1-2021

Public health insurance and pharmaceutical innovation: Evidence from China

Xuan ZHANG
Singapore Management University, xuanzhang@smu.edu.sg

Huihua NIE
Renmin University of China

Citation

ZHANG, Xuan and NIE, Huihua. Public health insurance and pharmaceutical innovation: Evidence from China. (2021). *Journal of Development Economics*. 148, 1-27.
Available at: https://ink.library.smu.edu.sg/soe_research/2407

Public Health Insurance and Pharmaceutical Innovation: Evidence from China

Xuan Zhang[a,*], Huihua Nie[b]

[a] *Singapore Management University*
[b] *Renmin University of China*

Abstract

Developing countries are characterized by low levels of pharmaceutical innovation. A likely reason is their small market size, which is not because of the population size but because of low levels of income and lack of health insurance coverage. This study exploits a natural experiment from the implementation of a public health insurance program for rural residents in China (New Cooperative Medical Scheme [NCMS]) to examine whether the pharmaceutical industry increases innovation regarding diseases covered by the NCMS that are prevalent in rural areas. We examine the 1993–2009 patent data to gauge pharmaceutical innovation in China. Diseases with a 10% higher rural patient share saw a 12.4% increase in relevant domestic pharmaceutical patent applications and a modest increase in patent quality after the NCMS implementation. By providing public health insurance to low-income individuals in developing countries, governments can create incentives for pharmaceutical firms to develop new medical technologies.

Keywords: Pharmaceutical innovation, Public health insurance, Market size, Patent
JEL: O31, L65, O12, I13, H51

1. Introduction

In 2011, developing countries accounted for over 80% of the world population (United Nations 2011). However, nearly 70% of the pharmaceutical

*Corresponding author
Email addresses: xuanzhang@smu.edu.sg (Xuan Zhang), niehuihua@vip.163.com (Huihua Nie)

research and development (R&D) investment worldwide was spent in developed countries (OECD 2015). Moreover, most of the research targeted diseases common in developed countries. In contrast, developing countries have inadequate pharmaceutical research and innovation, especially regarding infectious diseases that mainly afflict low-income people. It is important to understand why the level of innovation in developing countries is low since technological advancement is a key contributor to health improvement (Kremer 2002). Furthermore, health is essential for social welfare and economic development (Weil 2007). Economists have noted the low level of pharmaceutical R&D regarding diseases prevalent in developing countries. However, few studies have empirically examined the underlying mechanisms and policies that may boost innovation in developing countries (Chen and Puttitanun 2005).

In the past two decades, many developing countries have started to provide public health insurance for citizens, especially for disadvantaged subgroups (Hsiao et al. 2007). The main goals of this demand-side intervention are to guarantee health care access, to relieve the financial burden of individuals, and to increase the utilization of existing medical technologies. However, this intervention may also have spillover effects on the supply side by inducing pharmaceutical innovation via an (expected) market size expansion (Acemoglu and Linn 2004; Dubois et al. 2015).

Evidence from developed countries (mainly the US) has shown that both supply- and demand-side policies can incentivize medical innovation (Finkelstein 2004; Yin 2008; Blume-Kohout and Sood 2013; Clemens 2013). In particular, Blume-Kohout and Sood (2013) similarly find that the passage of the Medicare Part D (prescription drug insurance) spurs pharmaceutical innovation in drugs more heavily used by the elderly. Thus far, prior studies have found no relationship between pharmaceutical innovation and medical demand (measured by the disease burden) in developing countries (Lichtenberg 2005; Civan and Maloney 2006; Lakdawalla 2018). Kremer (2002) attributes this pattern to low affordability. Therefore, public health insurance programs in developing countries provide an ideal setting to test whether pharmaceutical innovation would increase when more people can afford drugs.

To test this, we exploit the introduction of the New Cooperative Medical Scheme (NCMS), a heavily subsidized public health insurance program for rural residents in China that was announced in 2002. Previous research has shown that the NCMS increased the health care utilization of rural residents

and the revenue of village clinics (Wagstaff et al. 2009; Yu et al. 2010; Babiarz et al. 2010). Moreover, it induced more prescriptions from village doctors (Sun et al. 2009). In this study, we provide additional corroborative evidence to demonstrate that the sales growth among major Chinese pharmaceutical firms coincided with the timing of the NCMS.[1]

Even though the public health insurance is expected to expand the healthcare market size in developing countries, whether firms or other stakeholders would respond by increasing innovation activities is uncertain, given the i) poor intellectual property (IP) protection, and ii) low level of technology, as compared to developed countries. Even though China is not an exception, it has unique institutional settings. First, unlike most other developing countries, China's pharmaceutical IP protection had basically met the requirements of the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement by providing patent protection on both process and product and extending the patent term to 20 years since 1993, which is much earlier than many other developing countries (Zhang 2002; Kyle and McGahan 2012). Moreover, the IP protection level exhibits much variation within China. Ang et al. (2014) show that provinces with better enforcement of IP rights have a larger investment in R&D. Second, we acknowledge that the pharmaceutical technology level in China was relatively low. Before 2008, China hardly produced new molecular entity drugs. Thus, the innovations in this context are seldom breakthroughs; instead, they are mainly imitative innovations (Ding et al. 2011; Yu et al. 2015).[2]

We gauge innovation by analyzing the pharmaceutical patenting behavior from 1993 to 2009 in China, and we examine innovation at the disease level. Unlike new drug applications which take place at the end of the new drug discovery and development process, patent applications occur across the new medicine innovation timeline. In general, patent applications start as early as when new drugs entering the preclinical testing stage (Lakdawalla 2018). As the NCMS affects different diseases differently, we expect to see a larger increase in innovations regarding diseases whose potential market size is more

[1] In addition, phone interviews with managers of several pharmaceutical firms in China further confirmed that the NCMS provided a huge opportunity, and they reacted proactively and immediately.

[2] People may give such innovation different names; for example, Williamson and Yin (2014) call it accelerated innovation. As the name suggests, since such innovations are not breakthroughs, they can be generated faster.

influenced by the policy. Given that the NCMS is a health insurance for rural residents, a disease covered by the NCMS that is more prevalent in rural areas is expected to experience a larger percentage increase in its market size. Therefore, we measure the treatment intensity of the NCMS on each disease with two sources of variation: the coverage of the NCMS and the rural prevalence of a disease, measured by the share of rural patients among all patients suffering from this disease.

To estimate the NCMS' effect on pharmaceutical innovation, we rely on a generalized difference-in-differences (DID) framework by comparing innovations before and after the NCMS with respect to diseases with different treatment intensities. Since our main outcome variables (patent quantity and patent quality) are count data, we use the quasi-maximum likelihood method to estimate a distribution-free fixed effects Poisson model (Wooldridge 1999).

Overall, an NCMS-covered disease with a 10% higher rural patient share saw a 7.8% increase in its relevant patent applications from 2003 to 2009 in China after the introduction of the NCMS, and this was mainly driven by domestic applicants.[3] When patent applications are restricted to domestic applications (by firms, academic institutions, and individuals), they increased by 12.4%. Furthermore, domestic firms were the main drivers, which increased patent applications by 27.5% regarding NCMS-covered diseases with a 10% higher rural patient share. Regarding the timing, we find that the response was immediate, starting from the next year after the NCMS announcement. On the one hand, this is consistent with the rapid increase in stock price and preclinical testing of drugs with higher Medicare market share in the US after the passage of Medicare Part D (Friedman 2009; Blume-Kohout and Sood 2013). On the other hand, the quick response is due to the relatively low quality of Chinese patent applications before 2009. Zhang (2004) show that some applicants would submit patent applications before the preclinical testing stage, and Cheng (2008) show that some applicants would spend less time on patent claims when competing for speed.

Although there is a strong positive impact of the NCMS on the number of patent applications, the impact on the patent quality improvement is modest and marginally significant (at 10%). We find a 6.8% and a 7.8% increase in

[3]Domestic applicants are firms, academic institutions, and individuals with their applicant's address in mainland China, which include joint ventures and wholly foreign-owned enterprises (WFOE) registered in mainland China.

patent approvals and renewals regarding the NCMS-covered rural-prevalent diseases, respectively. In addition, we find a 6% increase in patent citations, a 4.1% increase in claims count among domestic patent applications, and a 2.7% increase in claims count among granted domestic patents.

This study contributes to the literature on the relationship between the expected market size and pharmaceutical innovation by providing novel evidence from a developing country. The existing evidence on the strong positive effect of the expected market size expansion on pharmaceutical innovation is focused on the US (Acemoglu and Linn 2004; Finkelstein 2004; Blume-Kohout and Sood 2013). In a cross-country analysis, Dubois et al. (2015) obtain a much smaller elasticity of pharmaceutical innovation to the expected market size than that from the US. Lichtenberg (2005) finds that innovation and disease burden has a positive relationship in developed countries, which does not exist in developing countries. Civan and Maloney (2006) draw an even extreme conclusion that pharmaceutical innovation is driven almost exclusively by the demand from the US. Lichtenberg (2005) posits that the lack of incentive for firms to develop medicine for diseases afflicting people in developing countries is the most plausible reason for inadequate innovation. However, the claim is not tested. Although we cannot deliver a comparable elasticity estimate due to data limitations, this study shows that pharmaceutical innovation responds to the expected market size expansion, even in a developing county context.[4]

In addition, our findings demonstrate that public health insurance programs can have spillover benefits beyond its direct impact on the health care access and utilization of individuals. Several papers have examined the social impacts of the NCMS. Existing studies find that the NCMS increases the health care utilization of rural individuals and shrinks the rural-urban gap in inpatient care utilization (Wagstaff et al. 2009; You and Kobayashi 2009; Jian et al. 2010; Yu et al. 2010). Bai and Wu (2014) show that the NCMS also increases the non-medical consumption of individuals. Regarding the supply side, Sun et al. (2009) find that the NCMS induces village doctors to prescribe more drugs, and Babiarz et al. (2010) show that village clinics' revenue increases by almost 30% after the NCMS. However, no study has investigated

[4]Our main independent variable (the treatment intensity) is only an approximation to the expected market size change. Without knowing other key parameters, we cannot measure the actual expected market size change due to the NCMS.

the effect of the NCMS on pharmaceutical firms. Consistent with the existing evidence from developed countries (Blume-Kohout and Sood 2013; Clemens 2013), we find that the NCMS, a demand-side health insurance policy, has a positive spillover effect on pharmaceutical innovation in a developing country context. Thus, when policymakers in developing countries design innovation policies, they should take this spillover effect into account.

The rest of the paper is organized as follows. Section 2 illustrates the institutional background of China's health insurance system and its IP protection. Section 3 describes the data and provides descriptive evidence. Section 4 illustrates our empirical strategy. Section 5 presents the results. Section 6 concludes.

2. Background

2.1. NCMS in Rural China

China initially employed the Rural Cooperative Medical System (CMS) from the mid-1950s to the mid-1970s, which raised funds and provided health services at the village level (Feng et al. 1995). However, the system collapsed in the late 1970s, leaving over 80% of rural residents uninsured until 2002 (Yip and Hsiao 2008). Prior to the NCMS, 38% of rural people did not seek medical care when they were sick (You and Kobayashi 2009), and about 2.6% of rural households were impoverished due to medical debts per year (Gustafsson and Li 2004).

To address these problems, the Chinese government announced the NCMS in October 2002. It aimed to provide health insurance for the entire rural population by 2010 (State Council 2002a). The document specifies three main guidelines of the NCMS: (1) participation is voluntary; (2) the administration and implementation are at the (rural) county level;[5] and (3) the NCMS focuses on catastrophic illnesses and receives funds from both the government (central and local) and individuals. In order to reduce adverse selection, the NCMS requires full household participation, i.e., either all or no family members would join the program (Lei and Lin 2009). Although the central and local governments (province or prefecture) provide main guidelines and instructions for the NCMS, rural counties are allowed to design and implement their own programs to meet local needs, as long as they adhere

[5]In China, a (rural) county belongs to and is under the governance of a prefecture.

to the main requirements raised by the central and local governments (State Council 2002a).

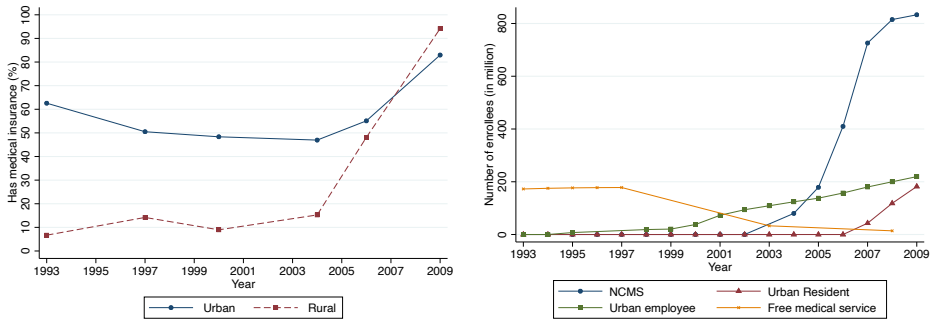
Financing of the NCMS comes from three sources: the central government, local governments, and individuals. However, government contributions are the main sources. Initially, the individual premium was set at no less than 10 RMB, and government subsidies were at least 20 RMB per person (Ministry of Health et al. 2003). In 2006, government subsidies doubled. Thus, the total budget per individual became 50 RMB at minimum (Ministry of Health et al. 2006). The financing doubled again in 2008, and the total budget per person became no less than 100 RMB (Ministry of Health and Ministry of Finance 2008). Government subsidies and individual premiums kept increasing, reaching 500 RMB in total per enrollee in 2015 (National Health Commission and Ministry of Finance 2015).

The program started in 2003. Initially, it had 304 pilot rural counties and reached 641 counties in mid-2005 when every prefecture had at least one county in the program (State Council 2005). It expanded nationally and rapidly since 2006. By the end of March 2006, there were already 1,451 counties participating in the NCMS (You and Kobayashi 2009). As of 2007, 2,451 out of 2,862 counties had adopted the NCMS (Lei and Lin 2009), with more than 700 million enrollees (about 90% of the rural population). Figure 1 (a) illustrates the changes in health insurance enrollment rates among rural and urban residents over time. Clearly, before the NCMS, the rural enrollment rate was much lower than that of urban areas. However, since 2003, the health insurance enrollment rate in rural areas has increased dramatically.

2.2. Health Insurance in Urban China

Figure 1 (a) demonstrates that there was also an increase in the urban health insurance enrollment rate after 2007 due to the launch of the Urban Resident Basic Medical Insurance (URBMI) program. There are two main health insurance programs in urban China: URBMI and Urban Employee Basic Medical Insurance (UEBMI).

UEBMI was introduced in 1998 and has gradually replaced the preexisting free medical services provided by state-owned enterprises and government agencies. Participation is mandatory for every urban firm but is voluntary for rural firms. Financing for UEBMI comes from firms and workers without any government subsidies. Among the three types of health insurance in China, UEBMI is the most generous in terms of deductibles and copayments, but it is less generous than the previous free medical system. Thus, its



(a) Insurance rate

(b) Enrollment of different insurances

Figure 1: Health insurance enrollment status in urban and rural China

Notes. (a) plots the average insurance rate among urban and rural residents over time in China using data from the China Health Nutrition Surveys. (b) plots number of enrollees (in millions) under each insurance in China using data from China Health Statistics Books and China Labor Statistics Books.

influences on the medical market are mixed. On the one hand, it provides workers in private firms with health insurance. On the other hand, people who enjoyed free medical services now reduce their outpatient care utilization and expenditures (Huang and Gan 2017).

URBMI is the voluntary public health insurance designed for urban children, students and the unemployed (except for retirees who have UEBMI from their former employers). Launched in the second half of 2007, it nearly achieved its goal of universal urban coverage by 2010. Governments and individuals finance the URBMI. Unlike the NCMS, however, the individual premium is the primary source of financing, except for those over age 70 (State Council 2007b). Figure 1 (b) depicts the changes in enrollment of these different kinds of health insurance in China. Notably, the NCMS has experienced the greatest degree of expansion among health insurance programs in China.

2.3. Pharmaceutical Industry and Pharmaceutical IP Protection in China

By 2011, China's pharmaceutical market mainly comprised three types of products: chemicals (43.7%), biological products (20.7%), and traditional Chinese medicine (35.6%). The pharmaceutical industry in early 2000s consisted of approximately 5,000 firms, of which 90% are generic drug producers. In addition, foreign investments play a big role in China's pharmaceutical

industry. Among the chemical drug producers, about one-third are joint ventures or WFOEs (Sun et al. 2008a; He 2016).

As generic drugs dominate China's pharmaceutical market, the innovations are generally modest and are not comparable with those in developed countries. However, over the past three decades, China's innovation level is increasing. Pharmaceutical innovation in China (excluding traditional Chinese medicine) is characterized by four phases (Ding et al. 2011): i) pure imitation (1949–1985), ii) innovation imitation (1984–1993), iii) imitative innovation (1993-2008), and iv) independent innovation (2008 to date). From the third phase onward, patents became the main pharmaceutical IP protection in China. Figure A.1 compares the overall pharmaceutical R&D investments between China and the OECD countries between 2000 and 2011. Although falling behind the US, Japan and some European countries, China's pharmaceutical R&D investment was comparable with the other OECD countries.

The Chinese patent system follows the "first-to-file" principle and allows a one-priority year to patent applications filed in other countries. Thus, applicants have the incentive to apply as soon as possible. Some applicants submit patent applications hastily and immaturely to capitalize on a preemptive opportunity, thereby resulting in low-quality patent applications and difficulties in patent examinations (Cheng 2008). By default, all patent applications (after passing preliminary examinations) are published in 18 months. Applicants can then decide on whether to submit a substantial examination request.

There are two main ways to protect pharmaceutical IP in China: patent and administrative protection (Zhang, 2002, 2004, 2015). Although compared with developed countries, China's patent system has a lower quality, it is mature and well regulated relative to other developing countries. The first patent law in China was enacted in 1984 and has been in effect since April 1, 1985. However, it only protected process inventions but not pharmaceutical products or chemical compounds. Moreover, the term of a patent was fifteen years. The first revision was in 1992 and was implemented from January 1, 1993. The amended patent law started to protect important IP rights embodied in pharmaceuticals since 1993 and extended the patent term to twenty years. This revision greatly stimulated pharmaceutical patenting behavior; applications increased from 1,266 to 2,415 from 1992 to 1993. To better accommodate with the TRIPS standard, the second revision was made in 2000 and implemented from July 1, 2001. After this revision, several firms' patent drugs become their major sales, such as the Tasly Holding Group's

compound Danshen dropping pills for heart diseases and Shandong Buchang Pharm's Naoxintong for cerebrovascular diseases. The third revision was conducted in December 2008 and implemented from October 1, 2009. In this revision, China replaced the criterion for invention and utility model from relative novelty to absolute novelty, thereby raising the patent standard.

Drugs are also protected by administrative means from 1993. However, the protection is weaker than the patent protection and only serves as a supplement. For instance, traditional Chinese medicines have market exclusivity from seven to thirty years by grade. Nonetheless, if multiple manufacturers have produced the same drug before the administrative protection, all manufacturers are granted market exclusivity.[6] Foreign drugs entering China before 1993 were given seven and a half years of protection. In addition, new drugs produced by firms located in China are granted a five-year market exclusivity. Even so, drugs that have already submitted a clinical trial application are not bound by the provision.[7]

3. Data and Descriptive Statistics

3.1. Data

3.1.1. Patent Data

This study employs data on the number of patent applications, granted patents, renewals, forward citations, and claims count to measure pharmaceutical innovation quantity and quality. Although patents and new drug applications do not align perfectly, as pharmaceutical patent filings occur at different stages across the new drug innovation timeline, relative to other R&D-intensive industries, a patent is still the dominant method of IP protection in the pharmaceutical industry (Lakdawalla 2018). Moreover, following Hu and Jefferson (2009), we show that R&D expenditures and patent applications are positively correlated with an elasticity of 0.37 among Chinese pharmaceutical firms during the 2001-2007 period.[8]

[6] No medicine ever gets thirty years of protection. Only 11 products get 10 or 20 years of protection, and the other 300 products get seven years of protection.

[7] Before 2015, China had a lax definition on "new drug", i.e., all drugs that had never marketed in China were considered as new drugs. Since 2015, new drugs are drugs never marketed in any country (SFDA, 2002, 2007; State Council, 2015).

[8] Using the zero-inflated Poisson regression, we find that the elasticity of patent applications to R&D expenditure is 0.37 among Chinese pharmaceutical final product producers

Patent data come from China National Intellectual Property Administration's (CNIPA, formerly known as State Intellectual Property Office [SIPO]) patent search and analysis system.[9] We mainly rely on the pharmaceutical patent database, which is a deeply-processed database with all pharmaceutical patent applications in China that have passed the preliminary examination (i.e. published) from 1985.[10] Data have been processed by medical professionals, which is similar to databases like the Chemical Abstracts Plus's STN AnaVist, the Questel's Orbit intelligence, and Derwent World Patents Index (DWPI); and each patent is generally classified as a treatment for up to three diseases (Sun et al. 2008b).[11] Among the detailed information on each patent, the following elements are most relevant for our analysis: patent name, application date, applicant name, applicant address, therapeutic purpose, and information on legal status (e.g., grant, renewal, and expiration dates).[12] In addition, we merge the CNIPA data with the web-scraped Google Patent data to obtain forward citation and claims count of patents.

Our analysis uses patent data from 1993 to 2009. Patent applications prior to 1993 are excluded because China did not protect chemical compounds or pharmaceutical products before 1993, which are critical components of pharmaceutical innovation. Data from 2010 are excluded because by then China had experienced several major changes. First, the novelty requirement on invention and utility-model patents had changed since October 2009 due to the 2008 patent law revision. Second, China launched the major new drugs development project in 2009, which was a generous government grant to support new drug innovations as part of the national outlines for medium and long-term planning for scientific and technological development (2006-2020) (State Council 2009). Third, China was no longer a lower middle-

and 0.28 among all pharmaceutical manufacturers (including ingredient producers) with annual sales above 5 million RMB.

[9] http://pss-system.cnipa.gov.cn/sipopublicsearch/portal/uiIndex.shtml

[10] In general, most patent applications pass the preliminary examination and are published in 18 months. Given that the database only releases published patent applications, "application" and "publication" are interchangeable in this study.

[11] We exclude non-pharmaceuticals, such as food, drinks, health supplements, and veterinary drugs from our analysis, which account for less than 10% of total patents included in the database.

[12] We hired several research assistants to do the web scraping and processed the data for our analysis.

income country since 2010.[13]

We do not use data on clinical trials, new drug applications and approvals from the National Medical Products Administration (formerly, State Food and Drug Administration of China [SFDA]) due to i) lack of pre-NCMS data and ii) low credibility. First, the earliest clinical trials and drug applications data were only available from late 2000 due to the reform of the SFDA, which integrated province-level administrations in 1998. Similarly, due to drug investigations and relabeling by the SFDA, all drugs approved before mid-2002 were uniformly updated with an approval date of late 2002. Second, the former SFDA director Zheng Xiaoyu was sentenced to death for the excessive approval of "new" but unqualified drugs from 1998 to 2005, thereby making the SFDA data in the early 2000s less credible.[14]

3.1.2. Disease-level Data

Disease morbidity rate and prevalence data are mainly from two sources: i) China National Health Services Surveys (NHSS 1993, 1998, 2003, and 2008) and ii) the Chinese Center for Disease Control and Prevention's (China CDC) public health science database. The NHSSs have urban and rural two-week morbidity rates of 15 non-birth-related ICD-10 disease categories and 11 specific diseases under five disease categories.[15] For the remaining 10 disease categories without morbidity rates on specific diseases, we supplement the data with that from the China CDC's public health science database on infectious and parasitic diseases, the China CDC's occupational disease reports, and the China Population Association's infertility reports.[16]

In summary, we examine 24 diseases in our analysis. It includes 11 diseases directly from the NHSSs and 10 representative infectious diseases that account for at least 1% (about 33,000 cases in 2003) of the ICD-10 category I infectious and parasitic diseases, two major occupational diseases (pneu-

[13]According to the World Bank classification, China was a low-income country before 1998 and was a lower middle-income country as of 2009. https://datatopics.worldbank.org/world-development-indicators/stories/the-classification-of-countries-by-income.html

[14]http://news.sina.com.cn/c/2007-07-10/122813415293.shtml

[15]The three birth-related ICD-10 categories have a very low morbidity rate of less than 0.2 in 1000 people.

[16]Prior to 2004, the China CDC only reported national-level cases for two Type A and 24 Type B infectious and parasitic diseases (excluding SARS). From 2004, the China CDC reports province-level cases for all 40 Type A, B and C infectious and parasitic diseases.

moconiosis and chemical poisoning) under category X respiratory diseases and category XIX injury, poisoning and other external causes, respectively. Further, we include infertility, under the category XIV genitourinary system. The remaining seven ICD-10 disease categories are excluded from the analysis because of no credible data on the disease-specific morbidity rate.[17]

Among these 24 diseases, five are not covered by the NCMS: gonorrhea, syphilis, infertility, pneumoconiosis, and chemical poisoning. The NCMS covers most health care costs, except for 1) occupational diseases, medical accidents, and non-productive pesticide poisoning; 2) organ transplant; 3) family planning, sexual dysfunctions and infertility; 4) expert consultation fee, ambulance fee and nursing fee; 5) injuries; 6) sexually transmitted diseases (except for AIDS), drug abuse, and suicide; 7) blood products, except for leukemia, aplastic anemia and hemophilia patients; and 8) non-therapeutic orthopedic surgeries (National Health Commission, 2006, 2008, 2011).[18] In general, gonorrhea, syphilis, and infertility are not covered by any public health insurance in China. Pneumoconiosis and chemical poisoning are covered by the occupational injury insurance.

3.1.3. Other Data

Several other datasets are used to depict descriptive trends. The China Health and Nutrition Surveys (CHNS 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011) include data from nine provinces and are used to generate rural and urban health insurance rates.[19] The Annual Survey of Industrial Firms (ASIF 1999–2007) has sales and R&D investment data from Chinese firms with more than five million RMB revenue each year. China's yearbooks on health statistics, labor statistics, and general statistics are used to depict the evolution of different types of health insurance, show the economic growth and demographic transition in China, and help calculate the number of rural and urban patients suffering from each disease.

[17]The excluded ICD-10 categories are as follows: II neoplasms, III diseases of blood and blood-forming organs, V mental and behavioral disorders, VI diseases of the nervous system, VII diseases of the eye and adnexa, VIII diseases of the ear and mastoid process, and XII diseases of the skin and subcutaneous tissue.

[18]Specifically, the 2006, 2008, and 2011 document comes from Anhui, Shanxi, and Hebei province's health commission, respectively.

[19]The nine provinces are as follows: Heilongjiang (added 1997), Liaoning (missing 1997), Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi and Guizhou.

3.2. NCMS and Pharmaceutical Market Size

For the NCMS to induce pharmaceutical innovation, a necessary condition is that the program expands the (expected) pharmaceutical market size. Existing studies have variously shown that the NCMS increased health care utilization and the market size for medicine in China.

Wagstaff et al. (2009) used 2003 to 2005 data from 10 expansion and 5 control rural counties and find that the NCMS increased outpatient visits at village clinics, outpatient visits at county hospitals, and inpatient visits by 56%, 81%, and 47%, respectively. Yu et al. (2010) use 2006 data from two provinces (Ningxia and Shandong) and find that the NCMS increased inpatient visits by 1.9 pp (76%) among the high-income groups but has no impact on middle- and low-income groups. You and Kobayashi (2009) surveyed 14 academic papers and 6 government reports and claimed that the NCMS substantially increased healthcare utilization in rural areas. Babiarz et al. (2010) use 2004 to 2007 data from 100 villages within 25 rural counties across five provinces and show that village clinics experienced a 26% increase in weekly patient flow and a 29% increase in monthly gross income after the NCMS. Sun et al. (2009) use 2005 data from Shandong province and find that the NCMS increased the number of drugs prescribed per doctor visit by 1.5 (48%). On average, drug spending accounts for 42.7% of expenditure per inpatient episode and 50.5% per outpatient visit in 2007 (Sun et al. 2008a).

We provide additional descriptive evidence from the pharmaceutical sales data to show that this necessary condition is satisfied. We construct a panel of major pharmaceutical firms in China from the ASIF to track their sales revenue over time. Figure 2 shows the average revenue (in 1999 RMB) among the major pharmaceutical firms in China from 1999 to 2007. The revenue was fairly stable between 1999 and 2002, substantially increased since 2003, and further increased since 2005, which coincided with the timing of the NCMS. We also overlay the average R&D expenditure over this period in Figure 2. Based on the available data, we find that domestic firms increased R&D investments since 2003 and further increased from 2006. The average R&D investment level is low in Figure 2, because over 60% of pharmaceutical firms in the ASIF had no R&D investment.

3.3. Summary Statistics

Table 1 describes the summary statistics of patent quantity and quality at the national level and by domestic and foreign applications separately. Domestic and foreign status is based on an applicant's address. Thus, patents

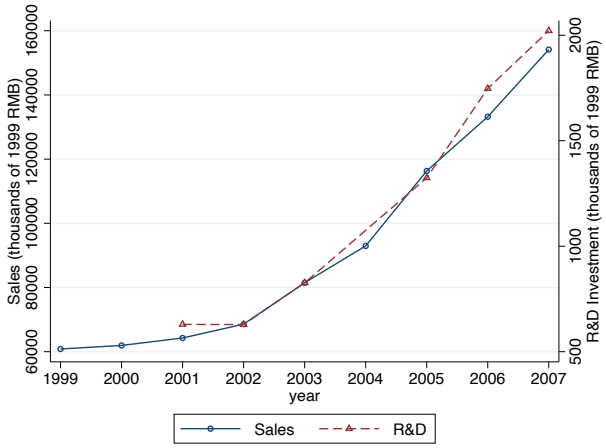


Figure 2: Average sales and R&D of major pharmaceutical firms in China

Notes. We include firms in the following industries: chemical/western medicine, traditional Chinese medicine, and biological medicine (industry code 2720, 2740, and 2760 by China's Industrial Classification for National Economic Activities). The ingredient and material producers are excluded. We construct a relatively balanced panel using pharmaceutical firms with records both before and after the the NCMS. There are around 1,000 firms each year. The ASIF did not collect R&D investment in 1999, 2000 and 2004.

filed by joint ventures and WFOEs that are located in mainland China are classified as domestic applications.[20] Since we are interested in patenting behavior in China, the date of foreign applications is coded as the date they filed an application at the CNIPA instead of their first-ever application date at a different patent office.

On average, the CNIPA received 64 patent applications each year on each disease in our sample from 1993 to 2009. Among these applications, about 60% were from domestic applicants. The average grant rate was 45%, with the approval rate of patent applications slightly higher among domestic applications than that of foreign applications at 49% and 39%, respectively. Among granted patents, nearly 90% of them had been renewed at least

[20]In our analysis, Hong Kong, Macau, and Taiwan applications are grouped into foreign applications to maintain consistency before and after being the special administration region for the former two. Moreover, since these three regions have their own patent offices, applicants in these areas may have strategically different patenting behavior at the CNIPA and at their respective patent office.

Table 1: Summary Statistics of Patent Data

	All	Domestic	Foreign
Quantity and quality			
Application	64.11	39.32	24.79
	(124.34)	(74.93)	(57.43)
Approval	28.77	19.22	9.55
	(50.50)	(36.13)	(20.52)
Renewal	25.81	17.33	8.48
	(45.90)	(33.19)	(18.06)
Quality (Google Patent)			
Avg. forward citations	0.69	0.89	0.31
	(0.61)	(0.71)	(0.45)
Avg. claims count (application)	12.03	4.90	27.97
	(7.62)	(1.98)	(18.37)
Avg. claims count (approval)	8.09	3.94	16.53
	(5.25)	(1.65)	(8.41)
By applicant type			
Firm	33.87	13.43	20.44
	(69.48)	(30.72)	(46.52)
Academic institution	10.46	9.11	1.35
	(25.70)	(23.18)	(3.10)
Individual	17.28	16.78	0.50
	(25.53)	(24.90)	(1.24)
By invention type			
Product	25.39	13.78	11.61
	(47.63)	(25.21)	(26.03)
Process	5.35	3.98	1.37
	(11.43)	(9.17)	(3.20)
Both product and process	30.57	21.25	9.32
	(59.70)	(42.85)	(21.63)

Notes. Data are from the CNPIA's publicly available patent database unless separately noted. Standard deviations are reported in parentheses. All patents include both domestic and foreign patents. Domestic and foreign classification is based on patent applicants' addresses. Renewal indicates a granted patent is renewed at least twice by paying the annual fees twice. Citations are the average number of forward citations among patent applications on each disease in each year. Claims count at application are the number of claims made by applicants. Claims count at approval are the number of claims approved by patent examiners among granted patents.

twice, and there was little difference between domestic and foreign granted patents.[21] Among these three patent measures, applications only measure the quantity, while the later two also reflect the intellectual and commercial value of the patent applications.

We then show the summary statistics on two quality measures from the Google Patent: forward citations and claims count. On average, each patent application in our sample is cited 0.7 times, with citations on domestic applications 0.6 times more than those on foreign applications. Considering the claims count at both the application and approval stage, the quality of domestic patents is far below that of foreign patents, with an around 80% difference.[22] There are two types of claims count. One is at the application (publication) stage, when patents pass the preliminary examination and are published 18 months after application dates. The other is among the granted patents, and the number can be smaller than that at the application stage because examiners may remove unreasonable claims during the substantial examinations.

To better understand the properties of these patent activities from 1993 to 2009, we also examine patent applications by applicant type and invention type. As expected, most patent applications were from firms, accounting for 55% of all patent applications, followed by individuals accounting for 28%. Academic institutions accounted for the rest at 17%. However, the composition of applicants was distinct among domestic and foreign applications. When considering the domestic applications only, individuals were surprisingly the top applicants, and individuals, firms, and academic institutions accounted for 43%, 34%, and 23% of total applicants, respectively.[23] However, for foreign applications, firms filed 91% of them in China, and individuals

[21] In China, the patent fee is paid once a year with a two-month grace period. If the annual fee is not paid, the patent will expire. Over 96% of granted patents renew at least once, and our patent legal status information is until early 2012. Therefore, we decide to use two years as the cutoff, i.e., renewals include patents that have a patent life of more than 793 days, which is the maximal days of two years plus two months.

[22] "Claims are the heart of a patent application. Whereas the description of the invention contained in a patent document teaches how to make and use the invention, the claims define the scope of legal protection." https://www.wipo.int/wipo_magazine/en/2006/01/article_0007.html

[23] Anecdotal evidence suggests that some Chinese firms file patents in disguise of individuals to be eligible for patent fee reductions and/or government subsidies. However, empirical evidence is mixed (Tan et al. 2015).

filed only 2%.

Although there are three types of patents in China (invention, utility model, and design), 99.5% of pharmaceutical patent applications are inventions. Therefore, instead of considering different patent types, we examine different invention types: product, process, or both product and process. On average, product, process, and both types accounted for 41%, 9%, and 50% in total inventions, respectively. However, similar to the difference between domestic and foreign applications by applicant type, invention types also exhibited such difference. For domestic applications, product, process, and both types accounted for 35%, 10%, and 54%, respectively. For foreign applications, they accounted for 52%, 6%, and 42%, respectively. Although process inventions accounted for the least proportion in both domestic and foreign applications, most domestic patents were under both product and process, while most foreign patents were products only. Process patents have the lowest novelty and weakest patent protection. When testing the quality between product patents and patents under both product and process inventions among foreign patents, we find little difference. However, domestic patents under both product and process inventions had higher quality than domestic product patents.

Table A.1 presents the summary statistics of the 24 diseases in our sample. The NCMS covers the top 19 diseases, and the rest 5 diseases are not covered. The 19 covered diseases can be classified into four subgroups based on their rural patient share in 2003 (approximate to the expected percentage change in their respective market size). The mostly affected group includes the first 12 diseases with higher rural morbidity rates and thus dominant rural patient shares (over 70%). The moderately affected group include 3 diseases (dysentery, gallbladder, and hepatitis C) that had similar morbidity rates in rural and urban areas. However, due to the larger rural population size, they still had higher rural patient shares (66%-68%). The slightly affected group consists of 3 diseases (cerebrovascular diseases, hypertension, heart diseases) with higher urban morbidity rates but similar urban and rural patient shares (43%-51%) due to the larger rural population base. The least affected disease among the covered diseases is diabetes, which had a dominant urban patient share (76%). The last three columns show the average number of patent applications regarding each disease. As expected, there is huge variation between diseases. Diabetes had on average 398 patent applications per year, whereas pnuemoconiosis only had on average 1.65 patent applications per year during 1993–2009.

4. Empirical Strategy

The econometric framework follows our main logic: If a disease is covered by the NCMS and more prevalent in rural areas, then we expect more pharmaceutical innovation towards this disease since the NCMS affects its expected market size more. Our specification is based on a generalized DID model. Instead of using a treatment dummy, we use different treatment intensities on different diseases by the NCMS as the main source of variation. In addition, since our outcome variables are count data, we use the quasi-maximum likelihood method to estimate a distribution-free fixed effects Poisson model (Hausman et al. 1984; Wooldridge 1999) with the following conditional mean:

$$E(N_{ct}|\boldsymbol{X_{ct}}, \alpha_c) = \alpha_c * exp(\beta Post_t \cdot NCMS_c + \phi ln(urban\ patients)_{ct} + \theta \alpha_c \cdot Year_t + \gamma_t), \tag{1}$$

where N_{ct} is the measure on patent quantity and quality from 1993 to 2009, such as the count of patent applications, approvals, renewals, and the average number of citations and claims count on patents filed on disease c in year t. We examine the total patent filings in China and separately consider the patenting behavior between domestic and foreign stakeholders. In addition, we explore heterogeneous responses by different types of applicants and on different invention types.

$Post_t$ is $1(2003 \leq t \leq 2009)$, indicating whether a year t is in the post-NCMS period. $NCMS_c = 1(covered_c) \cdot ruralshare_c$ is the key variation at the disease level, as defined by equation (A.7) in Section A.1. It combines two sources of variation, whether a disease is covered by the NCMS, and the share of rural patients among all patients suffering from disease c before the NCMS.[24] By intuition, we expect to see a larger percentage increase in market size among diseases with a higher share of rural patients after the implementation of the NCMS. The logic follows Acemoglu et al. (2006) and Blume-Kohout and Sood (2013) by exploiting the variation from the Medicare, i.e., the elderly share in each drug category. β is the primary

[24]The number of rural patients equals to the rural population times the morbidity rate in rural areas. In our main analysis, we calculate $ruralshare_c$ using the pre-NCMS data since we expect applicants to form their expectations on the market size change before the implementation of the NCMS. Ideally, we would use the 2002 data to compute $ruralshare_c$, but due to data limitations, we use the 2003/2004 data instead.

parameter of interest. α_c and γ_t are disease and year fixed effects.

In addition, we disentangle the two sources of variation by separately examining the impact of the NCMS coverage ($NCMSdummy_c = 1[covered_c]$) on innovation among all diseases and the impact of the expected market size change ($ruralshare_c$) on innovation among the 19 NCMS-covered diseases only. Moreover, as the NCMS focuses on catastrophic diseases (guideline [3]), which usually incur large drug costs, we expect to see a larger percentage increase in innovations towards catastrophic diseases. Therefore, we also investigate the heterogeneous impact on four catastrophic diseases in our sample: cerebrovascular diseases, heart diseases, chronic bronchitis, and cirrhosis (Sun et al. 2013).

During the study period, the dramatic economic growth and demographic changes in China may also expand the pharmaceutical market size and thus incentivize innovation. As shown in Figure A.2, the obesity rate and the aging population are both rising in China, leading to the increase in non-communicable chronic diseases, such as hypertension, diabetes, and coronary heart disease (US CDC 2005). Without accounting for the market size change driven by these socioeconomic factors, our main estimation would exhibit a downward bias. Since such diseases afflict the wealthy urban population more heavily (Chen and Ge 1995; Popkin 2008; Van de Poel et al. 2009), and urban diagnoses are less likely to change due to the URBMI (Lin et al. 2009), we use $ln(urban\ patients)_{ct}$ to control for market size changes driven by these socioeconomic factors. Furthermore, as different diseases have different growth trajectories in patent applications driven by unobserved factors, we also include disease-specific linear time trends in the model.

We report the clustered robust standard errors at the disease level, accounting for the serial correlation in the errors and robust to any misspecification of the distribution of the errors. In addition, as we have few clusters ($G = 24$), we may underestimate the clustered standard errors. Following Cameron and Miller (2015), we draw a conservative inference of the Wald statistics based on the T-distribution with T(G-2) critical values instead of the standard normal distribution.

There are two advantages of using a fixed effects Poisson model. First, the estimation is consistent as long as the conditional mean is correctly specified, so there is less requirement on the data generating process. To test whether the conditional means are correctly specified, we follow Silva and Tenreyro (2006) by doing the Ramsey RESET test. Second, since we have zero counts for some outcomes, by using a fixed effects Poisson model, we do not need

to worry about the transformation of outcome variables.[25] As a robustness check, we run the same analyses using log-linear models, and the details are included in Section 5.3.4.

Since the URBMI was initialized in late 2007, and the supply-side major new drugs development project had launched in 2009, the impact of the NCMS on pharmaceutical innovation is cleaner in the 2003–2006 period.[26] In contrast, the impact of the NCMS during 2007–2009 might be attenuated due to the expected higher profit of urban-prevalent diseases driven by the URBMI and the generous support on major diseases by the government grant. Therefore, we divide the post-NCMS period into two sub-periods, accordingly, to obtain a more accurate impact on pharmaceutical innovation in the first sub-period.

$$E(N_{ct}|\boldsymbol{X_{ct}}, \alpha_c) = \alpha_c * exp(\beta_1 Post1 \cdot NCMS_c + \beta_2 Post2 \cdot NCMS_c + \phi ln(urban\ patients)_{ct} + \theta\alpha_c \cdot Year_t + \gamma_t), \tag{2}$$

where $Post1$ is 2003 to 2006 when only the NCMS affected pharmaceutical innovation; and $Post2$ is 2007 to 2009 when the NCMS, the URBMI, and the supply-side intervention might all spur innovation.

Moreover, since the timing of the innovation response is interesting and policy-relevant, we examine the flexible annual effect of the NCMS on pharmaceutical innovation. Here β_t varies in each year. The omitted reference year is 2002, the policy announcement year.

$$E(N_{ct}|\boldsymbol{X_{ct}}, \alpha_c) = \alpha_c * exp(\beta_t \cdot \gamma_t \cdot NCMS_c + \phi ln(urban\,patients)_{ct} + \theta\alpha_c \cdot Year_t + \gamma_t) \tag{3}$$

[25] We have 4.9%, 7.8% and 20.8% zero counts for all, domestic and foreign patent applications, respectively.

[26] The major new drugs development project called for proposals in 2008 (State Council 2008). It provides generous subsidies to domestic firms and academic institutions for new drug invention on certain diseases (State Council, 2007a, 2009). In principle, supported diseases include cancer, heart diseases, cerebrovascular diseases, neuro-degenerative diseases, diabetes, mental disorders, autoimmune diseases, infections with drug resistance, tuberculosis (TB), and virus infectious diseases, In practice, however, the scope of diseases is broader.

5. Results

5.1. Baseline Results

Table 2 reports the estimated effects of the NCMS on patent applications, approvals, and renewals. Columns (1) and (2) of Panel A indicate that, on average, a disease covered by the NCMS with a 10% higher rural patient share went through a 7.8% increase in overall patent applications from 2003 to 2009 (at the 10% significance level), and the increase was slightly larger (8.5% vs 8%) in 2007–2009. Columns (3) and (4) demonstrate that domestic applicants' patenting activities mainly drove the NCMS' impact. Domestic applications on a disease covered by the NCMS with a 10% higher rural patient share increased by 12.4% in the post-NCMS period, and the response was larger (11.3% vs. 9.4%) during the 2003–2006 period before the URBMI and supply-side subsidies took into effect. Columns (5) and (6) show that foreign applicants did not respond to the NCMS, and the RESET test results suggest that our main model is not appropriate to explain foreign applicants' patenting behavior.[27] Two reasons may explain why foreign firms did not respond to the NCMS. First, although China's pharmaceutical market size was big, it was not comparable to the major markets in the world that drove most innovations.[28] Second, joint ventures and WFOEs located in mainland China are classified as domestic firms. Therefore, for those foreign companies who were interested in China's market, their response was captured by domestic patenting behavior.

Panels B and C in Table 2 show the NCMS' impact on patent grants and renewals. These two measures, unlike patent applications, evaluate not only the quantity but also the quality of patenting activities, as granted patents generally have higher intellectual value, and patent renewals imply higher commercial value. Columns (1) and (2) demonstrate that, on average, there is little evidence that the NCMS increased overall patent grants and renewals among patent applications filed since 2003. When restricting to domestic patents only in columns (3) and (4), there was a 6.8% increase

[27] Columns (1) to (4) all pass the RESET test as p-values are above 0.05, whereas columns (5) and (6) reject the null hypothesis that conditional means are correctly specified.

[28] According to the IMS Health, China's pharmaceutical market size in 2003 ranked the 9th in the world. The rank became the 5th in 2008. https://www.chemistryworld.com/news/pharmas-new-world-order/3003163.article

Table 2: Effect of the NCMS on patent quantity: Fixed effects Poisson model

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Applications						
post*NCMS	0.78*		1.24**		-0.23	
	(0.38)		(0.56)		(0.30)	
post1*NCMS		0.80*		1.13**		-0.01
		(0.41)		(0.46)		(0.40)
post2*NCMS		0.85*		0.94**		0.52
		(0.48)		(0.38)		(0.66)
RESET test	0.497	0.508	0.056	0.122	<0.01	<0.01
Panel B: Grants						
post*NCMS	0.51		0.68*		-0.19	
	(0.34)		(0.38)		(0.42)	
post1*NCMS		0.46		0.48		-0.10
		(0.41)		(0.32)		(0.49)
post2*NCMS		0.37		0.15		0.40
		(0.64)		(0.35)		(0.90)
RESET test	0.216	0.193	0.039	0.032	<0.01	<0.01
Panel C: Renewals						
post*NCMS	0.57		0.78*		-0.21	
	(0.35)		(0.40)		(0.42)	
post1*NCMS		0.50		0.57*		-0.13
		(0.40)		(0.33)		(0.49)
post2*NCMS		0.34		0.24		0.32
		(0.56)		(0.27)		(0.84)
RESET test	0.134	0.086	0.038	0.018	0.011	<0.01
Observations	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24

Notes. All patents are the sum of domestic and foreign patents. Domestic and foreign classification is based on patent applicants' address. Post is 2003 to 2009; Post1 is 2003 to 2006; Post2 is 2007 to 2009. RESET test p-values are reported. Standard errors are clustered at the disease level. To adjust for potential bias in clustered standard errors due to few clusters, we draw the inference based on critical values from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in approvals and a 7.8% increase in renewals among the NCMS-covered diseases with a 10% higher rural patient share, but both effects are only statistically significant at the 10% level. Compared with the magnitude of the application response, the increase in patent grants is only slightly more

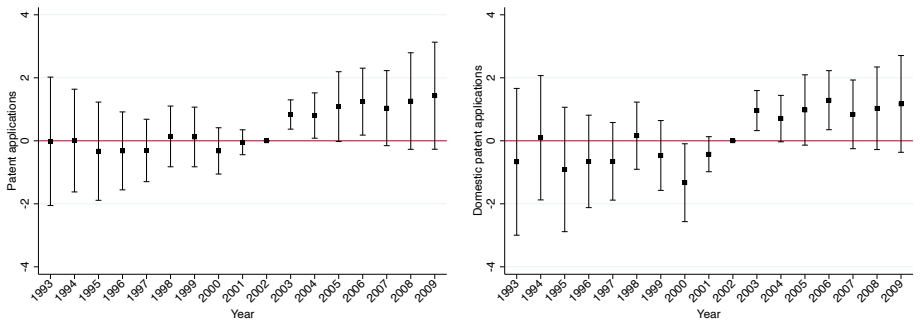
than half of the former, which implies the average approval rate among the increased new patent applications was lower than that among pre-NCMS applications. Therefore, even though there was an increase in the number of granted patents among NCMS-covered diseases prevalent in rural areas, the increase in approvals was not proportional to the increase in applications, suggesting that a substantial amount of these new patent applications might have low quality or were repetitive. The smaller increase in patent renewals among patent applications submitted after the NCMS is as expected. On the one hand, this is consistent with the smaller increase in patent approvals. On the other hand, as the patent review process generally takes several years, with the passage of the NCMS, patent applications towards rural-prevalent diseases that submitted before 2003 might also see higher commercial value. Given that there is no impact on patent applications in columns (5) and (6) in Panel A, it is not surprising to find no impact on approvals and renewals either among foreign applications.[29]

To better understand the speed in innovation activities, Figure 3 presents yearly effects on patent applications. The left graph shows the yearly estimates on all patent applications, and the right graph is restricted to domestic applications only. Overall, the zero coefficients before 2002 imply that the generalized parallel trends assumption holds, i.e., there were no disproportionate innovation activities towards NCMS-covered diseases prevalent in rural areas before the NCMS.[30] Consistent with Panel A of Table 2, the increase in patenting activities was sparked by domestic applicants, and the response was immediate and stronger between 2003 and 2006.

The fast response in patent applications in China is worthy of notice. On the one hand, this is consistent with previous "off the shelf" evidence based on the Medicare Part D establishment (Blume-Kohout and Sood 2013) and the vaccine policies (Finkelstein 2004) in the US. Specifically, Blume-Kohout and Sood (2013) found a rapid increase in preclinical testing in 2004 after the passage of Medicare Part D in 2003. For the typical timeline of the new drug

[29]We acknowledge that the specifications on domestic patent approvals and renewals do not pass the RESET test at the 5% significance level (due to our small sample); thus, the positive effects found in Panels B and C should be viewed with caution.

[30]We note that the 2000 coefficient on domestic applications is negative and statistically significant. However, as it is a temporary dip, and it is unlikely that the persistent increase between 2003 and 2006 is due to the mean reversion, we believe there is no systematic pre-trend.



(a) Patent applications (b) Patent applications: Domestic

Figure 3: Patent applications: Yearly effects

Notes. We interact $NCMS_c$ with year dummies and report the point estimates and 95% confidence intervals based on the T-distribution. Year 2002 is the reference year.

discovery and development process, patent applications and preclinical testing start simultaneously (Lakdawalla 2018). On the other hand, the result might be surprising, because China's pharmaceutical industry had lower innovation level, as compared to developed countries. Thus, stocks on the new drug pipelines might be insufficient. We reconcile this fast response with two China-specific reasons. First, speed in filing patents is prioritized by many Chinese applicants, given that many innovations are imitative innovations which take less effort than breakthroughs. Hence, to seize the preemptive opportunity, some applicants even submit applications with a rough idea in the initial drug discovery stage before any preclinical testing (Zhang 2004). They may sacrifice quality for speed. As a result, a noticeable pattern among these quick applications is the low number of patent claims (Cheng 2008). This is also shown by Table 1. Second, although the formal announcement of establishing the NCMS was in October 2002, a few relevant government documents had been published since 1997. In January 1997, the central government announced "Decisions on Healthcare Reforms", which stated that improving the rural healthcare system was a priority (State Council 1997) and paved the way for the subsequent "Decisions on Strengthening Rural Healthcare", i.e., the announcement of the NCMS (Ministry of Health 2005). Since 2000, the government also started to place much emphasis on Three Rural Issues: agriculture, rural areas, and farmers, which was initially raised in a government report in June 2000, though the earlier documents mainly

covered rural tax problems (State Council, 2000, 2001, 2002b). Given this, sophisticated pharmaceutical firms might already be prepared before the formal announcement of the NCMS.

We then examine the impact on patent quality measured by forward citations and claims count from the Google Patent in Table 3. Similar to Panel B and C of Table 2, we find a modest increase in patent quality, and the impact is only statistically significant at 10% level. Panel A shows that the average citations increased by 6% on patents regarding NCMS-covered diseases with a 10% higher rural patient share, and the increase was much higher among foreign patents, 17.2% vs. 4.8%. Although we find an immediate increase in other patenting activities, Panel B demonstrates that there is a delayed response in claims count among new patent applications, with the average claims count among domestic and foreign applications increasing by 4.1% and 8.5% during the 2007–2009 period only. Panel C illustrates that the average claims count among granted domestic patents increased by 2.8% during the entire post-period, suggesting a slight increase in the average quality of approved patents due to the NCMS.

Table 4 examines the heterogeneous impact of the NCMS on patent applications by different applicant and invention types. Since domestic reactions drove the increase in innovation activities, we focus on domestic applications only. Panel A indicates that domestic firms were the main driver of the increased innovation activities, and the increase in patent applications was over 27% on NCMS-covered diseases with a 10% higher rural patient share. The stronger reaction from domestic firms makes sense since the NCMS affects the pharmaceutical market via an (expected) increase in the pharmaceutical demand. Therefore, firms have the strongest financial incentive to innovate new drugs to generate more profit.[31] Panel B illustrates that the new domestic patents were mainly innovations involving both the product and process, which is a positive sign. As discussed, process patents are the least novel and have the weakest protection among these three invention types. Moreover, domestic patent applications involved both product and process, on average, have higher quality than the other two types.[32]

[31]However, we note that the RESET test p-values are smaller than 0.05; thus, our current model (due to data limitations) may not be the best to explain firms' patenting behavior in response to the NCMS.

[32]The grant rate was 50% among domestic patent applications under both product and process, while it was 44% among domestic product patent applications from 1993 to 2009.

Table 3: Effect of the NCMS on patent quality: Fixed effects Poisson model

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Citations						
post*NCMS	0.60*		0.48		1.72	
	(0.34)		(0.37)		(1.49)	
post1*NCMS		0.60*		0.48		1.72
		(0.34)		(0.37)		(1.48)
post2*NCMS		0.62		0.58		2.24
		(0.54)		(0.50)		(1.87)
RESET test	0.906	0.912	0.139	0.110	0.907	0.960
Observations	388	388	376	376	319	319
Number of diseases	24	24	24	24	23	23
Panel B: Application claims count						
post*NCMS	0.48		0.28		0.31	
	(0.47)		(0.22)		(0.30)	
post1*NCMS		0.07		0.30		0.39
		(0.24)		(0.20)		(0.31)
post2*NCMS		0.85*		0.41*		0.85**
		(0.47)		(0.21)		(0.38)
RESET test	0.173	0.046	<0.01	<0.01	0.297	0.274
Observations	388	388	376	376	323	323
Number of diseases	24	24	24	24	24	24
Panel C: Granted patent claims count						
post*NCMS	-0.10		0.28*		0.12	
	(0.61)		(0.17)		(0.28)	
post1*NCMS		-0.08		0.27*		0.08
		(0.60)		(0.16)		(0.28)
post2*NCMS		0.03		0.24		-0.18
		(0.61)		(0.27)		(0.56)
RESET test	0.718	0.757	0.192	0.176	0.205	0.318
Observations	370	370	347	347	274	274
Number of diseases	24	24	24	24	23	23

Notes. All patents are the sum of domestic and foreign patents. Domestic and foreign classification is based on patent applicants' address. For completeness, we report estimates on claims count of all patents. However, due to the large difference between claims count of domestic and foreign patents, column (1) and (2) in Panel B and C should be viewed with caution. Post is 2003 to 2009; Post1 is 2003 to 2006; Post2 is 2007 to 2009. RESET test p-values are reported. Standard errors are clustered at the disease level. To adjust for potential bias in clustered standard errors due to few clusters, we draw the inference based on critical values from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: NCMS' effect on domestic patent applications: Fixed effects Poisson model

	(1)	(2)	(3)	(4)	(5)	(6)
	Firm		Academic institution		Individual	
Panel A: By applicant type						
post*NCMS	2.75**		0.84		0.75*	
	(1.16)		(0.58)		(0.43)	
post1*NCMS		2.50***		0.70		0.70*
		(0.96)		(0.78)		(0.39)
post2*NCMS		2.13***		0.49		0.60
		(0.73)		(1.13)		(0.42)
RESET test	0.033	0.044	<0.01	<0.01	<0.01	<0.01
	Product		Process		Both	
Panel B: By invention type						
post*NCMS	0.93*		0.28		1.69**	
	(0.48)		(0.41)		(0.71)	
post1*NCMS		0.74*		0.27		1.67***
		(0.43)		(0.46)		(0.58)
post2*NCMS		0.29		0.27		1.64***
		(0.47)		(0.75)		(0.44)
RESET test	<0.01	<0.01	0.350	0.356	0.429	0.450
Observations	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24

Notes. Only domestic patent applications are included. Post is 2003 to 2009; Post1 is 2003 to 2006; Post2 is 2007 to 2009. RESET test p-values are reported. Standard errors are clustered at the disease level. To adjust for potential bias in clustered standard errors due to few clusters, we draw the inference based on critical values from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Our baseline results demonstrate the average treatment effect (ATE) during the whole post-period and the treatment effect in each sub-period of the NCMS on patenting behavior. In summary, we find that the NCMS had a strong positive impact on patent quantity and a modest positive impact on patent quality. However, as shown by Borusyak and Jaravel (2017), when there are strong dynamic treatment effects and the treatment and control groups are allowed for group- or unit-specific time trends, the canonical DID estimator might suffer from the negative weighting of long-term effects and have a short-term bias. The solution is to estimate the semi-dynamic models

Moreover, the average number of claims of the former was 6.6, whereas the latter was 3.5.

to obtain yearly treatment effects and then manually calculate the weighted ATE. We report the yearly effects and the calculated weighted ATEs in Tables A.2 to A.4. In general, most patenting activities do not show strong dynamics, and thus the discrepancies between the calculated ATEs and the canonical estimates are relatively small. Moreover, none of the discrepancies affect our interpretations. Therefore, we use the succinct canonical estimates as our main results.[33]

5.2. Disentangling Sources of Policy Variation

In our baseline analysis, we focus on the policy intensity that combines two sources of variation: whether a disease is covered by the NCMS and the share of rural patients suffering from a disease. This section disentangles these two sources of variation to understand better how different applicants perceive and respond to the NCMS. In addition, we exploit another variation arising from the NCMS' guideline (3): the emphasis on catastrophic diseases. As the NCMS focuses on catastrophic diseases, which usually incur large drug costs, we expect to see a larger percentage increase in innovations towards catastrophic diseases.[34] Based on the 2008–2009 hospital data from six provinces, Sun et al. (2013) identified 60 catastrophic diseases in China. The average hospitalization cost on these 60 diseases is 25,084 RMB, while the average hospitalization cost on the rest 1,355 diseases is only 12,701 RMB. Drug costs account for over 38% in the treatment of these 60 diseases while only 33% on the rest. Among these 60 diseases, four are included in our sample: cerebrovascular diseases, heart diseases, chronic bronchitis, and cirrhosis. The former two diseases have relatively more urban patients, and the latter two have more rural patients.

Panel A of Table 5 shows that all applicants responded to the NCMS

[33]However, due to the strong dynamic effects in claims count among all patent applications, we replace the negative but insignificant canonical estimate (-0.05) in column (1) of Panel B in Table 3 with the positive but insignificant calculated ATE (0.48). The same procedure is applied to all analyses regarding the average claims count of all patent applications. Additionally, we report estimates on claims count (at both the application and the grant stage) of all patents for completeness, but due to the large difference of claims count between domestic and foreign patents, such results should be viewed with caution.

[34]Although the NCMS' guideline (3) focuses on catastrophic diseases, formally defining and establishing the catastrophic disease insurance as a part of the NCMS only began in 2010 (Dai et al. 2013). Before 2010, counties often reacted to this guideline by setting a more generous reimbursement rate on inpatient care than outpatient care.

by increasing patent applications on NCMS-covered diseases. In columns (1), (4), and (7), when using a treatment dummy instead of the treatment intensity, we find that on average, domestic applicants increased patent applications by 100% on covered diseases, and foreign applications also increased by 70%. However, although domestic applicants responded to the NCMS by shifting resources towards diseases that were more prevalent in rural areas, foreign applicants still focused on diseases prevalent in urban areas. Among the 19 covered diseases, domestic applicants increased by 10.5% patent applications on diseases with a 10% higher rural patient share, though not statistically significant, while foreign applicants decreased by 3.8% patent applications on diseases with a 10% higher rural patient share.[35] We then consider another policy variation arising from the special focus on catastrophic diseases. As expected, we find a much stronger positive response in patent applications on catastrophic diseases in columns (3), (6), and (9), even among foreign applications.

In Panels B and C of Table 5, we find similar patterns in granted patents and patent renewals as in patent applications for foreign patents but different patterns for domestic patents. In particular, the magnitude of the increases in patent approvals and renewals in column (4) is similar to that of patent applications, thereby suggesting that the increased patent applications on the NCMS-covered diseases on average assured the minimal quality for passing the substantial examination and had relative high commercial value. However, considering the specific disease-level variation in column (5), even though a disease with a 10% higher rural patient share saw a 10.5% increase in domestic patent applications, it only resulted in a 4.1% increase in approvals and a 4% increase in renewals (both are insignificant), which implies the quality increase lagged the quantity increase among diseases that were more prevalent in rural areas. In columns (3), (6), and (9), consistent with the application response, we find a stronger increase in granted patents and patent renewals on catastrophic diseases.

Table 6 examines the change in patent quality, and it exhibits different patterns from Table 5. Panel A column (1) reveals that the increase in overall citations is mainly driven by patents regarding rural-prevalent diseases, which suggests an increase in the intellectual value or attention towards these new

[35] Although the estimates in columns (2) and (5) of Panel A are not significant, the magnitudes are similar to those of columns (1) and (3) in Panel A of Table 2.

Table 5: NCMS' effect on patent quantity: Disentangling sources of policy variation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		All			Domestic			Foreign	
Panel A: Applications									
post*NCMSdummy	0.71***			1.01***			0.71***		
	(0.09)			(0.11)			(0.18)		
post*NCMS		0.61	0.74***		1.05	1.25***		-0.38	-0.25
		(0.53)	(0.22)		(0.87)	(0.32)		(0.37)	(0.25)
post*NCMS*catastrophic			1.10***			1.49***			0.39
			(0.31)			(0.48)			(0.26)
RESET test	0.142	0.340	0.328	0.414	<0.01	0.044	<0.01	<0.01	<0.01
Panel B: Grants									
post*NCMSdummy	0.49***			1.01***			0.54*		
	(0.10)			(0.12)			(0.28)		
post*NCMS		0.35	0.49**		0.41	0.71**		-0.34	-0.25
		(0.45)	(0.24)		(0.54)	(0.28)		(0.51)	(0.30)
post*NCMS*catastrophic			0.76***			0.74*			0.83***
			(0.27)			(0.36)			(0.28)
RESET test	0.241	0.268	0.817	0.435	0.020	0.052	<0.01	<0.01	0.012
Panel C: Renewals									
post*NCMSdummy	0.61***			1.19***			0.51**		
	(0.09)			(0.13)			(0.26)		
post*NCMS		0.35	0.56**		0.40	0.81***		-0.39	-0.27
		(0.46)	(0.25)		(0.55)	(0.31)		(0.52)	(0.32)
post*NCMS*catastrophic			0.78***			0.76*			0.79**
			(0.29)			(0.37)			(0.32)
RESET test	0.317	0.150	0.672	0.522	<0.01	0.054	<0.01	<0.01	0.023
Observations	408	323	408	408	323	408	408	323	408
Number of diseases	24	19	24	24	19	24	24	19	24

Notes. *NCMSdummy* takes 1 if a disease is one of the 19 diseases covered by the NCMS and 0 otherwise. Catastrophic diseases are: cerebrovascular diseases, heart diseases, chronic bronchitis, and cirrhosis. Post is 2003 to 2009. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from T-distributions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

patents on rural-prevalent diseases. In column (5) of Panel B, we find a 7.4% increase in claims count among domestic patent applications towards rural-prevalent diseases. However, column (5) in Panel C shows that this increase in claims count among patent applications towards rural-prevalent diseases occurred only at the application stage but did not result in the corresponding increase among the granted patents. Therefore, the increase in claims count among granted domestic patents found in Table 3 was primarily driven by the general NCMS coverage but not rural-prevalent diseases. In addition, although catastrophic diseases saw a larger increase in the patent quantity, their quality improvement was generally smaller than that of non-catastrophic diseases or even saw a quality decline, as shown in columns (3),

(6), and (9).

Table 6: NCMS' effect on patent quality: Disentangling sources of policy variation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		All			Domestic			Foreign	
Panel A: Citations									
post*NCMSdummy	0.24			0.12			0.71		
	(0.28)			(0.18)			(1.00)		
post*NCMS		0.68	0.63*		0.12	0.53		0.85	1.73
		(0.46)	(0.33)		(0.77)	(0.35)		(0.90)	(1.49)
post*NCMS*catastrophic			-0.50**			-0.80***			0.59
			(0.22)			(0.23)			(1.18)
RESET test	0.863	0.061	0.852	0.128	0.854	0.183	0.918	0.336	0.915
Observations	388	311	388	376	301	376	319	277	319
Number of diseases	24	19	24	24	19	24	23	19	23
Panel B: Application claims count									
post*NCMSdummy	0.56			0.04			-0.10		
	(0.43)			(0.11)			(0.23)		
post*NCMS		-0.12	0.49		0.74***	0.28		0.35	0.33
		(0.38)	(0.47)		(0.25)	(0.22)		(0.52)	(0.32)
post*NCMS*catastrophic			-0.26			0.01			-0.66*
			(0.43)			(0.16)			(0.37)
RESET test	0.178	0.068	0.238	<0.01	0.444	<0.01	0.303	0.326	0.329
Observations	388	311	388	376	301	376	323	277	323
Number of diseases	24	19	24	24	19	24	24	19	24
Panel C: Granted patent claims count									
post*NCMSdummy	-0.12			0.27			-0.02		
	(0.24)			(0.16)			(0.16)		
post*NCMS		0.08	-0.10		0.01	0.28		0.44	0.13
		(0.26)	(0.61)		(0.25)	(0.17)		(0.49)	(0.28)
post*NCMS*catastrophic			-0.06			0.06			-0.11
			(0.35)			(0.13)			(0.45)
RESET test	0.701	<0.01	0.709	0.158	0.896	0.201	0.187	0.315	0.198
Observations	370	300	370	347	285	347	274	242	274
Number of diseases	24	19	24	24	19	24	23	19	23

Notes. *NCMSdummy* takes 1 if a disease is one of the 19 diseases covered by the NCMS and 0 otherwise. Catastrophic diseases are: cerebrovascular diseases, heart diseases, chronic bronchitis, and cirrhosis. For completeness, we report estimates on claims count of all patents. However, due to the large difference between claims count of domestic and foreign patents, columns (1)-(3) in Panel B and C should be viewed with caution. Post is 2003 to 2009. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from T-distributions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, Table 7 considers responses by different applicants and on different invention types. As in Table 4, we only consider domestic patent applications, as they capture the increased innovation activities in China after the NCMS. Panel A shows that domestic firms responded most strate-

gically to the NCMS. Even though all types of domestic stakeholders focused more innovations on the NCMS-covered and catastrophic diseases, domestic firms carefully followed disease-specific market size changes by increasing 28% patent applications on diseases with a 10% higher rural patient share. This result is consistent with what economic theory suggests: domestic firms have the strongest financial incentive and thus understand and respond to the policy more sophisticatedly. Panel B indicates that domestic applicants increased product invention applications and inventions on both product and process regarding the NCMS-covered diseases, the rural-prevalent diseases, and catastrophic diseases.[36]

Table 7: NCMS' effect on domestic patent applications: Disentangling sources of policy variation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Firm			Academic institution			Individual	
Panel A: By applicant type									
post*NCMSdummy	0.92***			1.59***			0.53***		
	(0.31)			(0.34)			(0.10)		
post*NCMS		2.82*	2.87***		0.12	0.83		0.59	0.75***
		(1.44)	(0.70)		(0.53)	(0.54)		(0.69)	(0.25)
post*NCMS*catastrophic			2.33***			1.12***			1.23***
			(0.84)			(0.38)			(0.27)
RESET test	0.012	0.078	<0.01	0.174	<0.01	0.011	<0.01	<0.01	<0.01
		Product			Process			Both	
Panel B: By invention type									
post*NCMSdummy	1.04***			0.33			0.97***		
	(0.15)			(0.39)			(0.19)		
post*NCMS		0.64	0.92***		0.27	0.28		1.58	1.73***
		(0.88)	(0.28)		(0.50)	(0.41)		(0.96)	(0.44)
post*NCMS*catastrophic			1.57***			0.12			1.52***
			(0.51)			(0.86)			(0.51)
RESET test	<0.01	<0.01	<0.01	0.424	0.189	0.375	0.072	0.060	0.031
Observations	408	323	408	408	323	408	408	323	408
Number of diseases	24	19	24	24	19	24	24	19	24

Notes. *NCMSdummy* takes 1 if a disease is one of the 19 diseases covered by the NCMS and 0 otherwise. Catastrophic diseases are: cerebrovascular diseases, heart diseases, chronic bronchitis, and cirrhosis. Post is 2003 to 2009. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from T-distributions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In summary, both domestic and foreign applicants focused more innovations on the NCMS-covered diseases. However, only domestic firms re-

[36]Although the estimates in columns (2) and (8) of Panel B are not significant, the magnitudes are close to those of columns (1) and (5) in Panel B of Table 4.

sponded sophisticatedly to the expected market size change at the micro-level by increasing the R&D investment in rural-prevalent diseases. The increases in patent approvals, renewals, and claims count among granted patents were mainly driven by the difference between covered and non-covered diseases. However, the increases in patent citations and claims count among patent applications were mainly driven by rural-prevalent diseases. The special focus of the NCMS on catastrophic diseases incentivized more innovation activities targeted at these diseases but did not translate into higher innovation quality.

5.3. Robustness Check

In this section, we perform the following robustness checks: 1) using the post-NCMS rural patient share as the main source of variation, 2) leave-one-out estimations, 3) excluding diseases that might be affected by a confounding event, and 4) estimating the effects with log-linear models. In general, our results are robust to all of these sensitivity analyses.

5.3.1. Different Measures of Rural Patient Share

In our main analysis, we use the pre-NCMS rural patient share at the disease-level to predict the expected pharmaceutical market size change of each disease, because we presume innovators would form their expectations based on these observed rural patient shares by the time that the NCMS was announced. However, as the NCMS might increase medical diagnoses among rural people via increased health care utilization, the observed pre-NCMS rural patient shares might underestimate the expected market size change, and thus we may overestimate the NCMS' impact. Meanwhile, the demographic composition, socioeconomic and living conditions in China also experienced rapid changes, and sophisticated decision-makers might also take these into account when predicting the pharmaceutical market size. As a result, it is hard to predict the direction of the changes in rural patient shares among different diseases, and it is unclear whether pre-NCMS or post-NCMS rural patient shares are more close to innovators' expectations. Therefore, we conduct a robustness check by replacing the pre-NCMS rural patient shares with post-NCMS rural patient shares using the 2008 data. Tables A.5 to A.7 show the results. In addition, in our main analysis, the pre-NCMS rural patient shares are measured with the 2003 data. As a robustness check, we replace pre-NCMS rural patient shares with the 1998 data, and the results

are shown by Tables A.8 to A.10. All of the estimates are close to our main estimates.[37]

5.3.2. Leave-One-Out Estimation

Since we only have 19 treated diseases and 5 control diseases, among which the former provide key variation for the estimation, our estimation may suffer from the small sample bias. Therefore, we re-run our regressions 19 times by excluding one treatment disease each time to test whether the results are sensitive to some outlier. The results are shown in Tables A.11 to A.13. The estimates on quality are similar by excluding any disease, and the impact on quantity is also robust, except for excluding diabetes. Regarding the exclusion of diabetes, although we still obtain a positive coefficient on domestic patent applications, the effect size is only one-third of the main effect. Conceptually, however, diabetes is a critical disease in our analysis, as it is the only disease with a dominant urban patient share (76% were urban patients in 2003) and thus serves as an irreplaceable "control" disease for the other 18 treated diseases with higher rural patient shares.[38] After all, our conclusion that the NCMS increased domestic pharmaceutical innovation and patent quality still holds.

5.3.3. The SARS Epidemic

In 2003, the SARS Epidemic was another significant event in China. SARS was first clinically recognized at the end of February 2003, and the epidemic broke out in mainland China since March 2003. The reported cases surged from 806 to 5,328 from late March to late May in 2003 (WHO 2003).

The SARS event could potentially affect the pharmaceutical industry. After the epidemic, people became more cautious of diseases with similar symptoms as SARS, either due to fear or strengthened government monitoring. Therefore, the market size for similar diseases may increase, and

[37]Results with the 2003-2008 average or the 1998-2003 average rural patient shares are also similar and available upon request.

[38]Diabetes is the least affected disease by the NCMS among the 19 NCMS-covered diseases. Although heart diseases and hypertension also had higher urban patient shares, 57% and 52% in 2003, respectively, their substantial rural patient shares (43% and 48%) indicated that their (expected) market size would also expand substantially due to the NCMS. Moreover, heart disease is also a catastrophic disease and thus resulted in a larger increase in innovation. Excluding heart disease increases the estimate on patent applications by 20%.

pharmaceutical firms might respond to such an opportunity. The three diseases that have similar symptoms as SARS (pneumonia, TB, and acute upper respiratory infections [AURI]) happen to be more prevalent in rural areas. Therefore, we worry that the increased innovations after the NCMS were driven by these three diseases.

As a robustness check, we drop pneumonia, TB, and AURI and re-conduct our analysis. Tables A.14 to A.16 show the results. The magnitude of estimated NCMS' impact is slightly smaller than that of the main results, but the positive impact on patent applications and the quality of granted patents remained statistically significant.[39] This robustness check indicates that SARS was not a confounding factor in incentivizing pharmaceutical innovation towards rural-prevalent diseases.

5.3.4. Log-linear Model

In addition to the fixed effects Poisson models, we also conduct our analysis with the log-linear models:

$$log\tilde{N}_{ct} = \beta Post_t \cdot NCMS_c + \phi ln(urban\ patients)_{ct} + \theta\alpha_c \cdot Year_t + \alpha_c + \gamma_t + \epsilon_{ct}, \tag{4}$$

and

$$\begin{aligned} log\tilde{N}_{ct} = {} & \beta_1 Post1 \cdot NCMS_c + \beta_2 Post2 \cdot NCMS_c \\ & + \phi ln(urban\ patients)_{ct} + \theta\alpha_c \cdot Year_t + \alpha_c + \gamma_t + \epsilon_{ct}, \end{aligned} \tag{5}$$

In equation (4) and (5), we use two different transformations of the outcome variable: $\tilde{N}_{ct} = N_{ct} + 1$ and $\tilde{N}_{ct} = N_{ct} + \sqrt{N_{ct}^2 + 1}$, the Inverse Hyperbolic Sine (IHS) transformation to deal with the zero count.[40]

Tables A.17 to A.19 presents estimates from log-linear models using different transformations of the dependent variables. Columns (1) to (6) report estimates from using $log(N+1)$ as the outcomes, and columns (7) to (12) report estimates from using the IHS transformation. The results are consistent with our estimates from the fixed effect Poisson models and show a stronger

[39] Due to the small sample size, dropping three diseases reduces our sample by more than 10% observations, which further reduces the statistical power.

[40] The advantage of using the IHS is that, except for very small values of N, the IHS is approximately equal to $log(2) + log(N)$, so it can be interpreted in the same way as a standard logarithmic dependent variable, i.e. the coefficient can be interpreted as elasticity.

increase in patent renewals as well.

6. Conclusion

This study provides novel empirical evidence on the positive effect of public health insurance on pharmaceutical innovation in a developing country context. Our estimates show that a disease with 10% higher rural patient share saw an approximately 12.4% increase in domestic patent applications from 2003 to 2009 after the establishment of the NCMS in China. Although our estimates cannot be directly compared with the estimated elasticity of pharmaceutical innovation to market size from the US (Acemoglu and Linn 2004; Blume-Kohout and Sood 2013) and across countries (Dubois et al. 2015), this study presents the first evidence to show that pharmaceutical innovation responds to the expected market size expansion in a developing country setting.

We acknowledge that the pharmaceutical innovation level during our study period was relatively low in China. Nevertheless, we find modest evidence that the NCMS increased patent quality (at the 10% significance level). The surge in patent applications led to a 6.8% increase in granted patents and a 7.8% increase in renewals among patents targeted at the NCMS-covered rural-prevalent diseases. In addition, we find small increases in patent citations and claims count among these patents.

Our findings reveal the positive spillover effect of providing public health insurance programs. They also help us to understand better the mechanisms behind the low innovation level towards diseases that mainly afflict people in developing countries, such as infectious diseases. By providing public health insurance to increase the ability of the low-income population to afford healthcare, the government also creates incentives for firms to increase innovation activities. When governments in developing countries design pharmaceutical innovation policies (Kremer 2002), they should take into account the potential spillover effect of public health insurance on innovation.

However, to show that such pharmaceutical innovation improves social welfare, further analysis is needed. First, since patent filings occur at different stages of the new drug discovery and development process and in various forms, we need to know at which stage and how the patents contribute to the ultimate discovery of new drugs. Next, we need to evaluate the contributions of the ultimate innovations (i.e. new drugs), such as how effective they are in treating certain diseases. Finally, we need to measure and compare the

social costs and social benefits of developing a new drug, as in Finkelstein (2004). Future research needs to collect more data and conduct further analysis to examine the welfare impacts of the public health insurance-induced pharmaceutical innovation in developing countries.

Acknowledgements: We would like to thank Anna Aizer, Emily Oster, Jesse Shapiro, Kenneth Chay, Mingwei Fu, Ruixue Jia, Seonghoon Kim, Kanghyock Koh, Jing You, Jing Zhang, and participants at Brown University Micro Lunch and the NUS EAI seminar for giving us valuable comments and advice. We are grateful to the excellent research assistants who have worked on this project, especially to Rui Ruan, Yunjie Xie, and Ning Yang. This work was supported by Brown University Graduate School and the Population Studies and Training Center and the Key Project of Ministry of Education of China (18JZD048). Declarations of interests: None.

References

Acemoglu, D., Cutler, D., Finkelstein, A., Linn, J., 2006. Did Medicare Induce Pharmaceutical Innovation? Technical Report. National Bureau of Economic Research.

Acemoglu, D., Linn, J., 2004. Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry. The Quarterly Journal of Economics 119, 1049–1090. URL: https://academic.oup.com/qje/article-abstract/119/3/1049/1938820, doi:10.1162/0033553041502144.

Ang, J.S., Cheng, Y., Wu, C., 2014. Does Enforcement of Intellectual Property Rights Matter in China? Evidence from Financing and Investment Choices in the High-Tech Industry. The Review of Economics and Statistics 96, 332–348. URL: https://ideas.repec.org/a/tpr/restat/v96y2014i2p332-348.html. publisher: MIT Press.

Babiarz, K.S., Miller, G., Yi, H., Zhang, L., Rozelle, S., 2010. New Evidence on the Impact of China's New Rural Cooperative Medical Scheme and Its Implications for Rural Primary Healthcare: Multivariate Difference-in-difference Analysis. BMJ 341, c5617. URL: https://www.bmj.com/content/341/bmj.c5617, doi:10.1136/bmj.c5617.

Bai, C.E., Wu, B., 2014. Health Insurance and Consumption: Evidence from China's New Cooperative Medical Scheme. Journal of Comparative Economics 42, 450–469.

Blume-Kohout, M.E., Sood, N., 2013. Market Size and Innovation: Effects of Medicare Part D on Pharmaceutical Research and Development. Journal of Public Economics 97, 327–336. URL: https://linkinghub.elsevier.com/retrieve/pii/S0047272712001119, doi:10.1016/j.jpubeco.2012.10.003.

Borusyak, K., Jaravel, X., 2017. Revisiting Event Study Designs. Working Paper. Harvard University.

Cameron, A.C., Miller, D.L., 2015. A Practitioner's Guide to Cluster-Robust Inference. Journal of Human Resources 50, 317–372. URL: http://jhr.uwpress.org/lookup/doi/10.3368/jhr.50.2.317, doi:10.3368/jhr.50.2.317.

Chen, X.S., Ge, K.Y., 1995. Nutrition Transition in China: The Growth of Affluent Diseases with the Alleviation of Undernutrition. Asia Pacific Journal of Clinical Nutrition 4, 287–293.

Chen, Y., Puttitanun, T., 2005. Intellectual Property Rights and In-

novation in Developing Countries. Journal of Development Economics 78, 474–493. URL: https://linkinghub.elsevier.com/retrieve/pii/S0304387805000635, doi:10.1016/j.jdeveco.2004.11.005.

Cheng, T., 2008. Comparative Studies of "First-to-file" and "First-to-invent" Principles druing Patent Examination. Legal System and Society (in Chinese) doi:10.19387/j.cnki.1009-0592.2008.27.020.

Civan, A., Maloney, M.T., 2006. The Determinants of Pharmaceutical Research and Development Investments. The B.E. Journal of Economic Analysis & Policy 5. URL: http://www.degruyter.com/view/j/bejeap.2005.5.issue-1/bejeap.2006.5.1.1511/bejeap.2006.5.1.1511.xml, doi:10.1515/1538-0645.1511.

Clemens, J., 2013. The Effect of U.S. Health Insurance Expansions on Medical Innovation. Working Paper 19761. National Bureau of Economic Research. URL: http://www.nber.org/papers/w19761, doi:10.3386/w19761.

Dai, T., Mao, A., Xie, L., Zhou, Y., 2013. Policy Analysis on the Catastrophic Disease Insurance of New Rural Cooperative Medical Scheme in China. Chinese Journal of Health Policy (in Chinese) 6.

Ding, J., Xue, Y., Liang, H., Shao, R., Chen, Y., 2011. From Imitation to Innovation: A Study of China's Drug R&D and Relevant National Policies. Journal of Technology Management & Innovation 6, 1–13. URL: http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-27242011000200001&lng=en&nrm=iso&tlng=en, doi:10.4067/S0718-27242011000200001.

Dubois, P., Mouzon, O.d., Scott-Morton, F., Seabright, P., 2015. Market Size and Pharmaceutical Innovation. The RAND Journal of Economics 46, 844–871. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/1756-2171.12113, doi:10.1111/1756-2171.12113.

Feng, X., Shenglan, T., Bloom, G., Segall, M., Xingyuan, G., 1995. Cooperative Medical Schemes in Contemporary Rural China. Social Science & Medicine 41, 1111–1118.

Finkelstein, A., 2004. Static and Dynamic Effects of Health Policy: Evidence from the Vaccine Industry. The Quarterly Journal of Economics 119, 527–564. URL: https://academic.oup.com/qje/article-lookup/doi/10.1162/0033553041382166, doi:10.1162/0033553041382166.

Friedman, J.N., 2009. The Incidence of the Medicare Prescription Drug Benefit: Using Asset Prices to Assess its Impact on Drug Makers. Job Market Paper. University of California at Berkeley.

Gustafsson, B., Li, S., 2004. Expenditures on Education and Health Care and Poverty in Rural China. China Economic Review 15, 292–301.

Hausman, J., Hall, B.H., Griliches, Z., 1984. Econometric Models for Count Data with an Application to the Patents-R&D Relationship. Econometrica 52, 909–38.

He, Q., 2016. China's Pharmaceutical Industry Structure and Intellectual Property Protection. Technical Report. National Intellectual Property Administration, PRC. URL: http://www.sipo.gov.cn/gwyzscqzlssgzbjlxkybgs/zlyj_zlbgs/1062635.htm.

Hsiao, W.C., Shaw, R.P., Fraker, A., 2007. Social Health Insurance for Developing Nations. WBI development studies, World Bank, Washington, D.C. OCLC: ocn141177631.

Hu, A.G., Jefferson, G.H., 2009. A Great Wall of Patents: What is behind China's Recent Patent Explosion? Journal of Development Economics 90, 57–68. URL: http://www.sciencedirect.com/science/article/pii/S0304387808001120, doi:10.1016/j.jdeveco.2008.11.004.

Huang, F., Gan, L., 2017. The Impacts of China's Urban Employee Basic Medical Insurance on Healthcare Expenditures and Health Outcomes. Health Economics 26, 149–163. URL: http://onlinelibrary.wiley.com/doi/abs/10.1002/hec.3281, doi:10.1002/hec.3281.

Jian, W., Chan, K.Y., Reidpath, D.D., Xu, L., 2010. China's Rural-urban Care Gap Shrank for Chronic Disease Patients, but Inequities Persist. Health Affairs 29, 2189–2196.

Kremer, M., 2002. Pharmaceuticals and the Developing World. The Journal of Economic Perspectives 16, 67–90.

Kyle, M.K., McGahan, A.M., 2012. Investments in Pharmaceuticals Before and After TRIPS. Review of Economics and Statistics 94, 1157–1172. URL: http://www.mitpressjournals.org/doi/10.1162/REST_a_00214, doi:10.1162/REST_a_00214.

Lakdawalla, D.N., 2018. Economics of the Pharmaceutical Industry. Journal of Economic Literature 56, 397–449. URL: https://www.aeaweb.org/articles?id=10.1257/jel.20161327, doi:10.1257/jel.20161327.

Lei, X., Lin, W., 2009. The New Cooperative Medical Scheme in rural China: Does More Coverage Mean More Service and Better Health? Health Economics 18, S25–S46. URL: http://onlinelibrary.wiley.com/doi/abs/10.1002/hec.1501, doi:10.1002/hec.1501.

Lichtenberg, F.R., 2005. Pharmaceutical Innovation and the Burden of Disease in Developing and Developed Countries. Journal of Medicine and

Philosophy 30, 663–690.

Lin, W., Liu, G.G., Chen, G., 2009. The Urban Resident Basic Medical Insurance: A Landmark Reform towards Universal Coverage in China. Health Economics 18, S83–S96.

Ministry of Health, 2005. Report on Healthcare Reforms and Development. Technical Report. URL: http://www.gov.cn/ztzl/2005-10/20/content_80720.htm.

Ministry of Health, Ministry of Finance, 2008. Instructions of Enhancing New Cooperative Medical Scheme in 2008. Technical Report.

Ministry of Health, Ministry of Finance, Ministry of Agriculture, 2003. The Advice for Establishment of New Cooperative Medical Scheme. Technical Report.

Ministry of Health, National Development and Reform Commission, Ministry of Civil Affairs, Ministry of Finance, Ministry of Agriculture, State Food and Drug Administration, State Administration of Traditional Chinese Medicine, 2006. Decisions about Accelarating New Cooperative Medical Scheme. Technical Report.

National Health Commission, 2006. Anhui Province New Cooperative Medical Scheme's Non-covered Treatment Items and Health Care Services.

National Health Commission, 2008. Shanxi Province Measures on New Cooperative Medical Scheme's Treatment Items and Health Care Services.

National Health Commission, 2011. Hebei Province Regulations on New Cooperative Medical Scheme's Treatment Items. URL: http://www.hebwst.gov.cn/index.do?id=341787&templet=content&cid=2859.

National Health Commission, Ministry of Finance, 2015. Instructions of Enhancing New Cooperative Medical Scheme in 2015. Technical Report.

OECD, 2015. Research and development in the pharmaceutical sector. Health at a Glance 2015: OECD Indicators .

Van de Poel, E., O'Donnell, O., Van Doorslaer, E., 2009. Urbanization and the Spread of Diseases of Affluence in China. Economics & Human Biology 7, 200–216. URL: http://www.sciencedirect.com/science/article/pii/S1570677X09000434, doi:10.1016/j.ehb.2009.05.004.

Popkin, B.M., 2008. Will China's Nutrition Overwhelm Its Health Vare System and Slow Economic Growth? Health Affairs 27, 1064–1076. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2447919/, doi:10.1377/hlthaff.27.4.1064.

SFDA, 2002. Provisions of Drug Registration (Trial) (SFDA Order 35). Technical Report. State Food and Drug Administration, China.

SFDA, 2007. Provisions of Drug Registration (SFDA Order No. 28). Technical Report. State Food and Drug Administration, China.

Silva, J.M.C.S., Tenreyro, S., 2006. The Log of Gravity. The Review of Economics and Statistics 88, 641–658. URL: https://doi.org/10.1162/rest.88.4.641, doi:10.1162/rest.88.4.641. publisher: MIT Press.

State Council, 1997. Decisions on Healthcare Reforms. Technical Report. URL: http://www.nhc.gov.cn/wjw/zcjd/201304/743ba60a223646cd9eb4441b6d5d29fa.shtml.

State Council, 2000. Notice on the Pilot Work on Rural Tax and Fee Reforms. Technical Report. URL: http://jiuban.moa.gov.cn/zwllm/zcfg/flfg/200601/t20060123_540498.htm.

State Council, 2001. 2001 Report on the Work of the Government. Technical Report. URL: http://www.gov.cn/test/2006-02/16/content_201157.htm.

State Council, 2002a. Decisions on Strengthening Rural Healthcare. Technical Report.

State Council, 2002b. Notice on Expanding the Pilot Work on Rural Tax and Fee Reforms. Technical Report. URL: http://www.gov.cn/gongbao/content/2002/content_61425.htm.

State Council, 2005. Achievements in the Pilot Stage of New Cooperative Medical Scheme. Technical Report. URL: http://www.gov.cn/ztzl/2005-12/30/content_142860.htm.

State Council, 2007a. Guidelines for Implementation of Three National Science and Technology Major Projects (2007.12.26). Technical Report.

State Council, 2007b. Instructions on Establishing the Urban Residence Essential Medical Scheme. Technical Report.

State Council, 2008. Instructions on the First-round New Drug Innovation Project Applications. Technical Report.

State Council, 2009. Launch of Major New Drugs Devlopment Project. Technical Report.

State Council, 2015. Opinions of the State Council on Reform of the System of Evaluation, Review and Approval of Drugs and Medical Devices. Technical Report. URL: http://www.gov.cn/zhengce/content/2015-08/18/content_10101.htm.

Sun, N., Liang, M., Fang, S., Dong, D., Sun, D., Zhang, Z., Zhou, J., Wang, M., 2013. Analysis on Characteristics of Medical Expenses Based on Catastrophic Disease Classification. Chinese Journal of Health Policy (in Chinese) 6.

Sun, Q., Santoro, M.A., Meng, Q., Liu, C., Eggleston, K., 2008a. Pharmaceutical Policy In China. Health Affairs 27, 1042–1050. URL: http://www.healthaffairs.org/doi/10.1377/hlthaff.27.4.1042, doi:10.1377/hlthaff.27.4.1042.

Sun, X., Jackson, S., Carmichael, G.A., Sleigh, A.C., 2009. Prescribing Behaviour of Village Doctors under China's New Cooperative Medical Scheme. Social Science & Medicine 68, 1775–1779. URL: http://www.sciencedirect.com/science/article/pii/S0277953609001385, doi:10.1016/j.socscimed.2009.02.043.

Sun, Y., Liu, H., Wang, H., Liu, J., Zhang, C., 2008b. Deep Indexed Chinese Pharmaceuitcal Patent Database. Chinese Journal of Medicinal Guide (in Chinese) 10, 22–26.

Tan, L., Liu, Y., Yan, Z., Liu, W., 2015. Motiviations of Non-service Patent Licenses. R&D Management (in Chinese) .

United Nations, 2011. World Population Prospects: The 2010 Revision, Volume I - Comprehensive Tables. Technical Report. UN. New York. URL: https://www.un-ilibrary.org/population-and-demography/world-population-prospects_08b807d4-en, doi:10.18356/08b807d4-en.

US CDC, 2005. The Health Effects of Overweight and Obesity. Technical Report. Center for Disease Control and Prevention, US. URL: http://www.cdc.gov/healthyweight/effects/.

Wagstaff, A., Lindelow, M., Jun, G., Ling, X., Juncheng, Q., 2009. Extending Health Insurance to the Rural Population: An impact Evaluation of China's New Cooperative Medical Scheme. Journal of Health Economics 28, 1–19. URL: http://www.sciencedirect.com/science/article/pii/S0167629608001392, doi:10.1016/j.jhealeco.2008.10.007.

Weil, D.N., 2007. Accounting for the Effect of Health on Economic Growth. The Quarterly Journal of Economics , 1265–1306.

WHO, 2003. Cumulative Number of Reported Probable Cases of Severe Acute Respiratory Syndrome (SARS). URL: http://www.who.int/csr/sars/country/en/.

Williamson, P.J., Yin, E., 2014. Accelerated Innovation: The New Challenge From China. MIT Sloan Management Review 55.

Wooldridge, J.M., 1999. Distribution-free Estimation of Some Nonlinear Panel Data Models. Journal of Econometrics 90, 77–97.

Yin, W., 2008. Market Incentives and Pharmaceutical Innovation. Journal of Health Economics 27, 1060–1077. URL: https://

linkinghub.elsevier.com/retrieve/pii/S0167629608000039, doi:10.1016/j.jhealeco.2008.01.002.

Yip, W., Hsiao, W.C., 2008. The Chinese Health System at a Crossroads. Health Affairs 27, 460–468.

You, X., Kobayashi, Y., 2009. The New Cooperative Medical Scheme in China. Health Policy 91, 1–9. URL: http://www.sciencedirect.com/science/article/pii/S0168851008002777, doi:10.1016/j.healthpol.2008.11.012.

Yu, B., Meng, Q., Collins, C., Tolhurst, R., Tang, S., Yan, F., Bogg, L., Liu, X., 2010. How Does the New Cooperative Medical Scheme influence health service utilization? A study in Two Provinces in Rural China. BMC Health Services Research 10, 116. URL: https://doi.org/10.1186/1472-6963-10-116, doi:10.1186/1472-6963-10-116.

Yu, X., Yan, J., Assimakopoulos, D., 2015. Case Analysis of Imitative Innovation in Chinese Manufacturing SMEs: Products, Features, Barriers and Competences for Transition. International Journal of Information Management 35, 520–525. URL: http://www.sciencedirect.com/science/article/pii/S0268401215000274, doi:10.1016/j.ijinfomgt.2015.03.003.

Zhang, Q., 2002. Pharmaceutical Intellectual Property Protections in China. Chinese Journal of New Drugs (in Chinese) 11, 17–21.

Zhang, Q., 2004. Current Pharmaceutical Intellectual Property Protections and the Trend in China. China Intellectual Property News (in Chinese) .

Zhang, Q., 2015. Continuous Improvement on the Patent Law: Impact and Outlook for Pharmaceutical Innovation. China Invention & Patent (in Chinese) .

Appendix

A.1. Impact of the NCMS on Disease-level Market Size Change

This section presents a simple model to quantify the disease-level incentive brought by the NCMS to pharmaceutical firms. The logic here is that if a disease is relatively more prevalent among rural residents, the NCMS would lead to a larger percentage increase in its expected market size. Similar to Acemoglu and Linn (2004) and Blume-Kohout and Sood (2013), we presume innovators respond to the expected market size change in China, i.e., they increase innovation activities once the NCMS was announced and before the full expansion of the NCMS.

Assume that the average price of medicines for treating a disease is 1.[41] Both urban and rural residents can get this disease, and suppose that the number of urban patients in a year is U_t, and the number of rural patients is R_t. Urban and rural residents have different propensities to buy drugs, due to different levels of income and health insurance coverage. Suppose the proportion of urban patients buying drugs for a certain disease is λ_t^U, and the proportion of rural patients is λ_t^R. Therefore, the market size for a given disease in a given year is:

$$\pi = \lambda_t^R \cdot R_t + \lambda_t^U \cdot U_t \tag{A.1}$$

Since the NCMS only affects rural residents' health-seeking behavior, it affects the first part of equation (A.1). It potentially affects the rural market size by increasing rural patients' willingness to pay λ_t^R, and/or increasing rural people's health care utilization and thus increase diagnosed patients

[41] This price can be cancelled out in equation (2), so average price equal to 1 is just for simplicity.

R_t. Therefore, the NCMS' effect on the change in a disease's market size is:

$$NCMS = \frac{\Delta\pi}{\pi} = \frac{\lambda^R_{post} \cdot R_{post} - \lambda^R_{pre} \cdot R_{pre}}{\lambda^R_{pre} \cdot R_{pre} + \lambda^U \cdot U_{pre}} \tag{A.2}$$

$$= \frac{\lambda^R_{post} \cdot R_{post}(-\lambda^R_{post} \cdot R_{pre} + \lambda^R_{post} \cdot R_{pre}) - \lambda^R_{pre} \cdot R_{pre}}{\lambda^R_{pre} \cdot R_{pre} + \lambda^U \cdot U_{pre}} \tag{A.3}$$

$$= \frac{\Delta\lambda^R_t \cdot R_{pre} + \lambda^R_{post} \cdot \Delta R_t}{\lambda^R_{pre} \cdot R_{pre} + \lambda^U \cdot U_{pre}} \tag{A.4}$$

$$= \frac{\Delta\lambda^R_t}{\lambda^R_{pre} + \lambda^U \cdot \frac{U_{pre}}{R_{pre}}} + \frac{\lambda^R_{post} \cdot \frac{\Delta R_t}{R_{pre}}}{\lambda^R_{pre} + \lambda^U \cdot \frac{U_{pre}}{R_{pre}}} \tag{A.5}$$

Since pharmaceutical firms respond to the expected future market, the expected market size change of a given disease is:

$$E(NCMS) = \frac{E(\Delta\lambda^R_t) + E(\lambda^R_{post} \cdot \frac{\Delta R_t}{R_{pre}})}{\lambda^R_{pre} + \lambda^U \cdot \frac{U_{pre}}{R_{pre}}} = \frac{E(\Delta\lambda^R_t) + E(\lambda^R_{post} \cdot \frac{\Delta R_t}{R_{pre}})}{\lambda^R_{pre} + \lambda^U \cdot (\frac{1}{ruralshare_{pre}} - 1)} \tag{A.6}$$

Ideally, if we had disease-specific information on λ^R_{pre}, $E(\lambda^R_{post})$, $E(R_{post})$ and λ^U, combining with $ruralshare_{pre}$, we can precisely measure the NCMS' impact on each disease's expected market size change. However, we do not have such detailed information on disease-specific $\lambda' s$ before the NCMS, and $E(\lambda^R_{post})$ and $E(R_{post})$ depend on many factors, and different innovators may form different expectations on them. Nevertheless, we know at least two factors would affect $E(NCMS)$: the NCMS coverage, which will affect the numerator via both $E(\lambda^R_{post})$ and $E(R_{post})$, and $ruralshare_{pre}$ in the denominator. Therefore, our key independent variable is:

$$\begin{aligned} NCMS_c &= f(ruralshare_c, 1(\Delta\lambda^R_{t,c} > 0, \Delta R_{t,c} > 0)) \\ &= 1(NCMScovered_c) \cdot ruralshare_c, \end{aligned} \tag{A.7}$$

where $1(NCMScovered_c)$ is a dummy variable indicating whether a disease is covered by the NCMS, and $ruralshare_c$ uses pre-NCMS share of rural

patients of disease c, ranging from 0 to 1.[42] We acknowledge that the measured rural patient share might underestimate the actual prevalence of a disease in rural areas if rural patients were less likely to visit doctors and thus did not know their diagnosis before the NCMS. To overcome this potential measurement error, we also compute the rural patient share using the 2008 data after the NCMS had been fully expanded. Even so, we may still underestimate the actual rural patient shares, and our estimated effect might overestimate the impact of the NCMS on pharmaceutical innovation. In addition, although our logic is the same as in Acemoglu et al. (2006) and Blume-Kohout and Sood (2013) when estimating the elderly share in each drug class, we measure the population-based market share instead of sales-based market share. In our case, even if we have sales data in rural and urban areas, the rural market share measure by sales data are less preferable because they may underestimate rural patient share due to low affordability of rural patients. To illustrate, we have the following relationship between these three measures:

$$actual\ rural\ patient\ share_t \geq observed\ rural\ patient\ share_t \geq rural\ sales\ share_t \tag{A.8}$$

[42] In our main analysis, we use 2003/2004 rural patient share for each disease, since we do not have 2002 data.

A.2. Additional Figures and Tables

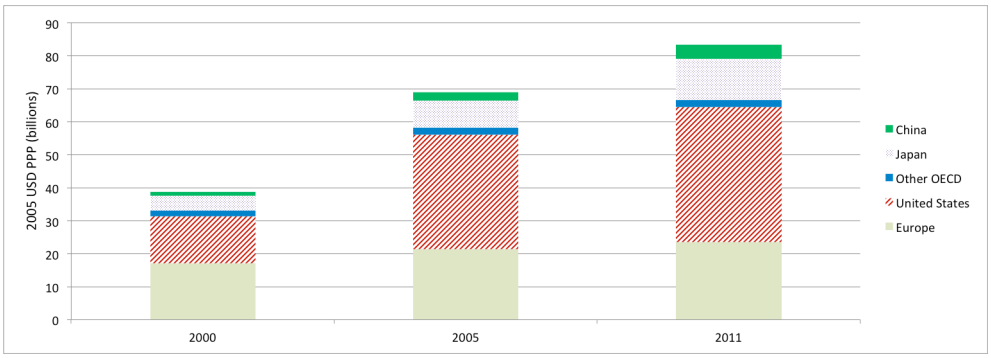
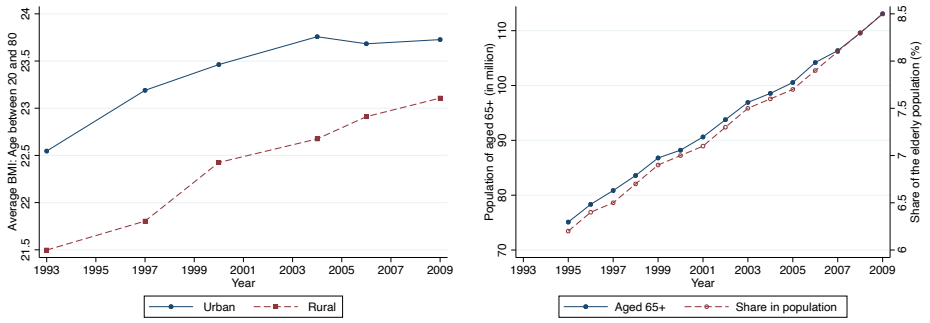


Figure A.1: Business expenditure on R&D in the pharmaceutical industry

Data source: The OECD Main Science and Technology Indicators Database



(a) Adult BMI

(b) Aging population

Figure A.2: Fatness and Aging in China

Notes. The left graph demonstrates the increasing adult body mass index (BMI) using the CHNS data. The right graph illustrates the aging population in China using data from China Statistics Books.

Table A.1: Summary statistics of sample diseases

Disease	ICD-10 disease category	Rural patient share				% in category	Category morbidity	No. of patent applications		
		1993	1998	2003	2008			All	Domestic	Foreign
Pneumonia	X: Respiratory system	0.85	0.81	0.87	0.75	2%	52.6	38.88	23.00	15.88
TB	I: Infectious & parasitic diseases	0.81	0.78	0.79	0.72	25%	2.6	30.59	24.65	5.94
Hepatitis B	I: Infectious & parasitic diseases	0.81	0.78	0.79	0.72	24%	2.6	98.59	83.53	15.06
Hepatitis A	I: Infectious & parasitic diseases	0.81	0.78	0.79	0.72	2%	2.6	4.94	3.71	1.24
Measles	I: Infectious & parasitic diseases	0.81	0.78	0.79	0.72	2%	2.6	3.71	2.59	1.12
Typhoid	I: Infectious & parasitic diseases	0.81	0.78	0.79	0.72	1%	2.6	2.94	2.53	0.41
Malaria	I: Infectious & parasitic diseases	0.81	0.78	0.79	0.72	1%	2.6	17.24	7.29	9.94
AURI	X: Respiratory system	0.75	0.74	0.77	0.72	84%	52.6	64.94	59.94	5.00
Gastritis	XI: Digestive system	0.79	0.76	0.77	0.78	50%	21.1	38.76	32.06	6.71
Rheumatoid arthritis	XIII Musculoskeletal system & connective tissue	0.78	0.79	0.76	0.78	35%	14.7	123.65	61.71	61.94
Chronic bronchitis	X: Respiratory system	0.76	0.74	0.72	0.73	9%	52.6	23.53	18.00	5.53
Cirrhosis	XI: Digestive system	0.70	0.68	0.71	0.60	2%	21.1	35.59	29.41	6.18
Gallbladder	XI: Digestive system	0.56	0.60	0.68	0.71	12%	21.1	17.94	15.71	2.24
Dysentery	I: Infectious & parasitic diseases			0.68	0.63	13%	2.6	11.59	11.00	0.59
Hepatitis C	I: Infectious & parasitic diseases			0.66	0.66	1%	2.6	57.24	13.94	43.29
Cerebrovascular	IX: Circulatory system	0.49	0.46	0.51	0.57	15%	24.4	152.47	104.41	48.06
Hypertension	IX: Circulatory system	0.42	0.41	0.48	0.41	49%	24.4	163.76	89.76	74.00
Heart diseases	IX: Circulatory system	0.42	0.39	0.43	0.41	30%	24.4	205.12	141.41	63.71
Diabetes	IV Endocrine, nutritional and metabolic diseases	0.22	0.23	0.24	0.25	71%	3.1	398.00	180.76	217.24
Gonorrhea	I: Infectious & parasitic diseases			0.64	0.61	6%	2.6	5.53	3.94	1.59
Syphilis	I: Infectious & parasitic diseases			0.63	0.62	2%	2.6	4.71	4.18	0.53
Infertility	XIV: Genitourinary system	0.73	0.72	0.75	0.71		5.2	31.29	23.94	7.35
Pneumoconiosis	X: Respiratory system			0.92	0.92		52.6	1.65	1.41	0.24
Chemical poisoning	XIX: Injury, poisoning & other external causes	0.76	0.75	0.79	0.73		5.7	6.06	4.82	1.24

Notes. Rural patient share equals to the number of rural patients divided by the number of total patients. For infectious diseases, since the China CDC only reports the number of cases in each province, we first calculate the number of rural patients by adding up the rural population share times the number of cases in each province and thus obtain the national rural patient share, which implicitly assumes the equal morbidity rate in rural and urban areas. Then we compare calculated national rural patient share with national rural population share. If the calculated rural patient share is larger than the rural population share, we assign ICD-10 category's rural patient share to this disease, as the disease is more rural-prevalent. Otherwise, we keep the calculated rural patient share. Category morbidity rate is per 1,000 people in 2003 from the NHSS. Empty cells indicate no available data.

Table A.2: Dynamic effects of the NCMS on patent quantity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Applications			Grants			Renewals		
	All	Domestic	Foreign	All	Domestic	Foreign	All	Domestic	Foreign
Yr(2003)*NCMS	0.88**	1.36***	0.06	0.41	0.53	-0.09	0.46	0.68**	-0.16
	(0.37)	(0.44)	(0.36)	(0.40)	(0.35)	(0.48)	(0.39)	(0.34)	(0.46)
Yr(2004)*NCMS	0.84*	1.08**	0.06	0.54	0.45	-0.11	0.56	0.56*	-0.15
	(0.49)	(0.52)	(0.44)	(0.51)	(0.34)	(0.56)	(0.50)	(0.34)	(0.59)
Yr(2005)*NCMS	1.11	1.33**	0.29	0.85	0.66	0.27	0.94	0.77*	0.37
	(0.68)	(0.67)	(0.58)	(0.66)	(0.42)	(0.64)	(0.67)	(0.41)	(0.68)
Yr(2006)*NCMS	1.26**	1.62***	0.45	0.93	0.79**	0.46	1.05	0.96***	0.57
	(0.61)	(0.54)	(0.64)	(0.70)	(0.38)	(0.87)	(0.67)	(0.35)	(0.85)
Yr(2007)*NCMS	1.04*	1.15***	0.65	0.71	0.49	0.42	0.73	0.60**	0.46
	(0.60)	(0.44)	(0.78)	(0.79)	(0.38)	(1.04)	(0.71)	(0.29)	(0.99)
Yr(2008)*NCMS	1.25	1.32**	0.87	0.57	0.16	0.73	0.59	0.30	0.66
	(0.78)	(0.58)	(0.88)	(0.91)	(0.42)	(1.13)	(0.84)	(0.38)	(1.09)
Yr(2009)*NCMS	1.41*	1.44**	1.23	1.00	0.50	1.87	1.07	0.70	1.81
	(0.78)	(0.56)	(0.89)	(1.08)	(0.49)	(1.30)	(1.01)	(0.44)	(1.27)
Observations	408	408	408	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24	24	24	24
ATE	1.112	1.328	0.515	0.715	0.510	0.507	0.772	0.652	0.510
SE	0.607	0.514	0.637	0.712	0.367	0.830	0.669	0.332	0.812

Notes. Yearly effects are reported. ATE is the calculated weighted average treatment effect. SE is the standard error of calculated weighted ATE. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.3: Dynamic effects of the NCMS on patent quality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Citations			Application claims count			Granted patent claims count		
	All	Domestic	Foreign	All	Domestic	Foreign	All	Domestic	Foreign
Yr(2003)*NCMS	-0.12	-0.21	1.74*	0.03	0.54**	0.22	-0.36	0.33**	-0.26
	(0.29)	(0.31)	(1.04)	(0.39)	(0.23)	(0.30)	(0.83)	(0.17)	(0.45)
Yr(2004)*NCMS	1.31**	1.24**	1.84	0.07	0.08	0.70	-0.10	0.12	0.59
	(0.56)	(0.61)	(1.96)	(0.29)	(0.36)	(0.46)	(0.45)	(0.26)	(0.42)
Yr(2005)*NCMS	0.80	0.86	0.53	0.51	0.53	0.23	0.51	0.25	0.10
	(0.53)	(0.65)	(2.25)	(0.63)	(0.33)	(0.54)	(0.48)	(0.18)	(0.41)
Yr(2006)*NCMS	1.46***	0.92*	4.06**	-0.09	0.57**	0.63	0.32	0.20	-0.05
	(0.54)	(0.51)	(1.74)	(0.72)	(0.25)	(0.61)	(0.48)	(0.45)	(0.38)
Yr(2007)*NCMS	1.12*	0.99	1.77	0.56	0.17	0.84*	0.36	0.09	0.12
	(0.58)	(0.63)	(2.01)	(0.63)	(0.26)	(0.49)	(0.45)	(0.23)	(0.43)
Yr(2008)*NCMS	1.05*	0.98*	2.73	1.11*	0.90***	0.95*	0.27	0.52	-0.35
	(0.60)	(0.52)	(2.12)	(0.63)	(0.23)	(0.57)	(0.57)	(0.34)	(0.49)
Yr(2009)*NCMS	0.15	0.17	2.90	1.16	0.69**	1.04	0.15	-0.12	0.14
	(0.95)	(0.82)	(2.73)	(0.81)	(0.28)	(0.67)	(0.56)	(0.29)	(0.89)
Observations	388	376	319	388	376	323	370	347	274
Number of diseases	24	24	23	24	24	24	24	24	23
ATE	0.823	0.706	2.224	0.478	0.497	0.660	0.164	0.197	0.042
SE	0.418	0.455	1.721	0.465	0.208	0.431	0.480	0.183	0.328

Notes. Yearly effects are reported. ATE is the calculated weighted average treatment effect. SE is the standard error of calculated weighted ATE. For completeness, we report estimates on claims count of all patents. However, due to the large difference between claims count of domestic and foreign patents, columns (4) and (7) should be viewed with caution. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.4: Dynamic effects of the NCMS on domestic patent applications

	(1)	(2)	(3)	(4)	(5)	(6)
	By applicant type			By invention type		
	Firm	Academic	Individual	Product	Process	Both
Yr(2003)*NCMS	2.89***	1.52**	0.72**	1.08**	0.90*	1.74***
	(0.93)	(0.74)	(0.28)	(0.54)	(0.55)	(0.47)
Yr(2004)*NCMS	2.50***	1.13	0.54	0.62	0.53	1.55***
	(0.87)	(0.87)	(0.47)	(0.54)	(0.73)	(0.55)
Yr(2005)*NCMS	3.09***	1.62	0.46	1.14*	0.97	1.68**
	(0.89)	(1.04)	(0.59)	(0.60)	(1.00)	(0.75)
Yr(2006)*NCMS	3.26***	1.74	0.96	1.36**	0.98	2.05***
	(0.63)	(1.15)	(0.62)	(0.57)	(1.14)	(0.51)
Yr(2007)*NCMS	2.69***	1.03	0.92*	0.44	0.97	1.90***
	(0.60)	(1.36)	(0.49)	(0.48)	(1.22)	(0.47)
Yr(2008)*NCMS	2.97***	2.14	0.33	0.92	0.91	1.83***
	(0.63)	(1.36)	(0.66)	(0.63)	(1.39)	(0.53)
Yr(2009)*NCMS	3.08***	2.41	0.40	1.07	1.72	1.66***
	(0.62)	(1.50)	(0.70)	(0.66)	(1.55)	(0.47)
Observations	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24
ATE	2.926	1.654	0.618	0.945	0.997	1.774
SE	0.676	1.120	0.510	0.522	1.036	0.507

Notes. Yearly effects are reported. ATE is the calculated weighted average treatment effect. SE is the standard error of calculated weighted ATE. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.5: Effect of the NCMS on patent quantity: Post-NCMS rural patient share

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Applications						
post*NCMS	0.79*		1.33**		-0.31	
	(0.45)		(0.61)		(0.31)	
post1*NCMS		0.78		1.19**		-0.11
		(0.48)		(0.50)		(0.41)
post2*NCMS		0.76		0.94**		0.39
		(0.56)		(0.40)		(0.70)
RESET test	0.498	0.479	0.083	0.208	<0.01	<0.01
Panel B: Grants						
post*NCMS	0.49		0.71		-0.29	
	(0.40)		(0.42)		(0.44)	
post1*NCMS		0.39		0.45		-0.21
		(0.48)		(0.36)		(0.52)
post2*NCMS		0.18		0.01		0.19
		(0.73)		(0.38)		(0.96)
RESET test	0.212	0.177	0.052	0.051	<0.01	<0.01
Panel C: Renewals						
post*NCMS	0.56		0.82*		-0.33	
	(0.42)		(0.45)		(0.44)	
post1*NCMS		0.42		0.55		-0.26
		(0.47)		(0.38)		(0.51)
post2*NCMS		0.13		0.08		0.08
		(0.65)		(0.32)		(0.89)
RESET test	0.140	0.069	0.053	0.029	0.011	0.011
Observations	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24

Notes. Post-NCMS rural patient shares are calculated using 2008 data. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.6: Effect of the NCMS on patent quality: Post-NCMS rural patient share

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Citations						
post*NCMS	0.64*		0.56		1.88	
	(0.35)		(0.39)		(1.66)	
post1*NCMS		0.64*		0.56		1.88
		(0.36)		(0.39)		(1.65)
post2*NCMS		0.61		0.64		2.79
		(0.55)		(0.53)		(2.12)
RESET test	0.891	0.886	0.142	0.120	0.924	0.984
Observations	388	388	376	376	319	319
Number of diseases	24	24	24	24	23	23
Panel B: Application claims count						
post*NCMS	0.58		0.32		0.44	
	(0.49)		(0.23)		(0.33)	
post1*NCMS		0.14		0.34		0.49
		(0.24)		(0.21)		(0.32)
post2*NCMS		0.99**		0.43**		0.83**
		(0.49)		(0.21)		(0.37)
RESET test	0.177	0.050	<0.01	<0.01	0.302	0.302
Observations	388	388	376	376	323	323
Number of diseases	24	24	24	24	24	24
Panel C: Granted patent claims count						
post*NCMS	-0.07		0.29*		0.15	
	(0.66)		(0.17)		(0.27)	
post1*NCMS		-0.04		0.28*		0.12
		(0.64)		(0.16)		(0.28)
post2*NCMS		0.18		0.24		-0.07
		(0.65)		(0.29)		(0.61)
RESET test	0.714	0.793	0.178	0.162	0.204	0.276
Observations	370	370	347	347	274	274
Number of diseases	24	24	24	24	23	23

Notes. Post-NCMS rural patient shares are calculated using 2008 data. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.7: NCMS' effect on domestic patent applications: Post-NCMS rural patient share

	(1)	(2)	(3)	(4)	(5)	(6)
	Firm		Academic institution		Individual	
Panel A: By applicant type						
post*NCMS	2.88**		1.02		0.80*	
	(1.29)		(0.61)		(0.45)	
post1*NCMS		2.47**		0.90		0.75*
		(1.10)		(0.82)		(0.40)
post2*NCMS		1.87**		0.72		0.65
		(0.91)		(1.20)		(0.45)
RESET test	0.034	0.046	<0.01	<0.01	<0.01	<0.01
	Product		Process		Both	
Panel B: By invention type						
post*NCMS	0.98*		0.52		1.79**	
	(0.50)		(0.41)		(0.78)	
post1*NCMS		0.79*		0.54		1.70***
		(0.45)		(0.47)		(0.64)
post2*NCMS		0.36		0.56		1.57***
		(0.52)		(0.80)		(0.51)
RESET test	<0.01	<0.01	0.346	0.360	0.694	0.821
Observations	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24

Notes. Post-NCMS rural patient shares are calculated using 2008 data. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.8: Effect of the NCMS on patent quantity: Pre-NCMS rural patient share

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Applications						
post*NCMS	0.64		1.08*		-0.33	
	(0.44)		(0.62)		(0.29)	
post1*NCMS		0.64		0.99*		-0.17
		(0.47)		(0.51)		(0.40)
post2*NCMS		0.66		0.85**		0.26
		(0.54)		(0.41)		(0.68)
RESET test	0.484	<0.01	0.031	0.153	<0.01	<0.01
Panel B: Grants						
post*NCMS	0.39		0.57		-0.33	
	(0.38)		(0.42)		(0.42)	
post1*NCMS		0.32		0.39		-0.27
		(0.46)		(0.35)		(0.49)
post2*NCMS		0.15		0.08		0.08
		(0.68)		(0.37)		(0.91)
RESET test	0.196	0.174	0.104	0.090	0.015	<0.01
Panel C: Renewals						
post*NCMS	0.44		0.65		-0.35	
	(0.40)		(0.44)		(0.42)	
post1*NCMS		0.34		0.46		-0.29
		(0.45)		(0.37)		(0.49)
post2*NCMS		0.13		0.15		0.02
		(0.60)		(0.30)		(0.85)
RESET test	0.121	0.025	0.039	0.013	<0.01	<0.01
Observations	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24

Notes. Pre-NCMS rural patient shares are calculated using 1998 data. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.9: Effect of the NCMS on patent quality: Pre-NCMS rural patient share

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Citations						
post*NCMS	0.61*		0.52		1.52	
	(0.34)		(0.38)		(1.45)	
post1*NCMS		0.61*		0.52		1.52
		(0.34)		(0.38)		(1.45)
post2*NCMS		0.67		0.64		1.84
		(0.54)		(0.51)		(1.85)
RESET test	0.896	0.910	0.134	0.101	0.895	0.934
Observations	388	388	376	376	319	319
Number of diseases	24	24	24	24	23	23
Panel B: Application claims count						
post*NCMS	0.44		0.27		0.20	
	(0.46)		(0.22)		(0.31)	
post1*NCMS		0.05		0.30		0.29
		(0.25)		(0.20)		(0.31)
post2*NCMS		0.82*		0.42**		0.80**
		(0.47)		(0.21)		(0.39)
RESET test	0.171	0.049	<0.01	<0.01	0.295	0.255
Observations	388	388	376	376	323	323
Number of diseases	24	24	24	24	24	24
Panel C: Granted patent claims count						
post*NCMS	-0.08		0.25		0.15	
	(0.61)		(0.17)		(0.29)	
post1*NCMS		-0.06		0.24		0.11
		(0.60)		(0.16)		(0.29)
post2*NCMS		0.05		0.21		-0.12
		(0.60)		(0.27)		(0.56)
RESET test	0.722	0.752	0.191	0.172	0.205	0.315
Observations	370	370	347	347	274	274
Number of diseases	24	24	24	24	23	23

Notes. Pre-NCMS rural patient shares are calculated using 1998 data. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.10: NCMS' effect on domestic patent applications: Pre-NCMS rural patient share

	(1)	(2)	(3)	(4)	(5)	(6)
	Firm		Academic institution		Indivdiseasesual	
post*NCMS	2.44*		0.75		0.66	
	(1.28)		(0.59)		(0.45)	
post1*NCMS		2.24**		0.61		0.62
		(1.07)		(0.77)		(0.40)
post2*NCMS		1.95**		0.40		0.54
		(0.82)		(1.11)		(0.44)
RESET test	0.027	0.032	<0.01	<0.01	<0.01	<0.01
	Product		Process		Both	
Panel B: By invention type						
post*NCMS	0.80		0.22		1.50*	
	(0.52)		(0.43)		(0.79)	
post1*NCMS		0.62		0.28		1.51**
		(0.47)		(0.46)		(0.64)
post2*NCMS		0.18		0.35		1.54***
		(0.51)		(0.75)		(0.49)
RESET test	<0.01	<0.01	0.353	0.357	0.708	0.700
Observations	408	408	408	408	408	408
Number of diseases	24	24	24	24	24	24

Notes. Pre-NCMS rural patient shares are calculated using 1998 data. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.11: Effect of the NCMS on patent quantity: Leave-one-out estimation

Exclude	Patent applications			Patent approvals			Patent renewals		
	All	Domestic	Foreign	All	Domestic	Foreign	All	Domestic	Foreign
Pneumonia	0.809**	1.170**	-0.0886	0.563	0.651	-0.0406	0.632*	0.747*	-0.0582
TB	0.832**	1.327**	-0.186	0.492	0.709*	-0.229	0.551	0.810**	-0.263
Hep B	0.881**	1.461***	-0.126	0.571	0.839**	-0.131	0.639	0.932**	-0.141
Hep A	0.812**	1.291**	-0.217	0.570*	0.758**	-0.148	0.639*	0.863**	-0.164
Measles	0.788**	1.252**	-0.216	0.512	0.693*	-0.195	0.577	0.791**	-0.217
Typhoid	0.783**	1.243**	-0.214	0.501	0.672*	-0.188	0.564	0.767*	-0.208
Malaria	0.787**	1.249**	-0.256	0.514	0.708*	-0.264	0.567	0.795**	-0.308
AURI	0.717*	1.194**	-0.188	0.409	0.531	-0.122	0.481	0.641	-0.137
Gastritis	0.780**	1.254**	-0.215	0.527	0.678*	-0.128	0.59	0.762*	-0.116
Rheumatoid arthritis	0.999***	1.376**	-0.0683	0.752***	0.814**	0.0942	0.829***	0.933**	0.0558
Chronic bronchitis	0.733*	1.192**	-0.251	0.477	0.662*	-0.237	0.532	0.751*	-0.265
Cirrhosis	0.770**	1.248**	-0.228	0.503	0.695*	-0.19	0.573	0.800**	-0.209
Dysentery	0.751**	1.211**	-0.236	0.485	0.658*	-0.2	0.544	0.749*	-0.222
Gallbladder	0.772**	1.245**	-0.23	0.503	0.685*	-0.182	0.555	0.766*	-0.203
Hep C	0.815**	1.266**	-0.26	0.515	0.695*	-0.205	0.589	0.805**	-0.231
Cerebrovascular	0.776**	1.263**	-0.219	0.509	0.692*	-0.204	0.572*	0.791**	-0.221
Hypertension	0.773**	1.235**	-0.256	0.503	0.676*	-0.231	0.572*	0.779*	-0.245
Heart diseases	0.895***	1.500***	-0.194	0.605**	0.884***	-0.146	0.672***	0.980***	-0.162
Diabetes	0.0833	0.409	-0.878	0.0127	0.382	-1.243*	0.121	0.529	-1.180*

Notes. Each row reports estimates from excluding one of the 19 NCMS-covered diseases. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.12: Effect of the NCMS on patent quality: Leave-one-out estimation

Exclude	Citations			Application claims count			Granted patent claims count		
	All	Domestic	Foreign	All	Domestic	Foreign	All	Domestic	Foreign
Pneumonia	0.519	0.431	1.870	0.491	0.242	0.166	-0.019	0.227	0.075
TB	0.643*	0.511	2.019	0.439	0.266	0.308	-0.156	0.272	0.043
Hep B	0.556	0.432	1.604	0.512	0.264	0.364	-0.093	0.285	0.193
Hep A	0.644*	0.539	1.688	0.354	0.300	0.279	-0.076	0.238	0.166
Measles	0.666**	0.554	1.762	0.418	0.310	0.238	-0.252	0.303*	-0.069
Typhoid	0.484	0.457	1.646	0.511	0.351	0.287	-0.088	0.301*	0.056
Malaria	0.580*	0.429	1.778	0.647	0.247	0.519**	-0.073	0.298*	0.229
AURI	0.609*	0.506	1.733	0.452	0.221	0.302	-0.119	0.208	0.152
Gastritis	0.599*	0.476	1.872	0.494	0.246	0.342	-0.086	0.265	0.141
R arthritis	0.580*	0.432	1.793	0.471	0.292	0.327	-0.084	0.291*	0.147
Chronic bronchitis	0.659*	0.559	1.795	0.463	0.273	0.330	-0.118	0.279	0.069
Cirrhosis	0.620*	0.508	1.619	0.519	0.284	0.371	-0.067	0.306*	0.208
Dysentery	0.602*	0.504	1.723	0.487	0.278	0.309	-0.113	0.287*	0.125
Gallbladder	0.599*	0.469	1.560	0.446	0.254	0.210	-0.095	0.281*	0.133
Hep C	0.769**	0.398	1.719	0.415	0.287	0.309	-0.140	0.313*	0.148
Cerebrovascular	0.610*	0.484	1.723	0.490	0.277	0.311	-0.098	0.282*	0.108
Hypertension	0.573*	0.423	1.752	0.501	0.265	0.295	-0.099	0.288*	0.105
Heart diseases	0.581*	0.436	1.751	0.498	0.266	0.313	-0.095	0.285*	0.125
Diabetes	0.642*	0.694*	1.65	0.589	0.208	0.285	-0.086	0.401***	0.127

Notes. Each row reports estimates from excluding one of the 19 NCMS-covered diseases. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.13: NCMS' effect on domestic patent applications: Leave-one-out estimation

Exclude	By applicant type			By invention type		
	Firm	Academic institution	Individual	Product	Process	Both
Pneumonia	2.673**	0.795	0.689	0.866*	0.0876	1.620**
TB	2.799**	0.79	0.849**	1.051**	0.232	1.769**
Hepatitis B	3.124***	1.301**	0.870**	1.086**	0.334	2.020***
Hepatitis A	2.866**	0.927	0.768*	0.993**	0.271	1.750**
Measles	2.766**	0.866	0.748*	0.938**	0.275	1.711**
Typhoid	2.781**	0.827	0.747*	0.941**	0.273	1.686**
Malaria	2.762**	0.953	0.736*	0.947**	0.185	1.718**
AURI	2.612**	0.691	0.848**	0.996**	0.228	1.556**
Gastritis	2.731**	0.852	0.776*	0.988**	0.291	1.677**
Rheumatoid arthritis	3.044***	0.888	0.806*	0.956*	0.464	1.893***
Chronic bronchitis	2.690**	0.793	0.706*	0.907*	0.251	1.630**
Cirrhosis	2.770**	0.873	0.712*	0.901*	0.575	1.699**
Dysentery	2.707**	0.823	0.723*	0.927*	0.277	1.644**
Gallbladder	2.707**	0.845	0.770*	0.940**	0.253	1.700**
Hepatitis C	2.902**	0.875	0.741*	0.931*	0.273	1.754**
Cerebrovascular	2.782**	0.848	0.777**	0.950**	0.292	1.725**
Hypertension	2.734**	0.832	0.746*	0.939**	0.233	1.685**
Heart diseases	3.265***	0.927*	0.925***	1.159***	0.369	1.997***
Diabetes	0.707	0.989	0.198	0.279	0.0352	0.622

Notes. Each row reports estimates from excluding one of the 19 NCMS-covered diseases. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.14: Effect of the NCMS on patent quantity: Exclude SARS-similar diseases

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Applications						
post*NCMS	0.81*		1.21*		0.01	
	(0.44)		(0.61)		(0.33)	
post1*NCMS		0.85*		1.09**		0.24
		(0.48)		(0.52)		(0.43)
post2*NCMS		0.92		0.89*		0.81
		(0.57)		(0.45)		(0.71)
RESET test	0.550	0.598	0.020	0.053	<0.01	<0.01
Panel B: Grants						
post*NCMS	0.44		0.49		0.01	
	(0.38)		(0.39)		(0.45)	
post1*NCMS		0.42		0.32		0.11
		(0.46)		(0.35)		(0.53)
post2*NCMS		0.38		0.01		0.64
		(0.72)		(0.41)		(0.94)
RESET test	0.584	0.576	0.089	0.091	<0.01	<0.01
Panel C: Renewals						
post*NCMS	0.52		0.62		0.02	
	(0.40)		(0.43)		(0.45)	
post1*NCMS		0.47		0.44		0.07
		(0.45)		(0.36)		(0.52)
post2*NCMS		0.37		0.14		0.56
		(0.62)		(0.32)		(0.87)
RESET test	0.354	0.313	0.071	0.055	<0.01	<0.01
Observations	357	357	357	357	357	357
Number of diseases	21	21	21	21	21	21

Notes. The excluded diseases with similar symptoms are: pneumonia, TB and AURI. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.15: Effect of the NCMS on patent quality: Exclude SARS-similar diseases

	(1) All	(2) All	(3) Domestic	(4) Domestic	(5) Foreign	(6) Foreign
Panel A: Citations						
post*NCMS	0.57		0.49		2.27	
	(0.37)		(0.42)		(1.58)	
post1*NCMS		0.56		0.49		2.26
		(0.37)		(0.42)		(1.58)
post2*NCMS		0.68		0.63		3.81**
		(0.55)		(0.54)		(1.92)
RESET test	0.989	0.983	0.136	0.110	0.969	0.923
Observations	337	337	326	326	271	271
Number of diseases	21	21	21	21	20	20
Panel B: Application claims count						
post*NCMS	0.41		0.15		0.16	
	(0.28)		(0.23)		(0.38)	
post1*NCMS		0.08		0.17		0.19
		(0.30)		(0.22)		(0.37)
post2*NCMS		0.84		0.28		0.41
		(0.52)		(0.22)		(0.40)
RESET test	0.289	0.099	<0.01	<0.01	0.358	0.415
Observations	337	337	326	326	275	275
Number of diseases	21	21	21	21	21	21
Panel C: Granted patent claims count						
post*NCMS	-0.10		0.11		-0.01	
	(0.65)		(0.17)		(0.34)	
post1*NCMS		-0.09		0.11		-0.05
		(0.64)		(0.16)		(0.33)
post2*NCMS		-0.01		0.09		-0.29
		(0.63)		(0.28)		(0.58)
RESET test	0.674	0.677	0.069	0.061	<0.01	0.013
Observations	319	319	298	298	235	235
Number of diseases	21	21	21	21	20	20

Notes. The excluded diseases with similar symptoms are: pneumonia, TB and AURI. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.16: NCMS' effect on domestic patent applications: Exclude SARS-similar diseases

	(1)	(2)	(3)	(4)	(5)	(6)
	Firm		Academic institution		Individual	
Panel A: By applicant type						
post*NCMS	2.53*		0.58		0.93**	
	(1.32)		(0.58)		(0.45)	
post1*NCMS		2.27**		0.56		0.83*
		(1.09)		(0.80)		(0.42)
post2*NCMS		1.89**		0.52		0.62
		(0.84)		(1.21)		(0.50)
RESET test	0.628	0.257	<0.01	<0.01	0.013	0.052
	Product		Process		Both	
Panel B: By invention type						
post*NCMS	1.07**		0.06		1.54*	
	(0.51)		(0.45)		(0.77)	
post1*NCMS		0.88*		0.02		1.51**
		(0.46)		(0.47)		(0.64)
post2*NCMS		0.44		0.13		1.46***
		(0.57)		(0.77)		(0.49)
RESET test	<0.01	<0.01	0.433	0.454	<0.01	<0.01
Observations	357	357	357	357	357	357
Number of diseases	21	21	21	21	21	21

Notes. The excluded diseases with similar symptoms are: pneumonia, TB and AURI. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.17: Effect of the NCMS on patent quantity: Log-linear model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	All		Domestic		Foreign		All		Domestic		Foreign	
Panel A: Applications												
post*NCMS	0.82**		1.01**		0.14		0.89**		1.09**		0.18	
	(0.35)		(0.39)		(0.29)		(0.40)		(0.45)		(0.35)	
post1*NCMS		0.83**		1.01**		0.17		0.90**		1.09**		0.21
		(0.35)		(0.39)		(0.28)		(0.41)		(0.46)		(0.34)
post2*NCMS		0.98*		1.02		0.61		1.07*		1.09		0.74
		(0.51)		(0.60)		(0.44)		(0.60)		(0.73)		(0.53)
RESET test	0.399	<0.01	0.319	0.321	0.103	0.084	0.355	0.355	0.520	0.709	0.037	0.016
Panel B: Grants												
post*NCMS	0.59		0.70*		0.00		0.62		0.77*		0.01	
	(0.35)		(0.35)		(0.30)		(0.42)		(0.42)		(0.37)	
post1*NCMS		0.57		0.68*		-0.00		0.60		0.75*		-0.00
		(0.35)		(0.34)		(0.30)		(0.42)		(0.42)		(0.37)
post2*NCMS		0.36		0.45		-0.09		0.36		0.47		-0.13
		(0.40)		(0.35)		(0.48)		(0.47)		(0.43)		(0.56)
RESET test	0.256	<0.01	0.043	0.030	0.201	0.184	0.337	0.011	0.645	0.022	0.079	0.270
Panel C: Renewals												
post*NCMS	0.72*		0.87**		0.09		0.79*		1.00**		0.12	
	(0.36)		(0.37)		(0.32)		(0.44)		(0.45)		(0.40)	
post1*NCMS		0.71*		0.86**		0.09		0.78*		0.98**		0.12
		(0.36)		(0.36)		(0.33)		(0.44)		(0.45)		(0.41)
post2*NCMS		0.45		0.56		0.07		0.48		0.62		0.07
		(0.40)		(0.35)		(0.52)		(0.48)		(0.45)		(0.62)
RESET test	0.199	0.231	0.768	0.014	0.068	0.036	0.233	0.260	0.470	0.020	0.050	0.046
Transformation	N+1						Inverse hyperbolic sine					

Notes. Outcome variables are log-transformed. Columns (1)-(6) use N+1 and columns (7)-(12) use IHS transformation. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.18: Effect of the NCMS on patent quality: Log-linear model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	All		Domestic		Foreign		All		Domestic		Foreign	
Panel A: Citations												
post*NCMS	0.24		0.18		0.23		0.31		0.23		0.32	
	(0.16)		(0.19)		(0.34)		(0.20)		(0.25)		(0.45)	
post1*NCMS		0.24		0.17		0.24		0.31		0.22		0.33
		(0.15)		(0.19)		(0.35)		(0.20)		(0.26)		(0.45)
post2*NCMS		0.22		0.14		0.35		0.29		0.19		0.49
		(0.20)		(0.26)		(0.40)		(0.27)		(0.35)		(0.51)
RESET test	0.859	0.854	0.125	0.145	0.289	0.359	0.933	0.930	0.142	0.157	0.426	0.526
Panel B: Application claims count												
post*NCMS	0.36		0.40*		0.25		0.42		0.51**		0.26	
	(0.33)		(0.19)		(0.25)		(0.37)		(0.24)		(0.26)	
post1*NCMS		0.17		0.41**		0.29		0.22		0.52**		0.31
		(0.19)		(0.18)		(0.25)		(0.22)		(0.22)		(0.26)
post2*NCMS		0.62		0.47***		0.73**		0.71*		0.60***		0.77**
		(0.37)		(0.15)		(0.30)		(0.41)		(0.18)		(0.32)
RESET test	0.221	0.085	0.007	0.014	0.956	0.965	0.226	0.072	0.014	0.029	0.899	0.976
Panel C: Granted patent claims count												
post*NCMS	0.09		0.22		0.17		0.13		0.27		0.19	
	(0.38)		(0.14)		(0.29)		(0.43)		(0.17)		(0.32)	
post1*NCMS		0.08		0.20		0.16		0.12		0.25		0.19
		(0.38)		(0.13)		(0.30)		(0.42)		(0.16)		(0.33)
post2*NCMS		0.05		0.10		0.15		0.06		0.11		0.19
		(0.41)		(0.24)		(0.56)		(0.47)		(0.30)		(0.63)
RESET test	0.043	0.052	0.147	0.131	0.280	0.286	0.021	0.030	0.124	0.110	0.301	0.307
Transformation	N+1						Inverse hyperbolic sine					

Notes. Outcome variables are log-transformed. Columns (1)-(6) use N+1 and columns (7)-(12) use IHS transformation. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.19: NCMS' effect on domestic patent applications: Log-linear model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Firm		Academic institutions		Individuals		Firm		Academic institutions		Individuals	
Panel A: By applicant type												
post*NCMS	1.40**		1.00***		0.74**		1.67**		1.29***		0.83*	
	(0.53)		(0.34)		(0.34)		(0.65)		(0.41)		(0.42)	
post1*NCMS		1.39**		1.03***		0.72*		1.66**		1.32***		0.82*
		(0.52)		(0.34)		(0.35)		(0.64)		(0.42)		(0.43)
post2*NCMS		1.20***		1.46***		0.54		1.42***		1.86***		0.58
		(0.41)		(0.40)		(0.54)		(0.50)		(0.50)		(0.67)
RESET test	<0.01	<0.01	<0.01	0.307	0.364	0.197	<0.01	<0.01	<0.01	0.488	0.303	0.367
	Produce		Process		Both		Produce		Process		Both	
Panel B: By application type												
post*NCMS	1.03**		0.45*		0.85*		1.25**		0.63**		0.87	
	(0.42)		(0.23)		(0.46)		(0.53)		(0.28)		(0.56)	
post1*NCMS		1.04**		0.46*		0.83*		1.27**		0.65**		0.85
		(0.43)		(0.23)		(0.46)		(0.54)		(0.29)		(0.56)
post2*NCMS		1.25**		0.75*		0.58		1.51*		1.01*		0.55
		(0.59)		(0.42)		(0.53)		(0.74)		(0.52)		(0.66)
RESET test	0.736	0.765	<0.01	<0.01	0.019	<0.01	0.201	0.161	0.202	<0.01	0.034	<0.01
Transformation	N+1						Inverse hyperbolic sine					

Notes. Outcome variables are log-transformed. Columns (1)-(6) use N+1 and columns (7)-(12) use IHS transformation. RESET test p-values are reported. Standard errors are clustered at the disease level, and inferences are drawn from the T-distribution. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.