Arrow (1962), but developing or utilizing all kinds of domestic technological knowledge. When it comes to learning by importing foreign technologies, the statements also differ, such as learning by importing (Kim, 1997), foreign technology transfer (Shen, 1999), absorption of foreign technology (Fu et al., 2011). Therefore, we explore the mechanisms from two aspects: learning by doing domestically and learning by importing technologies.

We utilize the number of co-applied patents by firms and research institutes as a proxy for learning by doing domestically. Research institutes provide domestic technological knowledge for firms. There are two ways in which firms and research institutes that cooperate can be categorized. The first is formal cooperation, which includes, among other things, co-applied patents, joint research and development projects, joint establishment of research institutions, transfer of patents to firms from research institutes, and joint ventures. The second is informal cooperation, including talent network, knowledge exchange, and knowledge sharing, among other things. Co-applied patents are a kind of relatively direct and deep cooperation that indicates not only the patent itself but also the wide cooperation between firms and research institutes. We employ FDI as a proxy for learning by importing technologies, which includes importing hard technologies such as capital goods and soft technologies such as talents.

Based on the above two streams of literature (on NTZ case studies and on technology catch-up), two interaction items are added to the basic regression model: the interaction item between co-applied patents and DID (FRU*DID) and that between FDI and DID (FDI*DID). In fact, the incorporation of the two interaction items is also in line with the original intention of Chinese central government in establishing NTZs: taking advantage of FDI and domestic technological knowledge to promote innovation.

The result for the whole period is shown in Column 2 of Table 10. Both interaction items are positive and significant at the 1% level. This indicates that both the research institutes and FDI serve as important mechanisms of the effect of NTZs on firm innovation.

To identify the evolution of the two mechanisms, we compare the results pre- and post-financial crisis. The results are shown in Columns 3–4 of Table 10. Before the financial crisis (1995–2008), both interaction items were positive and significant, meaning that both the research institutes and FDI served as the important mechanisms. However, the situation after the financial crisis (2009–2013) was a little bit different. The coefficient of FRU*DID is significant and positive, but that of FDI*DID is insignificant. This means that research institutes still serve as an important mechanism; however, FDI does not significantly impact the innovation effect of NTZs, which might be attributed to the sharp decline of FDI growth after the financial crisis. This might also indicate that China is relying more on learning by doing domestically. Kim (1997) asserts that learning by doing domestically becomes more important than learning by importing technologies when a country moves from the stage of imitative innovation to that of indigenous innovation. Therefore, our empirical results might also indicate that China is experiencing a great transition from imitative innovation to indigenous innovation.

We then analyze the coefficient of DID. In Column 2, the coefficient of DID is negative but is much smaller compared with that in Table 5. This indicates that without the two factors (research institutes and FDI), the establishment of NTZs would a negative but mild impact on firm innovation, which further indicates the importance of the two mechanisms. Now we analyze the two periods separately. Before the financial crisis (Column 3), the coefficient of DID is positive and significant at the 1% level, meaning that even without the two factors, there still would be, in all likelihood, other factors promoting the innovation effect of the establishment of NTZs. After the financial crisis (Column 4), the coefficient of DID is positive but only significant at the 10% level, which means that without the two factors, the establishment of NTZs would have no significant or weak impact on firm innovation. Both coefficients of DID are smaller compared with those in Table 6.

Table 10 Two Mechanisms of the Innovation Effect of NTZs

	1995-2013	1995-2008	2009-2013
DID	-0.2008**	0.9727***	0.1712*
	(0.0857)	(0.1451)	(0.1013)
DID*FRU	80.7641***	173.8567***	50.4120***
	(2.9154)	(5.1127)	(2.3841)
DID*FDI	0.7224***	0.7297***	0.0094
	(0.0393)	(0.0839)	(0.0437)
Scale	1.3520***	1.8416***	0.2004**
	(0.0599)	(0.0553)	(0.0904)
Export	0.4215***	0.1789***	0.2136***
	(0.0127)	(0.0105)	(0.0252)
Kintensity	1.2321***	0.5772***	0.5434***
	(0.0315)	(0.0302)	(0.0486)
Age	-1.0324***	-0.4831***	0.1669
	(0.0596)	(0.0451)	(0.1447)
Subordination	-0.0038	0.0031	-0.0149***
	(0.0029)	(0.0026)	(0.0056)
Ownership	-0.0746*	-0.0499	0.2422**
	(0.0395)	(0.0305)	(0.1038)
R square	0.0383	0.0238	0.0121
Obs	4701365	3019015	1682350

Note: Patent here refers to invention only. Patent quality is measured by five-year forward citations *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses. Innovation = Patent Quantity × (Average Patent Quality+1).

7. Conclusions and Policy Implications

Is China's innovation boom a miracle or mirage? The issue has attracted widespread attention around the world but remains to be answered in a strict and normative way. First, existing patent growth hypotheses focuses on one dimension (a certain institution or policy), and thus fail to illustrate many important parts of innovation development in China. Second, previous related studies consider only patent quantity without incorporating patent quality, making it difficult to accurately measure innovation. We solve the two challenges in the existing literature by focusing on the establishment of NTZs, which includes a range of institutions and policies, and identifying the quality of patents with our unique Chinese Patent Census Database. In doing so, we can systematically answer the above question.

Our empirical results show that China, in general, is creating an innovation miracle. The establishment of NTZs has promoted the overall level of innovation, the innovation of high-tech industries, and indigenous innovation measured by both the quantity and quality of invention patents. This conclusion has passed a series of robustness tests. Apart from this, the dynamic analysis shows that the effect of the establishment of NTZs on innovation is instantaneous and has strengthened over time.

However, there are two types of innovation mirages as well. The first is the mirage of patent quality after the financial crisis. The establishment of NTZs has no significant impact on patent quality after the financial crisis, which might be attributed to the relatively radical macro planning from then on. The second is the mirage of innovation structure; that is to say, the balanced development of China's innovation structure has deteriorated. The establishment of NTZs has brought patent quality enhancement for SOEs but not for non-SOEs (particularly FOEs), which might be ascribed to the imperfect market institution.

All in all, we have provided strong evidence that China in general is creating an innovation miracle with its national innovation development strategy. Though more studies are still needed in terms of the NTZ strategy package (institutions, policies, macro planning) in order to investigate the reasons behind the innovation miracle and innovation mirage in China, We are able to draw some broad policy suggestions on the basis of our analysis. First, innovation development is the result of the joint action of market (institutions) and government (policies, macro planning). The absence of either side would fail to explain the innovation boom in China. Second, a well-designed macro planning should consider not only patent quantity but also patent quality. Third, the market reform should keep pace with the evolution of innovation, or it would become a hindrance, and might lead to the mirage of innovation structure.

One thing to note is that the conclusions of our empirical results should be interpreted with caution when being generalized. First, there are some innovations that do not take the form of patents, but patents are a relatively better innovation indicator. Second, since non-above-scale industrial firms and firms in service sectors are not included in the Chinese Industrial Firm Census Database available, we are not able to investigate innovation of these firms. Patent applications by above-scale industrial firms account for 44.07% of the total patent applications by domestic firms and 83.88% of industrial firm patents; thus, our sample is relatively representative. Third, NTZs might not be able to tell the whole story of the national innovation development strategy although it is multidimensional and comprehensive when compared with patent subsidy policy, patent system reform, technology transfer policy, etc. Fourth, the cost of innovation development in China should also be considered when evaluating the innovation boom, which is what our future study will focus on.

Appendix

Appendix I: Figures Mentioned in Section 1 and Section 2

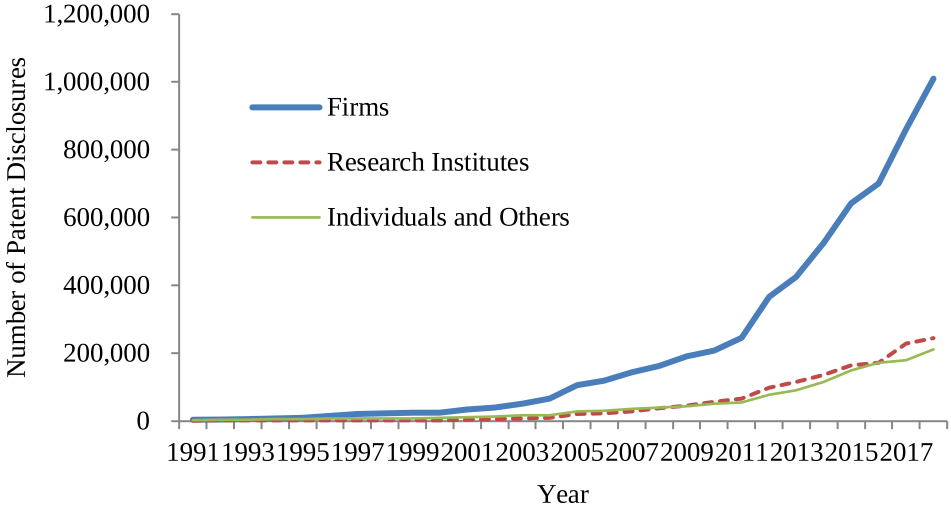

Figure A1 Number of Patent Disclosures by Applicant Type (1991-2018)

Note: To avoid the time-lag error between patent application and patent disclosure, we use the number of annual patent disclosures rather than that of annual patent applications. Research Institutes include scientific research institutions and universities.
Source: Author calculations based on Chinese Patent Census Database.

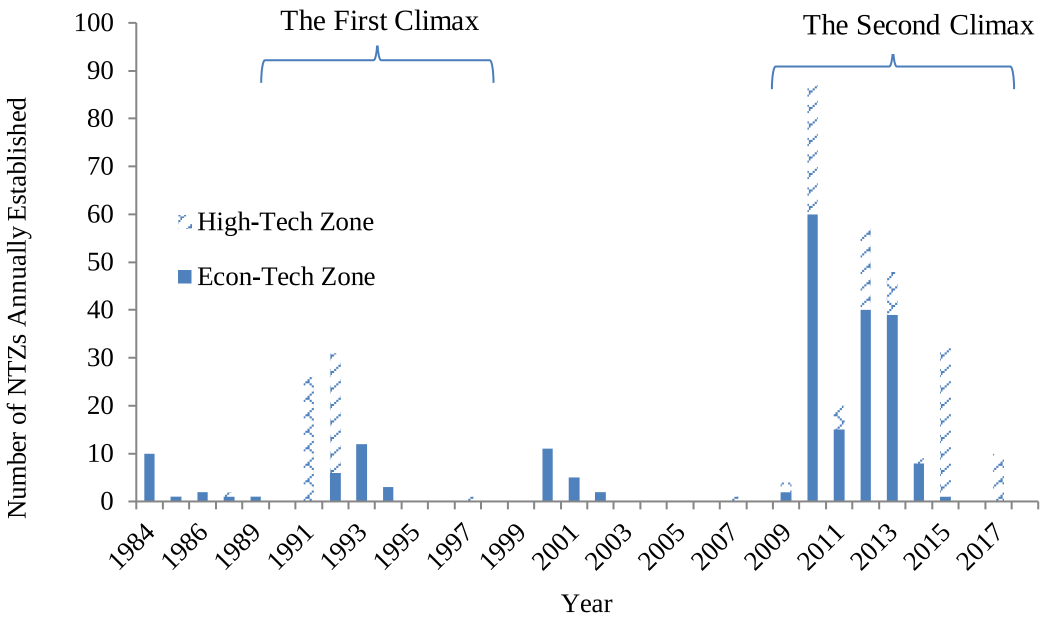

Figure A2 Number of NTZs Annually Established in China (1984–2018)

Source: Author calculations based on data from the China Development Zone Audit Announcement Catalogue (2018 Edition).

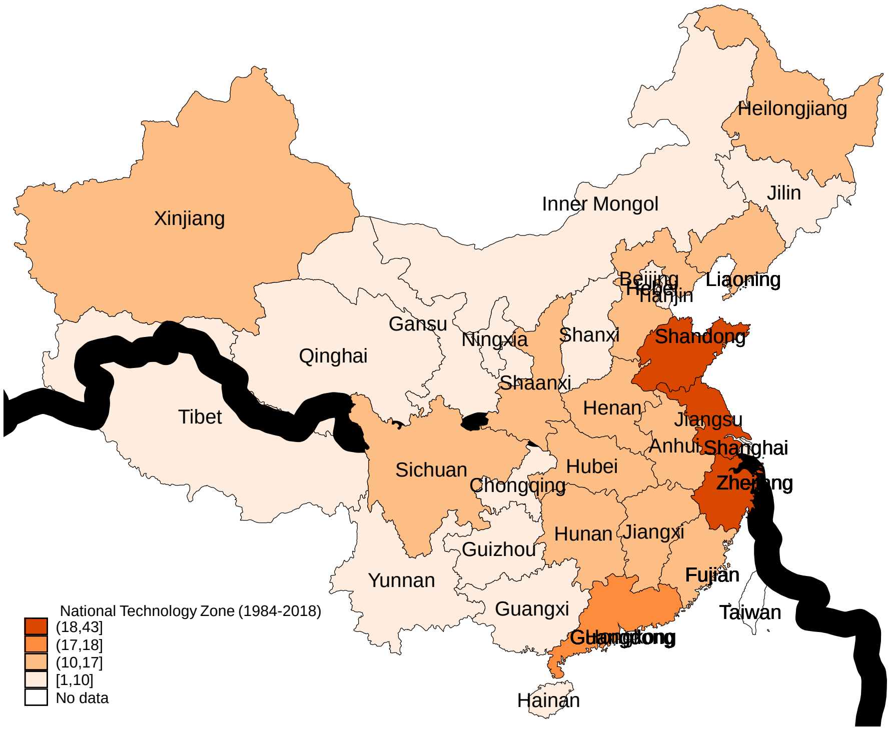

Figure A3 Provincial Distribution of the Number of Total NTZs in mainland China

Source: Author calculations based on data from the China Development Zone Audit Announcement Catalogue (2018 Edition).

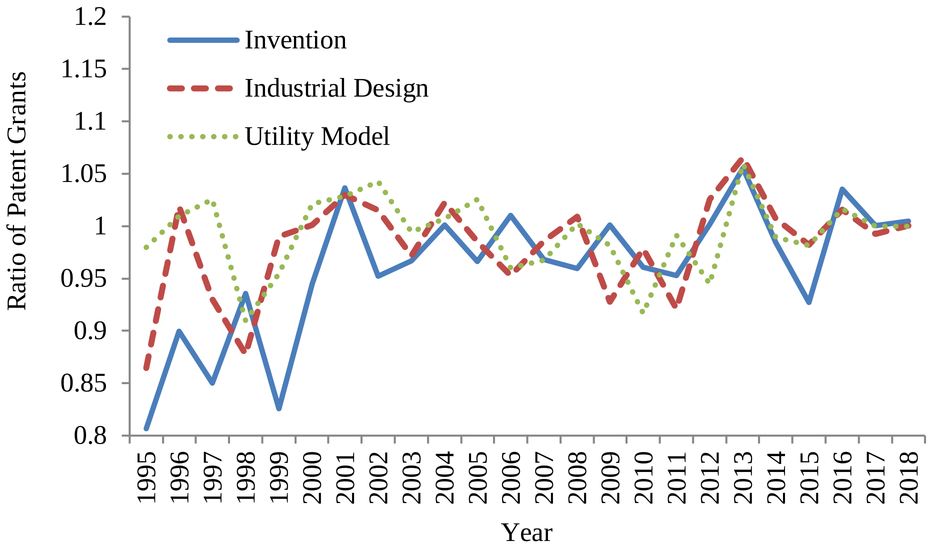

Figure A4 The ratio of patent grants from two resources: Chinese Patent Census Database and *Patent Statistics Annual Report.*

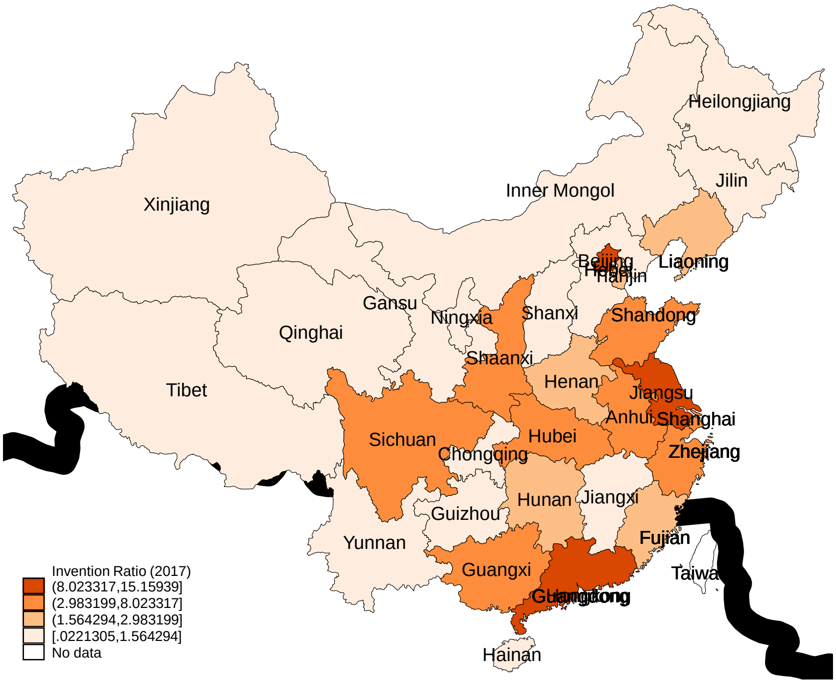

Figure A5 Provincial Distribution of Invention Ratio in 2017 (%) in mainland China

Note: Invention Ratio refers to the ratio of invention applications in certain provinces to those in mainland China.
Source: Author calculations based on data from Patent Statistics Annual Report.

Appendix II: Comparisons among Innovation Indicators

We explain here why a patent is an excellent indicator of technological innovation. Commonly used innovation indicators include R&D, patents, productivity, and the value of new products. The roles of these four types of innovation indicators can be illustrated with the input and output of technological knowledge as shown in Figure A6.

R&D is only one of the several input factors that are needed for the acquisition of technical knowledge. There are at least three drawbacks in measuring technological innovation with R&D. First, R&D is only an input of technological knowledge and does not necessarily result in outputs. Hu and Jefferson (2009) show that the correlation between the number of patents and R&D investment is very low. Second, R&D outsourcing has become an important way to make forays in innovation competition for many firms (Chesbrough, 2003), indicating that innovation does not necessarily require intramural R&D investment. Third, the problem of missing data is very serious for R&D investment (Koh and Reeb, 2015). Because the disclosure of R&D information is not mandatory, many enterprises choose not to disclose it.

Productivity and new products may (or may not) be the outputs of technical knowledge. Some productivity growth and new product benefits do not emanate from technological knowledge but rather from management innovation and innovation spirit (Nagaoka et al., 2010). Nonetheless, technological innovation is the major contributor to economic growth, particularly in the long run (Schumpeter, 1934; Nelson and Winter, 1982; Aghion and Howitt, 1992), although management innovation and innovation spirit are also important contributors.

In addition, there are two important drawbacks in relation to productivity indicators. First, there are various methods being used to calculate productivity, which might produce completely different results. Second, firm-level deflators are always unavailable, which makes the calculation of real inputs and outputs inaccurate. Furthermore, there are also two obvious deficiencies of new products. First, the definition of what constitutes a new product is subjective, and it is, to a large extent, up to firm owners. Second, new products can only reflect product innovation but not process innovation.

In contrast, patents are carriers of technical knowledge, and thus, they are at the core of technological innovation. In the knowledge production function, patents are outputs, while R&D is input. In the production function, patents serve as inputs to create final outputs, which, in turn, would lead to an increase in R&D investment as reflected in the R&D production function. R&D, patents, and final outputs form simultaneous equations regarding technological innovation, in which patents play a central role.

In fact, the simultaneous equations are originally from CDM model, which was first put forward by the seminal work of Crépon et al. (1998). Crépon et al. (1998) studied the impact of R&D on innovation and the effect of innovation on productivity. However, they neglect the impact of productivity on R&D. Many scholars (e.g., Janz et al.， 2003；Lööf and Heshmati，2006; Jefferson et al., 2006) have incorporated the impact of productivity on R&D into the CDM model. Based on Chinese firm-level manufacturing data, Jefferson et al. (2006) studied the R&D production function, knowledge production function, and production function with a recursive three-equation system. Lööf and Heshmati (2017) reviewed the CDM model and its variations in the past 20 years.

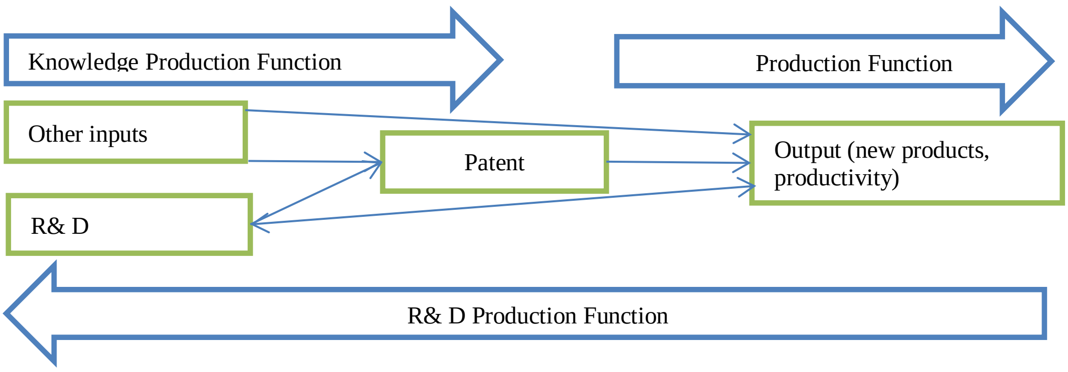

Figure A6 Input and Output of Technological Knowledge

Appendix III: Robustness Analysis

(i) Other Patent Quality Indicators

Although 5-year forward citations accounts for most citations by the end of 2018, they still cannot represent all forward citations. To avoid the influence of arbitrary selection of years, we also estimate with one-year forward citations.

The results shown in Table A1 are basically consistent with those in the basic regression (Table 4 and Table 5). The only exception is that the DID coefficients for granted patents in the equations of average patent quality are insignificant before adding control variables; however, they are moderately significant after adding the control variables. This might be the result of insufficient forward citations within 1 year, which further indicates the necessity of using 5-year forward citations. The proportion of patents citations within 1 year to those by the end of 2018 is only 17.82%.

Table A1 The Impact of the Establishment of NTZs on Patent Quality (One-year Forward Citations)

Dependent Variable	Average Patent Quality			Innovation		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
	Panel A：Without Controls					
DID	0.0587***	0.0227	0.0582***	1.1025***	0.3932***	0.9081***
	(0.0154)	(0.0141)	(0.0115)	(0.0717)	(0.0546)	(0.0531)
R square	0.0070	0.0050	0.0039	0.0260	0.0179	0.0160
Obs	4859810	4859810	4859810	4859810	4859810	4859810
	Panel B：With Controls					
DID	0.0629***	0.0255*	0.0623***	1.1299***	0.4089***	0.9280***
	(0.0157)	(0.0144)	(0.0118)	(0.0726)	(0.0554)	(0.0540)
Scale	0.0930***	0.0664***	0.0395***	0.7120***	0.3972***	0.3659***
	(0.0105)	(0.0097)	(0.0083)	(0.0485)	(0.0390)	(0.0344)
Export	0.0438***	0.0356***	0.0262***	0.3419***	0.2389***	0.1938***
	(0.0021)	(0.0020)	(0.0016)	(0.0100)	(0.0079)	(0.0072)
Kintensity	0.1361***	0.1081***	0.0774***	0.9516***	0.6350***	0.5371***
	(0.0058)	(0.0052)	(0.0043)	(0.0248)	(0.0190)	(0.0179)
Age	-0.1234***	-0.1038***	-0.0702***	-0.9108***	-0.6369***	-0.5374***
	(0.0094)	(0.0086)	(0.0068)	(0.0470)	(0.0367)	(0.0324)
Subordination	-0.0003	-0.0004	-0.0004	-0.0033	-0.0035*	-0.0020
	(0.0005)	(0.0005)	(0.0003)	(0.0023)	(0.0019)	(0.0016)
Ownership	-0.0092	-0.0152***	0.0001	-0.0655**	-0.0760***	-0.0219
	(0.0063)	(0.0056)	(0.0046)	(0.0301)	(0.0237)	(0.0204)
R square	0.0076	0.0055	0.0043	0.0289	0.0201	0.0176
Obs	4701365	4701365	4701365	4701365	4701365	4701365

Note: Patent here refers to invention only. Patent quality is measured by one-year forward citations *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses. Panel A includes regressions without control variables. Panel B includes regressions with all the six control variables mentioned above. Innovation = Patent Quantity × (Average Patent Quality+1).

Besides forward citations, there are some other indicators that can be used to measure patent quality, such as the number of claims. More claims indicate a wider scope of patent protection and thus higher patent quality (Gilbert and Shapiro, 1990; Lanjouw, Pakes, and Putnam, 1998; Bessen, 2008).

The Chinese Patent Census Database used in previous studies include not the variable of the number of claims.[10] The results are shown in Table A2, which, again, are basically consistent with those in the basic regression.

In brief, regardless of which index of patent quality is used, the establishment of NTZs has significantly promoted firm innovation.

[10] The only exceptions are Dang and Motohashi (2015), who use the number of nouns in the claims document as a proxy for the number of claims. This approach is approximately practicable, but it would be more accurate if the actual number of claims is available.

Table A2 The Impact of the Establishment of NTZs on Patent Quality (Number of claims)

Dependent Variable	Average Patent Quality			Innovation		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
			Panel A：Without Controls			
DID	1.0345***	0.5072***	0.9321***	1.9491***	0.7769***	1.6509***
	(0.0691)	(0.0586)	(0.0579)	(0.1190)	(0.0934)	(0.0929)
R square	0.0219	0.0153	0.0146	0.0267	0.0183	0.0169
Obs	4859810	4859810	4859810	4859810	4859810	4859810
			Panel B：With Controls			
DID	1.0483***	0.5163***	0.9459***	1.9857***	0.7985***	1.6791***
	(0.0701)	(0.0595)	(0.0589)	(0.1205)	(0.0947)	(0.0944)
Scale	1.0423***	0.6792***	0.6302***	1.4634***	0.8645***	0.8179***
	(0.0447)	(0.0386)	(0.0369)	(0.0785)	(0.0642)	(0.0589)
Export	0.3557***	0.2718***	0.2473***	0.6074***	0.4343***	0.3755***
	(0.0095)	(0.0082)	(0.0078)	(0.0164)	(0.0133)	(0.0124)
Kintensity	0.9673***	0.7027***	0.6752***	1.6515***	1.1218***	1.0198***
	(0.0243)	(0.0203)	(0.0199)	(0.0410)	(0.0321)	(0.0312)
Age	-0.7764***	-0.6246***	-0.5655***	- 1.4804***	-1.0708***	-0.9520***
	(0.0440)	(0.0374)	(0.0345)	(0.0768)	(0.0613)	(0.0557)
Subordination	0.0007	-0.0003	-0.0013	-0.0028	-0.0037	-0.0027
	(0.0022)	(0.0019)	(0.0018)	(0.0038)	(0.0031)	(0.0028)
Ownership	-0.0783***	-0.0893***	-0.0416*	-0.1288**	-0.1404***	-0.0606*
	(0.0295)	(0.0249)	(0.0232)	(0.0500)	(0.0401)	(0.0360)
R square	0.0242	0.0171	0.0162	0.0296	0.0205	0.0187
Obs	4701365	4701365	4701365	4701365	4701365	4701365

Note: Patent here refers to invention only. Patent quality is measured by the number of claims *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses. Panel A includes regressions without control variables. Panel B includes regressions with all the six control variables mentioned above. Innovation = Patent Quantity × (Average Patent Quality+1).

(ii) Considering the Number and Area of NTZs

In the basic regression, the number and area of NTZs are not taken into account. However, it is likely that NTZs numbering more than one are being established in one municipality in a given year. Besides, different NTZs differ in area. Both the number and the area of NTZs are likely to have important impacts on innovation. However, previous studies (e.g., Wang, 2013; Alder et al., 2013) neglect the two important factors. We incorporate the two factors by resetting the DID variable with similar ways as the original one. Owing to space limitations, we only list the results with innovation as dependent variable and with control variables.

The results are shown in Table A3. After considering the number and area of development zones, the DID coefficients corresponding to innovation were still significantly positive for all types of patents. The sign and significance of the regression coefficients of the control variables are basically the same as those shown in Tables 3 and 4 but are not listed here because of space limitations. These results provide further evidence of the robustness of the initial results.

Table A3 Innovation Effects after Considering the Number and Area of NTZs

Dependent Variable	Number			Area		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
DID	1.0762***	0.4550***	0.8605***	0.4839***	0.2706***	0.3263***
	(0.0659)	(0.0497)	(0.0506)	(0.0437)	(0.0351)	(0.0316)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0232	0.0157	0.0144	0.0230	0.0157	0.0141
Obs	4701365	4701365	4701365	4701365	4701365	4701365

Note: Patent here refers to invention only. The dependent variable is innovation. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

(iii) Considering Either National Econ-Tech Zones or National High-Tech Zones

In the basic regression, National Econ-Tech Zones and National High-Tech Zones are incorporated simultaneously. However, as mentioned above, there is still a little bit of difference between the two types of NTZ. Hence, we now analyze the effects of the two types of NTZ on innovation separately. Owing to space limitations, we only list the results with innovation as dependent variable and with control variables.

As can be seen from Table A4, all the DID coefficients are significantly positive, which further justifies the necessity of considering the two types of NTZs simultaneously.

Table A4 Innovation Effects of Either National Econ-Tech Zones or National High-Tech Zones

Dependent Variable	National Econ-Tech Zones			National High-Tech Zones		
	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
DID	1.5171***	0.6154***	1.2361***	1.0992***	0.3996***	0.8614***
	(0.0950)	(0.0730)	(0.0719)	(0.1508)	(0.1182)	(0.1105)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.0231	0.0157	0.0144	0.0229	0.0156	0.0141
Obs	4701365	4701365	4701365	4701365	4701365	4701365

Note: Patent here refers to invention only. The dependent variable is innovation. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

(iv) Firm Mobility among Municipalities

There are two effects when neighboring municipalities establish NTZs. The first is negative beggar-thy-neighbor effects, which means that the establishment of NTZs in neighboring municipalities leads to the outflow of resources in a specific municipality. The second consists of positive spillover effects; that is to say, NTZs in neighboring municipalities produce positive externalities to the given municipality. Alder et al. (2013) find that the establishment of special economic zones did not result in beggar-thy-neighbor effects, but instead, they resulted in spillover effects.

Following the establishment of the NTZs, the innovation growth might be from the inflow of firms with innovation activities in neighboring municipalities rather than from local firms. Considering the local segmentation among provinces, firm mobility within a province would be easier than that across provinces. Besides, we have included both the firm fixed effect and the province dummy variable, which, to a certain extent, controls the impact of firm mobility among provinces. Therefore, we define two neighboring municipalities not on the basis of geographical distance but on whether they are in the same province.

To control for the impact of firm mobility among municipalities, we set a new variable “Neighbor.” Assume that there were established NTZs in municipality A in year *t*. If there are also NTZs in neighboring municipalities in or after the year *t*, then we set “neighbor” at 1 for municipality A in or after the year (no earlier than *t*) when NTZs are granted in neighboring municipalities, and 0 otherwise.

The results are shown in Table A5. Columns 2–4 show the results without control variables and Columns 5–7 give the results with control variables. The coefficients of Neighbor are insignificant, which indicates that the positive spillover effects and negative beggar-thy-neighbor effects almost cancel each other out. The DID coefficients are all significantly positive, indicating that even after considering the cross-regional flow of enterprises, the establishment of NTZs still significantly promotes innovation.

Table A5 Innovation Effects after Considering Firm Mobility among Municipalities

Dependent Variable	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
DID	1.2400***	0.5022***	1.0206***	1.2686***	0.5233***	1.0375***
	(0.1101)	(0.0859)	(0.0828)	(0.1110)	(0.0868)	(0.0838)
Neighbour	-0.1415	-0.1399	-0.1729	-0.1369	-0.1465	-0.1604
	(0.1546)	(0.1223)	(0.1157)	(0.1569)	(0.1243)	(0.1178)
Controls	No	No	No	Yes	Yes	Yes

R square	0.0206	0.0138	0.0128	0.0231	0.0156	0.0143
Obs	4859810	4859810	4859810	4701365	4701365	4701365

Note: Patent here refers to invention only. The dependent variable is innovation. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

(v) Endogeneity Issues

Endogeneity problems arise from two main sources: missing variables and mutual causality. As for the problem of missing variables, we use two-way fixed effects and commonly used control variables to alleviate it. The problem of mutual causality will be explained in detail below.

To verify whether municipalities with more innovation are given priority to establish NTZs, we rank municipalities on the basis of innovation in each year and calculate the average rank of municipalities in the 2 years right before they are granted the first NTZ. Considering the minor changes in the number of municipalities, we calculate the ratio of the rank of each municipality to the total number of municipalities.

Figure A7 shows that before 2005, most scatters are on the left-hand side, which means that municipalities with more innovation are more easily granted NTZs, and thus, there exist certain endogeneity problems. However, after that, the distribution seems to be uniform. There are many municipalities that have few innovations but are authorized NTZs. This might be related to a regional development strategy aimed at narrowing gaps among regions.

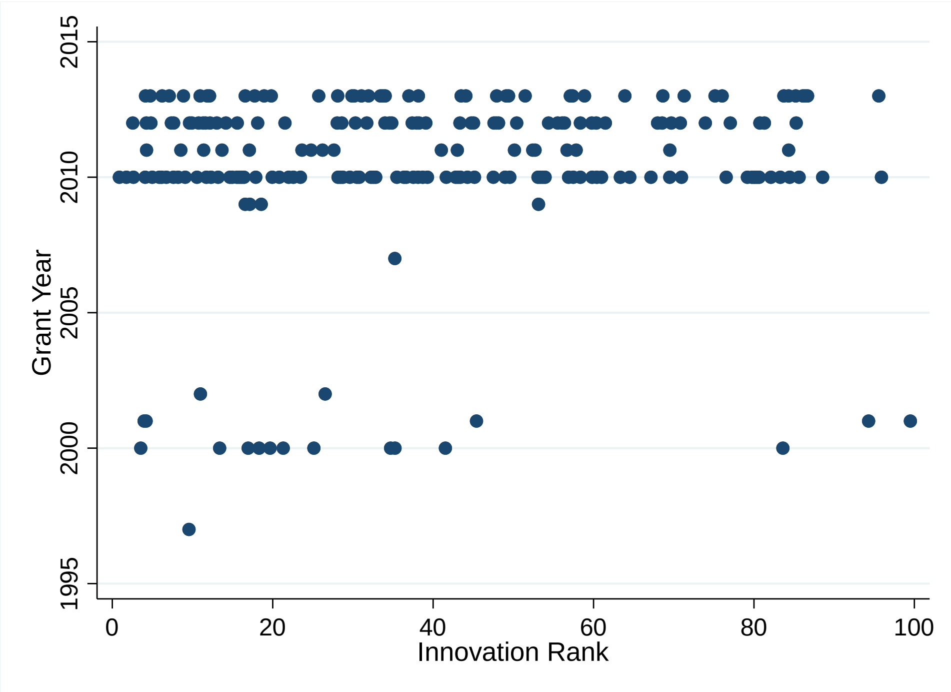

Figure A7 Innovation Rank of Municipalities in the Two Years Right before They Are Granted NTZs

Source: Our matching data.

Figure A7 reveals the possible endogeneity problems, particularly before 2005. The staggered DID method used in this study can, to a large extent, control for endogeneity problems. In addition, macro-level innovation is likely to have an impact on the authorization of NTZs. However, our dependent variable is firm-level innovation, which might have a less direct relationship with the authorization of NTZs.

Of course, it is also possible that both the authorization of NTZs and firm-level innovation are affected by some common factors, such as innovation culture, which might lead to the overestimation of the effects of an NTZ grant.

For the sake of robustness, we further use the instrumental variable (IV) method to alleviate the endogeneity problems. The connections of local officials in the central government (hereinafter referred to as "central connections") can serve as an IV in relation to the establishment of NTZs. In

China, the establishment of National Econ-Tech Zones and National High-Tech Zones is examined by the Ministry of Commerce and the Ministry of Science and Technology, respectively, and then approved by the State Council. Hence, local officials with central connections are more likely to make their application of NTZs approved.

We use the data collected by Jiang (2018), including 62,742 resumes of principal officials at and above municipality level from 1995 to 2015. The principal officials include the Party secretary and mayor of the municipality (2000–2015), the standing committee of the municipality (2000–2012), the provincial Party secretary and governor (1995–2015), and the central committee members (1997–2015).

The variable central connection is calculated through the following three steps. First, as to the current officials of each municipality, we identify their past positions in the central government and assign values to the positions based on their administrative levels. There are 10 administrative levels: "no level" (0); "less than vice country" (10); "vice country" (20); "country" (30); "vice municipality" (40); "municipality" (50); "vice province" (60); "province" (70); "vice state" (80); and "state" (90). The figures in parentheses are the values that we assigned to the various administrative levels.

Second, in addition to considering the administrative level, we also need to consider whether the administrative department directly or indirectly affects the establishment of NTZs. As mentioned above, the NTZs are mainly examined by either the Ministry of Commerce or the Ministry of Science and Technology, and then, they are approved by the State Council. Thus, we divided the departments into four categories: other departments (0); science and technology-related departments (1); the Ministry of Science and Technology or the Ministry of Commerce (2); and the Communist Party (at the central level), the State Council, and the Central Military Commission (3). The figures in parentheses signify the different department levels. Because the administrative level might have more influence on the establishment of NTZs when compared with department level, we assign two digits to the administrative levels and one digit to the department levels.

Third, we add up the value of the administrative level and that of the department level to obtain the value of central connections of each position. Then, we can take the maximum value of central connections for each official, on the basis of which we are able to further calculate the maximum value of central connections for each municipality.

The results are shown in Table A6. Before using the IV method, we must test whether the key explanatory variable is endogenous.

Because the traditional Hausman test applies only to the situation of homoskedasticity, we use the heteroskedasticity-robust DWH (Durbin-Wu-Hausman) test. The results show that the DWH tests are all highly significant and thus strongly reject the null hypothesis of the exogenous DID variable.

The coefficients of IV are significantly positive, which confirms the relevance between IV and the DID variable. In other words, stronger central connections benefit the establishment of NTZs.

We now further test the validity of IV. The identification test shows that the Kleibergen–Paap rk LM statistics are 81,000 and 75,000 in the equations with and without control variables, respectively, and are all significant at the 1% level, which strongly rejects the null hypothesis that the IV is unidentified. Then, we conduct weak IV test with Cragg–Donald Wald F statistics, which assume the disturbance items to be independent and identically distributed, and the Kleibergen–Paap rk LM statistics without the above assumption. In the equations without control variables, the two statistics are 100,000 and 85,000, respectively. After including the control variables, they are 93,000 and 78,000, respectively. Both are much larger than the critical value of 16.38 at the 10% significance level and thus strongly reject the null hypothesis of a weak IV. Because we only use one IV, there exists no over-identification problem.

As for the exogeneity of IV, there is no direct relationship between the central connections and firm innovation, and the IV is likely to be exogenous.

The DID coefficients in the IV regression are larger than those in the basic regression (Table 5), which might result from the local average treatment effect. Jiang (2017) investigates 255 journal articles using IV, and finds that on average, the results with IV are about nine times those without IV even if most of the results without IV are overestimated,[11] and attributes it to the local average treatment effect.

The central connections might also lead to the problem of local average treatment effect. We assume that there are four types of municipalities. The first municipality would actively apply for NTZs regardless of whether there are central connections. The second municipality would not apply for NTZs regardless of whether there are central connections. The third municipality would actively apply for NTZs if and only if there are central connections. The fourth municipality would actively apply for NTZs when there are no central connections but would not apply for NTZs when there are central connections. IV regression reflects only the third and fourth municipalities,[12] and thus, it is a kind of local average treatment effect, which might be larger than the results considering all the four municipalities.

Although the coefficients of the DID variable in the IV regression might be overestimated, they are significantly positive, which further verifies the robustness of the finding that the establishment of NTZs has promoted innovation.

To avoid the possible impact caused by the value of administrative levels and departmental levels, we assigned one digit to both the value of administrative levels and that of departmental levels. We also change the calculation operator from addition (summation) to multiplication with regard to the relationship between the two levels and consider only the Ministry of Commerce and the Ministry of Science and Technology when calculating departmental levels. Regardless of how we set the value of IV, the results are robust.

Table A6 The Impact of the Establishment of NTZs on Innovation (IV Regression)

Dependent Variable	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
DID	9.8596***	7.2841***	5.3738***	7.9172***	5.7975***	4.3625***
	(0.2292)	(0.1804)	(0.1598)	(0.2371)	(0.1866)	(0.1661)
Controls	No	No	No	Yes	Yes	Yes
R square	0.0118	0.0042	0.0102	0.0352	0.0250	0.0239
Obs	4859810	4859810	4859810	4701365	4701365	4701365
DWH Test	1034.6900***	1065.1310***	536.1410***	571.2220***	603.4190***	287.7240***
IV	0.0037***	0.0037***	0.0037***	0.0036***	0.0036***	0.0036***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: Patent here refers to invention only. The dependent variable is innovation. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses.

(vi) New Control Group

There are 63 municipalities that have been authorized NTZs before 1995, which might be different from those that have not been authorized NTZs when being used as the control group. Therefore, we drop the sample in the municipalities authorized NTZs before 1995, to obtain a new control group and redo the regressions as in Table 4 and Table 5. The results are still robust (see Table A7).

Most municipalities that had been authorized NTZs before 1995 are developed municipalities, including the four province-level municipalities (Beijing, Shanghai, Tianjin, and Chongqing), and other coastal municipalities. If we drop these municipalities, the endogeneity problem would be even more serious as shown in Figure A7. Therefore, we retain this sample in our basic regressions. As shown in Figure 2, the effect of the establishment of NTZs has strengthened over time. Hence, retaining this sample would only underestimate, rather than overestimate, the positive effect of the establishment of NTZs on innovation.

[11] Card (2001) comes to similar conclusions after analyzing a host of journal articles on labor economics.

[12] In fact, the situation of the fourth municipality is relatively rare and can be ignored. Therefore, the results of the IV regression only reflect the situation in the third municipality.

Table A7 The Impact of the Establishment of NTZs on Innovation (new control group)

Dependent Variable	Patent	Patent Granted	Patent Ungranted	Patent	Patent Granted	Patent Ungranted
			Panel A: Patent Quantity			
DID	0.9017***	0.4312***	0.6080***	0.9635***	0.4677***	0.6439***
	(0.0756)	(0.0564)	(0.0522)	(0.0776)	(0.0581)	(0.0537)
Controls	No	No	No	Yes	Yes	Yes
R square	0.0188	0.0124	0.0114	0.0211	0.0141	0.0128
Obs	2381040	2381040	2381040	2293074	2293074	2293074
			Panel B: Average Patent Quality			
DID	0.2572***	0.1639***	0.1934***	0.2851***	0.1855***	0.2090***
	(0.0522)	(0.0469)	(0.0369)	(0.0537)	(0.0484)	(0.0379)
Controls	No	No	No	Yes	Yes	Yes
R square	0.0064	0.0046	0.0037	0.0074	0.0054	0.0042
Obs	2381040	2381040	2381040	2293074	2293074	2293074
			Panel C: Innovation			
DID	1.1133***	0.5647***	0.7565***	1.1975***	0.6178***	0.8047***
	(0.1083)	(0.0864)	(0.0734)	(0.1111)	(0.0888)	(0.0754)
Controls	No	No	No	Yes	Yes	Yes
R square	0.0147	0.0094	0.0091	0.0167	0.0108	0.0102
Obs	2381040	2381040	2381040	2293074	2293074	2293074

Note: Patent here refers to invention only. Innovation = Patent Quantity × (Average Patent Quality+1). *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. Robust standard errors are in parentheses. We drop the sample in the cities that have been authorized NTZs before 1995 to obtain a new control group.

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