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Government reform and innovation performance in China

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ABSTRACT

Innovation is key for economic growth and well-being. The capacity for innovation, however, is profoundly influenced by the quality of local institutions. Although the impact of national institutions on innovation is well-documented, the effects of subnational institutional variations on innovation remain underexplored. This paper studies the impact of government agency reforms, designed to enhance local government effectiveness, on the innovation performance of city-regions in China. We examine the adoption of these reforms between 2009 and 2016 as an exogenous shock to regional institutions. Our analysis identifies a positive and significant relationship between improvements in institutional quality and the innovation performance of Chinese city-regions, particularly pronounced in regions with medium to high levels of innovation. The results are robust to a series of checks including placebo and endogeneity tests and potential confounding policies. This research highlights the critical role of government institutions in driving innovation across China, bringing to the fore important regional variations in the adoption of government agency reforms that are defining the country's innovation landscape.

1. Introduction

Innovation is a fundamental driver of economic activity, growth, and prosperity (Kogan et al., 2017). It is essential at both individual and corporate levels for enhancing competitiveness in the global marketplace (Zhou, 2014; Rodríguez-Pose and Zhang, 2020). Regions frequently aim to leverage innovation to secure a competitive advantage, attract investment, and foster economic development (Morgan, 2007). The relevance of innovation has prompted many researchers and policymakers to explore the dynamics of innovation extensively. Traditional research generally focused on the established drivers of innovation: R&D investment, human and social capital, agglomeration economies, networks, diversity, foreign direct investment (FDI), and infrastructure (e.g., Audretsch and Feldman, 1996; Cheung and Ping, 2004; Crescenzi et al., 2007, 2012; Faggian and McCann, 2009; Niebuhr, 2010; Peiró-Palomino, 2019).

However, the efficacy of these factors is often moderated by the broader social and institutional context in which economic actors operate. This context can either hinder or foster innovation. The social filter theory (Rodríguez-Pose, 1999) and the innovation ecosystems literature (Ottati, 1994; Camagni, 1995; Morgan, 2007) suggest that weak social conditions and institutions may impede innovation, undermining efforts to promote it. Conversely, strong institutions are at the root of investment and innovation (Rodríguez-Pose and Di Cataldo, 2015; Rodríguez-Pose and Zhang, 2020; D'Ingiullo and Evangelista, 2020; Donges et al., 2023). However, the role of institutions in shaping regional innovation potential remains underexplored, with much of the analysis concentrating at the national level (e.g., Tebaldi and Elmslie, 2013; Boudreaux, 2017; D'Agostino, Scarlato, 2019).

One major challenge in examining the influence of formal institutions on innovation at the subnational level is measuring institutional quality. The growing availability of sub-national institutional quality indices (e.g., the Quality of Government Index by Gothenburg University) has contributed to a small bloom of empirical research at subnational level, mostly in Europe. For instance, Rodríguez-Pose and Di Cataldo (2015) explored the effect of regional variations in government quality on innovation across Europe. D'Ingiullo and Evangelista (2020) did the same for Italian regions. Hussen and Çokgezen (2022) went beyond Europe and studied the link between regional institutions and firm performance in Africa. However, some of this research may not be immune to reverse causation, where institutional quality might be influenced by economic variables (Abadie and Gardeazabal, 2003; Tebaldi and Elmslie, 2013; Mosconi and D'Ingiullo, 2023), raising questions about endogeneity. To address this, instrumental variable techniques have been employed (e.g., Rodríguez-Pose and Di Cataldo, 2015), though the validity of these instruments often remains in question.

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Recent research has delved into the causal relationship between institutions and innovation through the examination of government institutional reforms as exogenous to local innovation activities. For example, Donges et al. (2023) used the French occupation of Germany after the 1789 French Revolution as an exogenous shock to assess the impact of the Napoleonic reforms on innovation. Nevertheless and despite a growing recognition of these issues, empirical evidence, especially for emerging countries, remains scarce. Our research thus addresses an important gap in existing knowledge by focusing on a profound recent reform of local government in China: that of local government development agencies. Our aim is to produce further evidence on the causal link between government institutions and innovation in an emerging economy.

A profound local government agency reform in China took place between 2009 and 2016. This reform has been implemented by city-regions on a voluntary basis and can be considered as exogenous to regional institutional quality. We in particular concentrate on changes to the local Administration for Industry and Commerce (AIC). This agency is tasked in China with crucial responsibilities such as verifying market entities' qualifications, ensuring product and service quality —particularly concerning food and drugs— protecting property rights, enforcing contracts, combating unfair competition, and facilitating market entry and exit. Historically, the AIC was highly centralised and besieged by inefficiency, unclear responsibilities, and overlapping management. From 2009 onwards the functions of the agency became more decentralised, following reform initiatives by cities such as Shenzhen. Many cities across China followed suit, consolidating AIC functions into new entities, the Market Supervisory Authorities (MSAs). Such a change, when implemented adequately, contributed to reduce red-tape, making services and procedures more transparent. It also facilitated the dismantling of institutional barriers, while enhancing the business environment and supporting measures to boost local industries. The implementation of the reform was bottom-up and voluntary, leading to an uneven adoption across the country. Whether the agency was reformed or not came down to each city-region's local development strategies. We therefore treat the reform as exogenous to regional innovation activities, as the significant variation in the adoption of the reform across the Chinese geography allows us to discern the influence of government agency reform on regional innovation.

The results of the analysis indicate that city-regions that were early adopters managed to increase their level of innovation compared to those where the reform was not adopted. This positive causal relationship between the implementation of the reform and regional innovation withstands various robustness checks. Moreover, the impact of institutional reform is particularly strong in some of the already most innovative Chinese city-regions.

Our research advances existing knowledge in several key ways: First, it delves deeper into the underexplored link between institutions and innovation in emerging countries. It also goes beyond existing studies covering China but adopting a broader definition of local government (e.g., Bai and Li, 2011), lacking empirical examination (e.g., Chen and Kenney, 2007), or employing rough institutional quality data at the provincial level (Zhou, 2014). Second, we introduce government agency reform as an external policy shock to estimate the causal impact of government institutional quality on regional innovation. In contrast to the more common tendency to measure government institutional quality directly, we avoid a reliance on institutional quality data, thus minimising a potential endogeneity bias. Moreover, by considering a recent reform, we are able to offer practical policy implications for future institutional reforms aimed at innovation development. We also consider variations in local innovation, often related to disparities in government efficiency and quality, which could affect the success of reforms.

The structure of the paper is as follows: the subsequent section looks into the relationship between institutional reform and local-level innovation capacity, discussing both empirical evidence and the theoretical underpinnings. The third section outlines the establishment of reformed agencies across Chinese city-regions, highlighting the different patterns of reform adoption. This precedes the presentation of our model, methodology, and data description. The remaining sections provide the econometric analysis of our findings, concluding with a discussion on policy implications.

2. Institutional reforms and local innovation

2.1. Institutional Reform and Local Innovation: The Evidence

Institutions encompass a wide array of dimensions, including rules, culture, demographics, market development, laws, regulations, and policies (Cunningham and Dibooglu, 2020; He and Tian, 2020). In our analysis we concentrate on formal government institutions (Thomas, 2010; Kaufmann and Kraay, 2023) and their impact on innovation. The relevance of government institutional quality for innovation has been increasingly analysed (e.g., Rodríguez-Pose and Di Cataldo, 2015; D'Ingiullo and Evangelista, 2020; Wang et al., 2021; Donges et al., 2023). However, the extent of government institutional quality's influence on local-level innovation still requires further investigation. Despite empirical efforts, quantifying the impact of differences in subnational institutional quality on innovation remains a challenge due to the difficulty in measuring government institutions and governance quality accurately. Consequently, the research investigating the link between institutional quality, innovation, and economic outcomes remains limited, with most existing research being conducted at the national level (e.g., Tebaldi and Elmslie, 2013; Kayalvizhi and Thenmozhi, 2018).

Progress in measuring subnational institutions, notably in Europe, has contributed to overcome some research barriers in this domain. The introduction of the European Quality of Government Index (EQI) by the Quality of Government Institute at the University of Gothenburg (Charron et al., 2015) has triggered a growing number of empirical studies examining the effects of government institutions on regional economic trends within European regions. The EQI has proven instrumental in exploring the nexus between government institutions and various economic facets (e.g., Barbero et al., 2021; Wang and Rodríguez-Pose, 2021; Barbero and Rodríguez-Crespo, 2022; Rodríguez-Pose and Ganau, 2022). This exploration is, however, not confined to Europe. Globally, research delving into subnational institutions' economic implications is expanding. Notable examples include Rodríguez-Pose and Zhang (2019) uncovering significant impacts of city-level government institutions on urban growth in China; Iddawela et al. (2021) identifying a positive correlation between subnational government quality and regional economic development across 22 African countries; and Balaguer-Coll et al., 2022 investigating the influence of government institutional quality on economic growth at Spain's municipal level. Moreover, there has been a shift towards examining the impact of institutional quality on innovation from a micro perspective, focusing on the level of the firm (e.g., Zhou, 2014; Mahendra et al., 2015; Rodríguez-Pose and Zhang, 2020).

With subnational government institutional quality indices, several studies have underscored institutions as crucial for enabling local economic actors to pursue innovation. For instance, Tebaldi and Elmslie (2013) observed significant cross-country variations in patent production tied to institutional arrangements; Rodríguez-Pose and Di Cataldo (2015) showed that government quality drove regional innovation capacity across the European Union. More recently, D'Ingiullo and Evangelista (2020) have pointed to institutional quality's positive effect on the innovative capacity of Italian provinces, underlining the importance of government effectiveness, regulatory quality, and accountability. However, these studies often grapple with endogeneity issues due to their reliance on survey-based indices. Another estimation challenge is that government institutional quality is often endogenous to innovation development. A common solution involves identifying instrumental variables for institutional quality, with historical variables like literacy rates being frequently used (e.g., Rodríguez-Pose and Di Cataldo, 2015).

To ascertain a causal relationship between institutions and development, other strands of research have leveraged exogenous variation sources in government institutions, often reflected through institutional reforms. For example, Abadie and Gardeazabal (2003) estimated the economic cost of conflict in the Basque country as a case study; Liu and Zhu (2021) used the administrative approval system reform to explore institutional quality variations across regions and time, demonstrating its impact on industrial dynamics. Donges et al. (2023) showed that institutional reforms and the introduction of more inclusive structures, such as the civil code in German regions under French rule during the Napoleonic era, significantly boosted long-term innovation.

Despite these advancements, a gap persists in understanding how institutional quality variations influence economic actors' innovation capacity, especially in emerging and developing countries. Further subnational-level research is essential for a deeper comprehension of why certain regions outperform others in innovation, extending the focus beyond Europe.

2.2. Institutional Reform and Local Innovation: The Mechanisms

How does institutional reform trigger changes in local innovation? When dealing with institutions, the concept of reform is notably challenging and multifaceted. Historically, institutions are seen as relatively enduring constructs, emerging from a protracted process of institutional development that often spans centuries (North, 1989; Charron and Lapuente, 2013). Hence, the idea of reforming such institutions is often considered a daunting, sometimes seemingly insurmountable task (Rodríguez-Pose and Storper, 2006; Elert et al., 2017; Liu and Zhu, 2021). Acknowledging how ineffective institutions undermine economic development and, more specifically, innovation, marks a significant initial step towards change. Several factors spell out how institutions may stifle innovation.

First, weak institutions erode the incentives for investment in innovation, impede technology transfer, and suppress the dynamics of knowledge markets (Lai, 1998; Sweet and Maggio, 2015). Inadequate protection of intellectual property rights —including, among others, failures to secure intellectual property or combat counterfeiting and piracy— deters economic agents from pursuing innovative activities. Moreover, the reliance of high-risk innovation on the potential monopoly profits from new products and services implies that without strong intellectual property rights, investment in innovation is likely discouraged. Having effective local courts and ensuring stringent law enforcement thus becomes a must for fostering innovation (Caselli and Coleman, 2001; Seitz and Watzinger, 2017). Moreover, there is a positive relationship between the rule of law and innovation, highlighting the influence of institutions on patent production and R&D investment (Tebaldi and Elmslie, 2013; Seitz and Watzinger, 2017).

Second, inadequate institutions proliferate red-tape and bureaucracy, reallocating resources from innovation to administrative procedures. More bureaucracy escalates agency and transaction costs, reducing revenue and diminishing potential returns, thereby making projects uncertain and less appealing for significant, long-term investments like R&D (Anokhin and Schulze, 2009). The cumbersome processes involved in acquiring licenses and protecting property rights further obstruct innovative efforts (Wang et al., 2015; Jiao et al., 2015; Alam et al., 2019), while bureaucratic hurdles also limit access to finance for R&D (Mahendra et al., 2015).

Third, inefficient institutions are often synonymous with corruption, which unfairly advantages well-connected projects over more innovative and deserving ones (Rodríguez-Pose et al., 2021). Corruption is not only a significant barrier to innovation, particularly in emerging economies (Riaz and Cantner, 2020), but also undermines the foundational institutional trust necessary for investment in innovation (Anokhin and Schulze, 2009). It leads to increased information asymmetry and operational costs, diminishing the influx of new goods and technology (Anokhin and Schulze, 2009; Alam et al., 2019). Areas plagued by corrupt institutions show reduced innovation capacity (Rodríguez-Pose and Di Cataldo, 2015).

Fourth, poor institutions detract from the effective formulation and execution of policies supportive of innovation. Weak institutional frameworks dampen investor confidence and the efficacy of R&D investment incentives (Alam et al., 2019). Ill-advised government interventions and regulations stifle market competition, efficiency, and innovation (Storper, 2005), with inconsistent regulations leading to mounting investment costs and discouraging high-risk R&D activities (Rodríguez-Pose and Zhang, 2020).

Last but not least, inadequate institutions impede the integration of firms, limit regional learning capacity, and deter local entrepreneurship (Rodríguez-Pose and Storper, 2006; D'Ingiullo and Evangelista, 2020). The capacity of a region to learn and adapt, thereby facilitating knowledge spillovers, is significantly influenced by its institutional framework (Morgan, 2007). Effective institutions nurture connections, networks, and cooperation, propelling knowledge exchange and innovation (Mahmood and Rufin, 2005; Capello et al., 2018; Caragliu, 2022).

Overcoming these institutional barriers is fundamental for fostering innovation, with institutional reform playing a key role in this process. Reform can bolster the rule of law and enhance property rights protection, thereby reducing risks and transaction costs. This creates a favourable ecosystem for exchange, learning, and entrepreneurial activities, contributing to the development of environments supportive of high-risk innovation (Tebaldi and Elmslie, 2013; Lasagni et al., 2015; D'Ingiullo and Evangelista, 2020; Rodríguez-Pose and Ganau, 2022).

Moreover, reform can lead to more streamlined government administration. Enhancing institutional efficiency promotes innovation by ensuring equal access to economic opportunities, reducing information asymmetry, and improving economic efficiency (Acemoglu et al., 2001; Donges et al., 2023). Effective institutions also ensure that R&D investments are more profitable, facilitated by a developed financial market offering low-cost capital and reduced information asymmetry. Additionally, well-functioning institutions complement market dynamics, further incentivising high-reward innovative activities (Szczygielski et al., 2017).

Addressing corruption is another primary goal of institutional reform. Reducing corruption levels fosters fair market competition, builds trust, lowers transaction costs, and encourages investment in high-risk, innovative ventures (Lee et al., 2020; Zhang and Xiao, 2020). Lower levels of corruption decrease the costs of doing business, rendering innovation more attractive to investors (Alam et al., 2019). Regions with effective anti-corruption measures demonstrate a greater capacity for innovation (Rodríguez-Pose and Di Cataldo, 2015).

Furthermore, institutional reform can improve regulatory quality. Enhanced regulation supports effective innovation strategies, targeted investment, and the transparent allocation of grants for research and development (Alam et al., 2019). Effective regulations facilitate market entry and enable firms to remain abreast of developments (Alam et al., 2019). Reform also encourages interaction and collaboration, leading to greater knowledge accumulation and spillovers, which in turn enhance a region's learning capacity and innovation potential (Ottati, 1994; Morgan, 2007).

Notably, reforms that promote the decentralisation of powers often equip local governments with the ability to implement tailored innovation policies. Such decentralisation renders local governments more responsive and potentially more effective in mobilising local organisations (Rodríguez-Pose, 1999; Aghion and Howitt, 2006), thereby fostering more active innovation policies at the local level.

This paper examines the impact of institutional reform on innovation, with a particular focus on one of the countries in the world that has undergone some of the most significant recent institutional reforms in business and economic support: China. We analyse the effects of local reforms aimed at improving the business environment in Chinese city-regions and their role in overcoming barriers to innovation by firms and other local economic actors.

3. Institutional Reform, Ease of Doing Business, and Innovation in China

The way in which governmental interventions influence businesses significantly shapes a region's business climate and the efficacy of economic entities within it. Since transitioning from a centrally planned to a market-oriented economy four decades ago, China has seen profound changes in governance. This institutional shift has been at the heart of China's remarkable economic growth and sustained periods of rapid development. However, the past decade has seen a deceleration in China's growth. To address this slowdown, various levels of the Chinese government have embarked on extensive efforts to remove institutional barriers, with the aim of averting the risk of falling into a middle-income trap (Gill and Kharas, 2015). These initiatives have focused on reforms to streamline administration, delegate authority, strengthen regulations, improve the enforcement of the rule of law, and optimise service delivery, thereby enhancing the local business environment. This commitment to institutional reform has notably improved China's global standing in the Doing Business Environment Index, as reported by the World Bank: the country has moved from 92^{nd} in 2012 to 31^{st} in 2023.

Although the push to improve the business climate has primarily come from the central government, managing such a vast and diverse nation as China, with its high degree of decentralised administration (Feltenstein and Iwata, 2005; Van der Kamp et al., 2017), poses unique challenges. The barriers to local innovation vary across different city-regions.

City-regions have been at the forefront of creating favourable conditions to attract and retain dynamic and innovative businesses. The Chinese local government operates numerous agencies to fulfil its functions, among which the Administrative Bureau for Industry and Commerce (AIC), established in 1978, oversees the supervision of market entities, with the aim of facilitating market-oriented activities. Following the economic reforms of 1978, the central government granted significant autonomy to local governments in managing their economies, with the AIC being a key beneficiary of this decentralisation.

The AIC is tasked with verifying the credentials of market entities, overseeing the safety and quality of products and services, managing market entry and exit requirements, providing law enforcement oversight, investigating and penalising unlawful market activities, disseminating regulatory information to the public, and resolving market-related disputes. In response to rapid economic growth, the AIC has undergone considerable evolution. However, prior to 2009, the agency faced criticism for its inefficiency, lack of transparency, and ambiguous powers and responsibilities (Jiang, 2011; Zhang and Bi, 2019).

In addressing these institutional hurdles, strong decentralised reforms of the AIC have been implemented of recent. Shenzhen City pioneered the reform of its local AIC in 2009. Shenzhen —one of China's fastest-growing and largest metropolitan areas— merged the AIC with the Supervision Bureau of Technical Quality (SBTQ) and the Food and Drug Administration (FDA) to form a new, local-level AIC-type agency called the Market Supervisory Authority (MSA), with expanded responsibilities. Following the reform, the previous entities (AIC, SBTQ, FDA) were dissolved. The MSA now solely manages issues related to the safety and quality of products and services, as well as traditional market entry and exit operations. The reform introduced a clear definition of roles and responsibilities for the MSA, significantly streamlining business procedures. Key measures of this reform in Shenzhen included the consolidation of multiple certificates into a single document, the shift from pre-approvals to post-approvals, the modification of the paid-up registered capital system to a subscription model, and the simplification of domicile registration requirements. As a result, there was a marked reduction in the average time required for businesses to obtain operational licences from the government, which went down from 22.9 to 8.5 days. This achievement was primarily due to the elimination of overlapping governmental functions and the reduction of interference from multiple administrative bodies in business operations. Shenzhen has since been celebrated as a centre for business and innovation, attracting high-quality, innovative enterprises and highly skilled workers.

The Shenzhen reform set the stage for the establishment of new MSAs across China. Spurred by Shenzhen's achievements, subsequent cities embarked on analogous reforms, leading to a relatively widespread implementation of AIC-type administrative changes. This adoption process was, however, inconsistent. Between 2009 and 2013, only Shenzhen in Guangdong Province and Zhoushan in Zhejiang Province had initiated reforms. The period between 2013 and 2016 saw a rapid increase in momentum for such reforms, particularly after the central government, recognising the successes in Shenzhen and Zhoushan, started to encourage other cities to adopt similar reforms. By 2016, among the 283 prefectural cities considered in the analysis, 202 had established business and economic support agencies akin to AIC. By the close of 2018, every local government in China had completed the reform. Before 2018, in the absence of compulsory instructions from the central government regarding institutional reform, the decision to establish MSAs or to reform existing AICs was at the discretion of the prefectural governments, influenced by their political agendas, administrative capacities, and evaluation of reforms in other regions. Moreover, the reform was not directly designed to promote innovation. The variability in innovation across Chinese cities during the study period likely did not significantly affect the propensity to undertake the reform, thereby reducing concerns regarding endogeneity.

The effectiveness of the reform in fostering a more pro-business ecosystem largely depended on its execution. The introduction of reformed agencies has in most cases permitted local city-region governments to improve the regulation of the economic environment in which local firms operate, thereby creating local ecosystems more conducive to innovation. Some local botched reforms, by contrast, have resulted in the introduction of an additional layer of bureaucracy without the intended benefits for innovation. Whether the reform was a success or a failure is closely linked to the competency and efficacy of prefecture-level governments and administrations across China. This paper posits that the implementation of the reform introduced variability in government institutional quality. Given the reform's gradual rollout, commencing in a select few cities and subsequently replicated across others, there exist variations in governmental institutional quality across regions and over time, allowing for an examination of the marginal impact of institutional quality on regional innovation.

Several aspects, however, underscore that, on the whole, reforms have spurred regional innovation. Firstly, such local reforms have been aimed at dismantling entry barriers for firms, encouraging a broader spectrum of economic participants to enter the market. This enhancement in competition requires innovation for success. Secondly, the reform has strengthened the rule of law, with the newly established local MSAs actively addressing infringements on property rights, and combating counterfeit products. Thirdly, local MSAs have made significant efforts to reduce unfair competition, tackling bribery and illicit transactions, thereby strengthening corruption control. Fourthly, MSAs have improved information dissemination, becoming more transparent and accountable entities. Fifthly, the simplification of business procedures and the fight against corruption have substantially reduced institutional costs, incentivising innovation investment. Sixthly, by aligning MSAs to directly meet market needs, unnecessary governmental interventions have been minimised, and appropriate public goods provided. This has

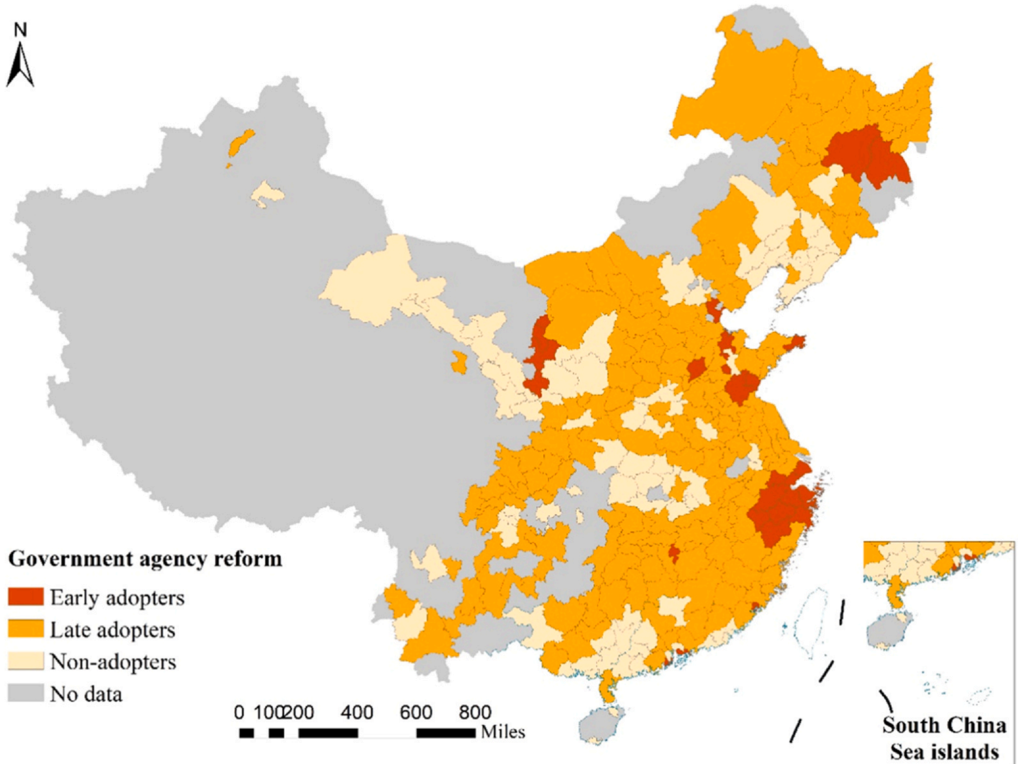

Fig. 1. Government agency reform. "Early adopters" denote city-regions that finalised the government agency reform by 2014. "Late adopters" those that executed the government agency reform between 2015 and 2016. "Non-adopters" encompass city-regions that had not yet undergone the reform by 2016.

led to a more efficient market economy, which in turn, has facilitated innovation through enhanced networking and knowledge spillovers. Moreover, streamlined administration and the delegation of authority to local government entities have better positioned these agencies to formulate and implement policies conducive to innovation, tailored to the realities of their regions.

This paper assesses the impact of these reforms on local level innovation, with Fig. 1 depicting the variance in reform adoption, differentiating early adopters, late adopters, and non-adopters.

Early adopters of reforms span both more and less innovative regions. Economically less developed early adopters include cities such as Mudanjiang in Heilongjiang Province and several in Shandong Province

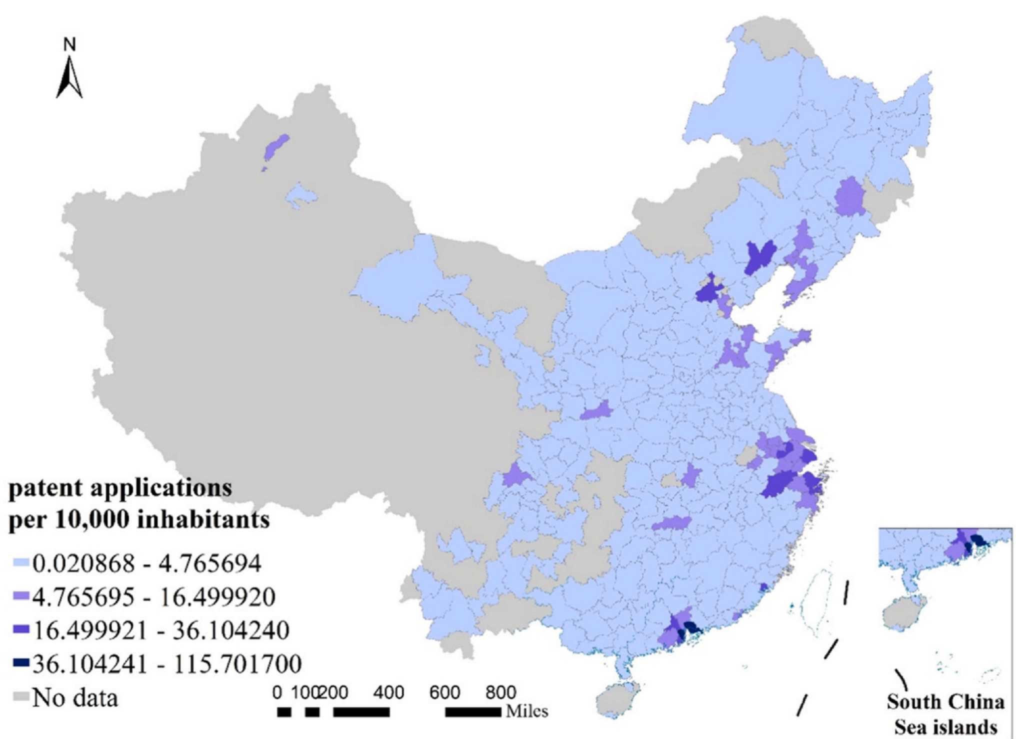

Fig. 2. Patenting per capita, 2009.

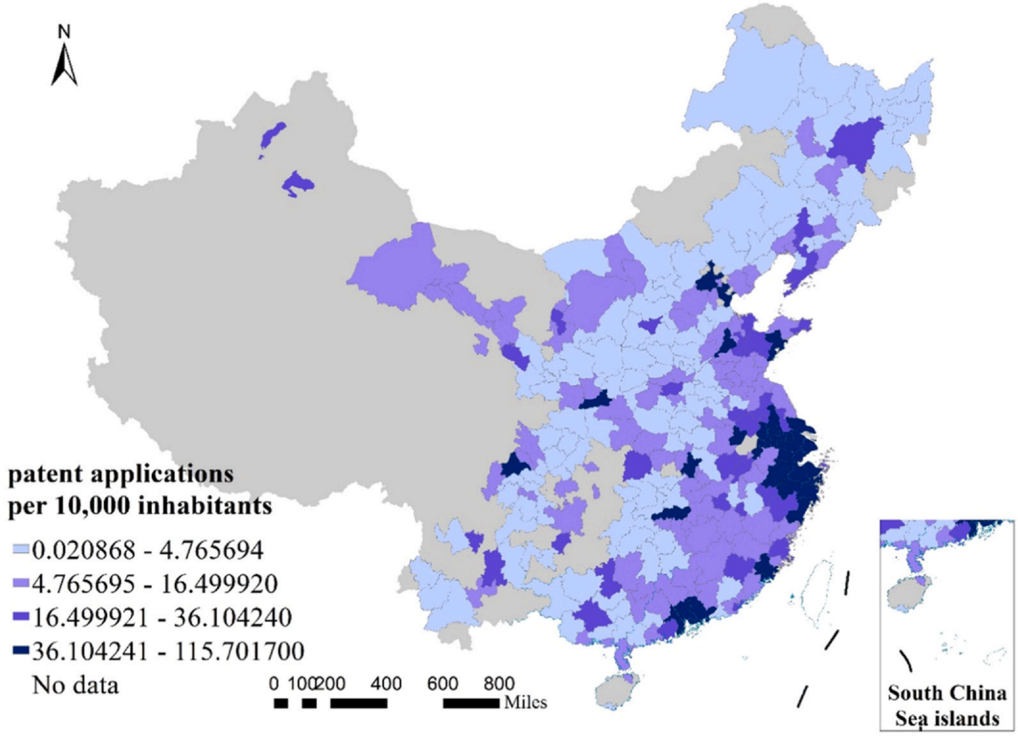

Fig. 3. Patenting per capita, 2016.

like Weihai and Linyi, alongside Yinchuan in Ningxia Province and Pingxiang in Jiangxi Province. Conversely, more innovative early adopters comprise cities like Shenzhen in Guangdong Province, Taizhou in Jiangsu Province, several cities in Zhejiang Province, and Shanghai. Out of the 283 city-regions sampled, 175 are identified as late adopters, leaving 81 as non-adopters. Non-adopting city-regions include both more innovative cities such as Beijing, Nanjing, and Xi'an, and less innovative ones like Ezhou and Zibo.

Given the varied innovation levels among early adopters and non-adopters, as illustrated in Fig. 1, the reform's influence on local innovation is not directly correlated with initial innovation levels. Consequently, the governmental agency reform pursued by early adopters is considered exogenous to local innovative activities, offering insightful perspectives on the intricate relationship between institutional reform and innovation within China's dynamic economic landscape.

3.1. Urban Innovation in China

Figs. 2 and 3 illustrate the distribution of patent-based innovation across Chinese city-regions in 2009 and 2016, respectively.

To evaluate innovation, we use patents per capita, defined as patent applications per 10,000 inhabitants. Given the high concentration of patenting innovation in specific Chinese regions, the natural fault classification method[1] is employed to categorise city-regions into four tiers. In 2009, the first tier, representing the most innovative cities, included only four cities, all in Guangdong Province (Shenzhen, Dongguan, Zhongshan, and Foshan). The second tier, slightly less innovative, comprised nine cities: four from the Yangtze River Delta region (Shanghai, Wuxi, Changzhou, Hangzhou, Ningbo), two from the north (Beijing, Chaoyang), and two from the south (Zhuhai, Xiamen). The bulk of the cities under review fell into the third and fourth tiers, indicating lower levels of innovation. Specifically, the third tier, classified as less innovative, consisted of 31 cities, while the fourth tier, the least innovative, encompassed 239 cities (Fig. 2). This classification underscores a pronounced geographical concentration of patent-based innovation within China.

By 2016 there was a notable shift in the geography of patent-based innovation. Maintaining the same group criteria, the number of cities in the first tier expanded to include 36 cities. This tier now incorporates not only all cities from the first and second tiers in 2009, alongside several capital cities previously ranked in the third tier, such as Tianjin, Hefei, Chengdu, Wuhan, Jinan, Xi’an, and Changsha. Furthermore, the distribution of cities across tiers became more balanced; 92 cities were classified as less innovative in the third tier, and 119 cities were deemed the least innovative in the fourth tier. This indicates a rapid expansion of innovation capacity in the middle of the city-region innovation distribution. Additionally, the most innovative city-regions continued to advance significantly. For example, Shenzhen's patents per capita increased from 115.7 in 2009 to approximately 337.6 in 2016, effectively tripling its innovation output within seven years. Between 2009 and 2016, innovation spread to more regions; while the most innovative cities sustained a rapid growth, numerous emerging cities previously considered second-tier or less innovative made considerable progress, contributing to a marginal closing of the gap with the most innovative regions.

4. Empirical Approach, Variables, and Data

4.1. Empirical approach

4.1.1. Difference-in-Difference Strategy

To investigate the impact of the reform on innovation —specifically, whether reforms aimed at enhancing the quality of local business services have resulted in significant improvements in the innovative capacity of reformed cities— we resort to a time-varying Difference-in-

[1] We chose the natural fault classification rather than quartiles to divide the sample cities into four categories because innovation is highly agglomerated in a few Chinese city-regions. In 2009, the intensity of the most innovative city-region (Shenzhen, 115.7 patent applications patent applications per 10,000 inhabitants) was more than 5,000 times larger than that of the least innovative (Lincang, 0.021 patent applications per 10,000 inhabitants). The display based on the natural fault classification provides a better picture to understand the geography of innovation in China during the period of analysis.

Difference (DID) model. This approach is suitable as the reform introduced an exogenous shock to local government institutional quality and city-regions reformed their institutions at varying times.

The treatment group[2] is composed of 27 cities (the early adopters) that had completed reforms by 2014, while the control group includes 81 cities (the non-adopters) that had not implemented the reform by 2016. Fig. 4 showcases the marked differences in innovation —measured by patent applications per capita— between city-regions that were early adopters of the reform and those that were non-adopters. Interestingly, the innovation gap between non-adopters and late adopters remains minimal. Prior to the institutional reform, innovation trends in early-adopter and non-adopter city-regions were parallel. After the reform, a notable divergence emerged, with the innovation gap between early adopters and non-adopters widening. The gap between late adopters and non-adopters remained fairly stable. This delineation highlights a significant reform impact on early adopters, thereby justifying the selection of our treatment and control groups. Consequently, our analysis will concentrate on city-regions within the early-adopter and non-adopter categories.

Building on existing literature (e.g., Ó hUallacháin and Leslie, 2007; Rodríguez-Pose and Di Cataldo, 2015), our estimation model is specified as follows:

$$\begin{aligned} Innovation_{i,t} = \alpha &+ \beta_1 reform_{i,t} + \beta_2 RD_{i,t} + \beta_3 education_{i,t} \\ &+ \beta_4 employmentdensity_{i,t} + \beta_5 popu_{i,t} + \beta_6 manufacturing_{i,t} \\ &+ \beta_7 GDPpc_{i,t} + \beta_8 pollution_{i,t} + \mu_i + \nu_t + \varepsilon_{i,t} \end{aligned} \tag{1}$$

where $Innovation_{i,t}$ represents the outcome variable of interest at the city-region level, measured by the number of patent applications per 10,000 individuals; $reform_{i,t}$ is an interaction variable of the treatment group dummy and the reform post-year dummy, taking the value of 1 for the treatment group in the reformed year and onwards, and 0 otherwise.[3] The control variables encompass R&D input ($RD_{i,t}$), human capital ($education_{i,t}$), population size ($popu_{i,t}$), employment density ($employmentdensity_{i,t}$), manufacturing activities ($manufacturing_{i,t}$), economic wealth ($GDPpc_{i,t}$), and air quality ($pollution_{i,t}$). μ_i and ν_t control for city and year fixed effects. $\varepsilon_{i,t}$ denotes the error term. By comparing outcome variables between the treatment and control groups before and after the institutional reform, we can identify the effect of the government agency reform.

4.1.2. Instrumental Variable Strategy

To mitigate potential biases arising from omitted variables, we incorporate an instrumental variable (IV) approach. The primary variable of interest in this context is the likelihood of government institutional reform. Drawing on established literature (North, 1991; Tabellini, 2010; Tebaldi and Elmslie, 2013), the process of institutional evolution exhibits path dependence, meaning that local historical conditions shape the potential for current and future institutional reforms and are intricately linked to the probability of such reforms taking place in the present day. Moreover, empirical studies on institutions suggest that variations in contemporary institutions can often be explained by factors determined historically, such as colonial status and the origins of the legal system (Acemoglu and Johnson, 2005; Tebaldi and Elmslie, 2013). Similarly, the political and social history of China offers a

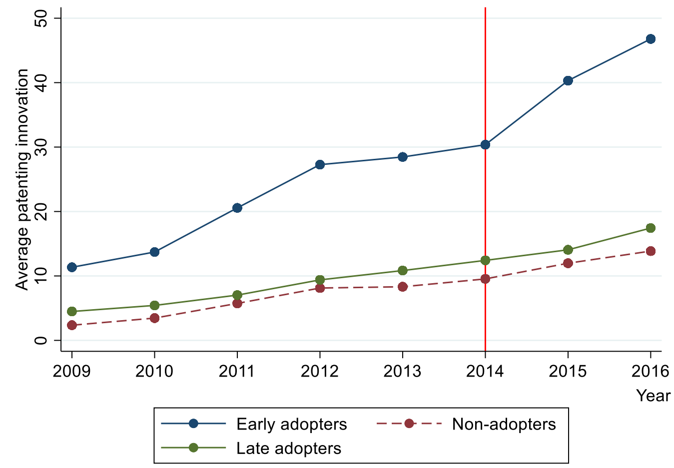

Fig. 4. Evolution of patenting per capita by the timing of the reform. In this study, we categorise early adopter city-regions as those 27 cities that had completed the reform by 2014. Late adopter city-regions comprise the 175 cities that implemented the reform between 2015 and 2016. Non-adopter city-regions encompass the 81 cities that had not initiated the reform by 2016.

diverse range of variations in government institutional quality at the regional level. This diversity arises from history's role in the emergence and consolidation of political interests vested in specific institutions (Tabellini, 2010; Wang et al., 2021).

In this context, we follow (Wang et al., 2021) and use a historical government quality indicator —the *chongfanpinan* system established during the Qing dynasty— as the instrumental variable for government institutional reform.[4] The *chongfanpinan* system, instituted in 1731, categorised prefectural regions into four tiers based on criteria such as transport significance, governance complexity, tax collection challenges, and regional security concerns. This hierarchical classification facilitated a more effective allocation of bureaucratic resources, with regions higher up in the hierarchy receiving better resources (e.g., more qualified civil servants) and greater governance autonomy, indicative of higher government institutional quality. We map the historical *chongfanpinan* hierarchy on contemporary Chinese city-regions, aligning with Qing dynasty territorial demarcations.

Fig. 5 showcases the historical variations in governance quality as measured by the *chongfanpinan* hierarchies during the Qing dynasty. Within our sample of 283 city-regions, 55 were placed in the highest *chongfanpinan* category, signalling superior historical government institutional quality. These include seven cities in Guangdong Province (Shenzhen, Dongguan, Zhongshan, Zhuhai, Foshan, Guangzhou, Quanzhou), seven in Jiangsu Province (Wuxi, Zhenjiang, Changzhou, Yangzhou, Yancheng, Huaibei, Suqian), three in Fujian Province (Xiamen, Fuzhou, Zhangzhou), two in Zhejiang Province (Jiaxing, Taizhou), among others scattered across China. An additional 126 cities were rated with a *chongfanpinan* score of 3, positioning them in the second tier regarding local government quality. Seventy-two cities received a score of 2, and nine cities scored 1, placing them in the lowest category of government institutional quality three centuries ago. There are 21 cities without historical records, either because they were located outside the ancient Chinese boundaries or due to challenges in matching current city locations with their historical *chongfanpinan* counterparts.

[2] The treatment group excludes the late-adopter cities throughout the study period to facilitate model fitting. Given that there are 175 late-adopter cities which implemented the reform between 2015 and 2016, their inclusion would result in a significant imbalance between the treatment and control groups during 2015 and 2016.

[3] The DID regressions employed in this study are time-varying. It is the actual year of reform, rather than 2014, that is used to determine whether a treatment city has completed the reform.

[4] In considering the IV, we explored various historical institutional variables as potential instruments for predicting the likelihood of institutional reform. These included the establishment of administrative approval centres, the number of church schools in the 1900s, the opening of ports to trade in the 1900s, and historical literacy rates. However, the test results showed that only the *chongfanpinan* can be considered as a suitable instrument. This variable reflects the quality of historical institutions in ancient Chinese regions almost 300 years ago.

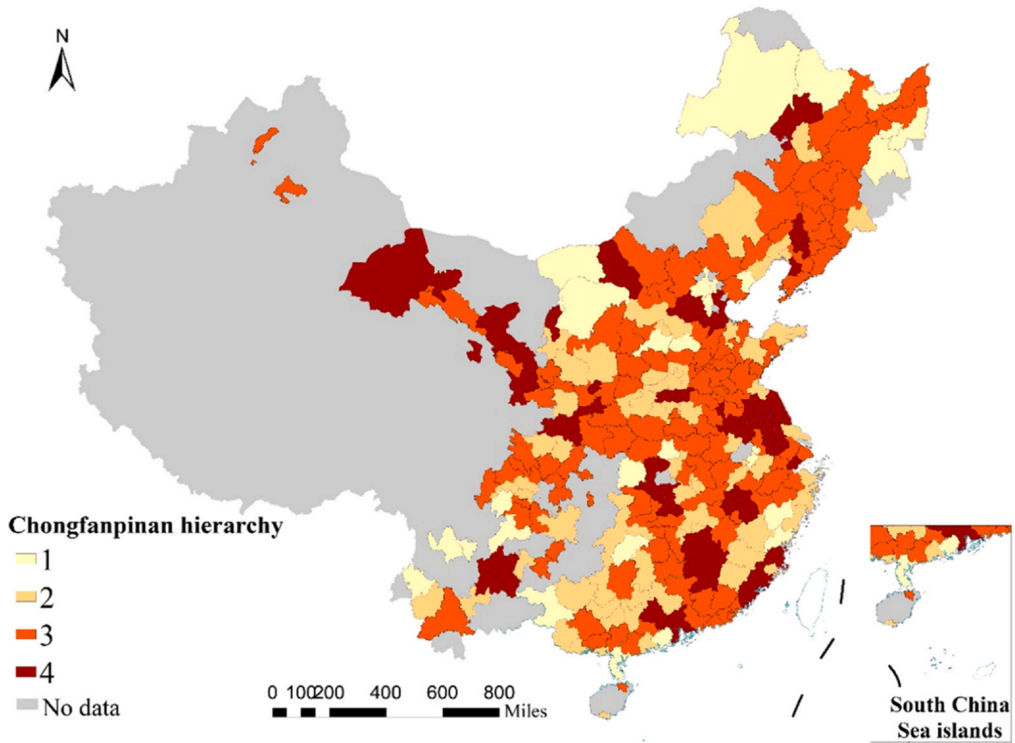

Fig. 5. Historical government quality. A higher *chongfanpinan* hierarchy indicates a higher level of historical government institutional quality.

As Wang et al. (2021) show, there is a positive correlation between a city-region's historical government quality —as signified by its *chongfanpinan* score— and its contemporary government institutional quality.

4.2. Variables

The analysis incorporates a diverse set of variables to explore regional innovation and its underlying determinants. The primary variable under examination is the innovative performance within city-regions, quantified by the number of patent applications per 10,000 inhabitants. Despite certain limitations associated with using patents as a measure of innovation, patent applications are widely recognised as a robust indicator of commercially viable and tangible innovation outcomes (e.g., Fontana et al., 2013; Rodríguez-Pose, Wilkie, 2019). Consequently, it serves as a reliable metric for comparative econometric analysis concerning innovation (Hu et al., 2017).

Furthermore, the analysis integrates control variables to capture other factors contributing to regional variations in innovation. These include:

1. **R&D Input**: Investment in research and development (R&D) is acknowledged as a basic component of the innovation process, significantly influencing a location's innovation capacity and its localised effects (Maurseth and Verspagen, 2002; Rodríguez-Pose, Wilkie, 2019). To reflect the impact of R&D investment on innovation, we employ the ratio of R&D expenditure to GDP.
2. **Human Capital**: Skilled labour availability affects innovation through the development of new technologies, products, and processes (Howitt and Aghion, 1998; D'Ingiullo and Evangelista, 2020). A region's human capital —proxied by the quality and quantity of its workforce— affects its absorptive capacity and knowledge spillovers (Rodríguez-Pose and Crescenzi, 2008). The educational level of workers serves as a proxy for human capital in our study.
3. **Density and Agglomeration**: The geographic concentration of economic activity significantly influences innovation (Duranton and Puga, 2003; Charlot and Duranton, 2004). High density enhances the transmission, creation, and spillover of knowledge. Knowledge is often geographically localised and is most efficiently shared through direct interactions (Von Hippel, 1994; Morgan, 2004). Economies that are highly agglomerated promote face-to-face interactions, which in turn, facilitate the generation of innovation (Charlot and Duranton, 2004; Crescenzi et al., 2012). Moreover, agglomeration is known to positively affect knowledge flows and spillovers, which are crucial for innovation (Chatterji et al., 2014; Donges et al., 2023). To measure density and agglomeration within this framework, we look at urban employment density and population size as key indicators.
4. **Industrial Composition**: The potential for innovation within a region is closely linked to its industry-specific demands. The economic landscape and the activities it encompasses shape a region's capacity for innovation (Capello et al., 2012; Rodríguez-Pose et al. 2021). Manufacturing industries, in particular, are regarded as fundamental to technological progress and show a positive correlation between the proportion of employment in these sectors and the level of innovation at the city level (Carlino et al., 2007; D'Ingiullo and Evangelista, 2020). To evaluate the effect of industrial composition on regional innovation, we include the proportion of employment within manufacturing industries in our analysis.
5. **Wealth**: The economic status of a region serves as an indicator of its proximity to the technological frontier, thereby acting as a proxy for its innovative capacity (Greunz, 2003). Economies that experience rapid growth are often at the forefront of technological progress (Rodríguez-Pose, Wilkie, 2019; Filippopoulos and Fotopoulos, 2022). Factors that contribute to prosperity, such as the availability of resources, a robust industrial base, and comprehensive infrastructure, are instrumental in driving the innovation process (Rodríguez-Pose, Wilkie, 2019). In this analysis, we use GDP per capita to signify the relative wealth of a city-region.
6. **Amenities**: The quality of amenities, including accessible services, culture, and environmental conditions, can influence innovation, especially in sectors driven by creative activities (Florida, 2002; Wu

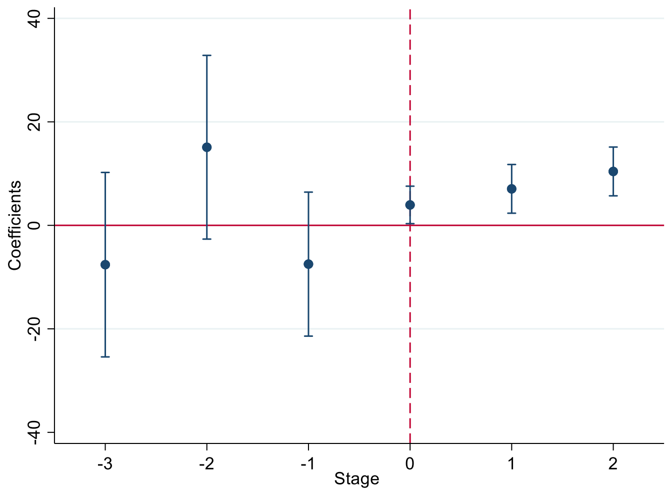

Fig. 6. Parallel trend test.

and Dong, 2014; He et al., 2019). Recent discussions around the negative impacts of air pollution on innovation, through reduced workforce productivity and the exodus of high-skilled individuals seeking better quality of life, have highlighted the importance of amenities in innovation dynamics (He et al., 2019; Zhang and Chung, 2020). Thus, air quality, as an indicator of pollution levels, is included to partially gauge the influence of amenities on regional innovation in China.

4.3. Data Sources

The overall analysis encompasses a total of 283 city-regions, while the DID analysis concentrates on the 108 city-regions identified as either early-adopters or non-adopters. This dataset spans the years from 2009 to 2016, covering the timeframe before and after the implementation of the reform. Information regarding institutional reform is sourced from the Yearbook of the Industry and Commerce Administration of China. This publication offers detailed insights into commercial regulatory agencies by listing names, addresses, and personnel details. Through an examination of agency names, we determine the reform status of cities. Specifically, cities listed with an AIC are classified as traditional, indicating no reform, whereas cities identified with agencies titled MSA, or those including terms like "Quality Supervision Bureau" or "Food and Drug Administration," are considered to have undergone reform.

Patent information is procured from the State Intellectual Property Office of the People's Republic of China. This dataset provides a direct measure of innovation output. Data concerning city-region level variables, such as R&D input, worker education, population size, share of employment in the manufacturing industry, employment density, and GDP per capita, are derived from the China City Statistical Yearbook. Data on air quality are obtained from van Donkelaar et al. (2018) offering a quantitative measure of environmental conditions across city-regions. The *chongfanpinan* data —which serve as a historical indicator of government institutional quality— are sourced from the 'Veritable Records of the Qing Emperors (Qingshilu).

For an in-depth understanding of the variables used in our study, including their definitions, sources, and descriptive statistics, please refer to Tables A1 and A2 in the appendix.

5. Empirical Analysis

5.1. Parallel Trend Test

To implement the DID estimation effectively, we need to verify that there were no significant disparities in innovation outputs between cities in the control and treatment groups prior to the institutional

Table 1
The impact of government institutional reform on regional innovation.

Dependent var. innovation	(1)	(2)	(3)	(4)	(5)	(6)
	FE	RE	FE	FE	DID	IV
reform		**9.895*****	**6.279*****	**7.476*****	**7.939*****	**35.790*****
		(4.036)	**(4.247)**	**(2.781)**	**(4.992)**	**(6.613)**
RD	1.247***	4.898***	1.248***	4.883***	1.347***	5.210***
	(5.239)	(9.398)	(3.490)	(9.368)	(3.801)	(0.560)
population	4.835***	-0.174	22.398***	-0.169	23.232***	-0.555**
	(3.689)	(-0.687)	(6.046)	(-0.669)	(6.329)	(0.267)
employment density	0.886***	2.490***	2.463***	2.511***	2.397***	2.635***
	(7.002)	(15.265)	(10.096)	(15.330)	(9.870)	(0.170)
education	6.276***	-0.060	5.142***	-0.079	6.233***	-0.431**
	(17.656)	(-0.398)	(11.495)	(-0.525)	(10.935)	(0.168)
manufacturing	0.198***	0.102	0.228**	0.121	0.285***	0.214**
	(3.353)	(1.155)	(2.463)	(1.362)	(3.071)	(0.093)
pollution	-0.154***	-0.189***	-0.266***	-0.174***	-0.246**	-0.237***
	(-2.714)	(-3.615)	(-2.890)	(-3.317)	(-2.326)	(0.055)
GDP per capita	0.642***	2.848***	-0.313	2.804***	-0.142	2.035***
	(3.616)	(8.379)	(-1.377)	(7.852)	(-0.599)	(0.391)
constant	-50.896***	-11.595***	-111.758***	-11.905***	-120.936***	-7.970***
	(-8.486)	(-5.706)	(-8.159)	(-5.827)	(-8.738)	(2.154)
City FE	Yes	No	Yes	No	Yes	Yes
Year FE	Yes	No	No	Yes	Yes	Yes
chongfanpinan						0.081***
F value excluded IV						135.65
Sargan statistic						0.000
Observations	2114	804	804	804	804	796
R-squared	0.410	0.633	0.928	0.640	0.931	0.591
F	90.105	171.571	104.155	163.685	64.758	

t statistics in parentheses.
Note: two-way fixed regression in column (5) in this table denotes the DID regression. IV results in column (6).
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$.

reform. This verification is essential to meet the parallel trend assumption. Accordingly, our analysis starts by conducting parallel trend tests through an event study, which serves to confirm the suitability of the DID model for our examination. More specifically, we refine our estimation by substituting the reform variable with an interaction term that combines the dummy variables for the treatment group (TREAT), covering three years preceding the reform and extending to two years post-reform, with the dummy for treatment city. The equations for conducting the event study are outlined as follows:

$$Innovation_{i,t} = \alpha + \alpha_1 reform_{i,t}^{-3} + \alpha_2 reform_{i,t}^{-2} + \alpha_3 reform_{i,t}^{-1} + \alpha_4 reform_{i,t} + \alpha_5 reform_{i,t}^{1} + \alpha_6 reform_{i,t}^{2} + \beta Controls_{i,t} + \mu_i + \nu_t + \varepsilon_{i,t} \quad (2)$$

where $reform_{i,t}^{-j}$ is a dummy variable that takes the value of 1 once the reform was conducted in j years before the real reform for the treated cities and 0 otherwise. $reform_{i,t}^{+j}$ denotes a dummy variable that takes value of 1 once the reform was conducted j years after the real reform for the treated cities and 0 otherwise. $Controls_{i,t}$ refers to the same set of the control variables in model (1). Fig. 6 presents the results of the parallel trend tests using the patenting innovation at the outcome. In Fig. 6, the Y axis denotes the coefficient estimate whereas the X axis denotes the stage. Stage 0 is the time point of the AIC-type reform year, while Stage 1 is the year immediately after the AIC-type reform. The vertical line is the 95% confidence interval. The coefficient is not significant at the 5% level once the vertical line crosses the horizontal dashed line ($y = 0$). As shown in Fig. 6, there is no significant difference between the control and treatment group cities before Stage 0, that is, before the reform took place. In contrast, the outcome difference between the two groups becomes significant from the reform year onwards, pointing to significant outcome differences between the control and treatment groups after the implementation of the reform. All results pass the parallel trend test, meaning that the selection of the treatment and control group and model is appropriate.

5.2. Institutional Reform and Innovation

Table 1 provides the estimates for Eq. (1). Initially, we apply a basic two-way fixed OLS regression focusing solely on control variables (see Table 1, Column 1). Subsequently, we introduce the government institutional reform variable, indicating whether a city-region, classified as an early adopter, has implemented the reform (as detailed in Table 1, Columns 2–6). Columns 2 through 4 report the estimation using random and one-way OLS fixed effects, while Column 5 presents the two-way fixed OLS estimates, displaying the DID results.

The essence of our analysis, captured in Columns 2–5 of Table 1, establishes a strong link between institutional reform in early-adopter city-regions and their innovation output. The reform variable's positive and significant coefficient underscores the important role of the reform in enhancing the ease of conducting business locally, thus contributing to higher local patent counts. The reform —aimed at eliminating institutional barriers, notably in improving the rule of law, particularly with regard to Intellectual Property Rights (IPR) protection and contract enforcement— have bolstered innovation. This could be attributed to the reform enhancing the provision of public goods and services, streamlining business processes, increasing the efficiency of public officials, devolving authority to local levels, reducing corruption, and improving the transparency of public information. These findings corroborate the effectiveness of the reform as a factor driving increases in innovation within Chinese city-regions (Hu et al., 2017).

To address potential endogeneity concerns related to institutional indicators and innovative outcomes, the IV analysis uses the *chongfanpinan* hierarchy as instrument. This historical measure of government quality helps mitigate biases arising from omitted variables. Column (6) in Table 1 displays the 2SLS estimation's second-stage and first-stage results, employing this instrument. The consistent positive and significant coefficient of the *chongfanpinan* in the first-stage result suggests, as anticipated, that city-regions with a higher historical government quality have been more inclined towards early adoption of the reform, validating the predictive power of *chongfanpinan* as an instrument for current institutional differences across Chinese city-regions (Wang et al., 2021). The second-stage results in Column (6), largely mirroring the DID findings from Column (5), sanction the institutional reform variable's positive and significant impact in the full sample regression, reinforcing the reform's role in fostering innovation.

The control variables' results are in alignment with theoretical expectations. The R&D variable's positive and significant coefficient across the board confirms the established positive correlation between

Table 2
Innovation drivers across different quantiles of regional innovation output.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Decile	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
reform	**2.040*** **	**2.212*** **	**3.402*** **	**5.583*** **	**8.141*** **	**9.583*** **	**8.553*** **	**7.647***	**3.969**
	(2.643)	**(3.084)**	**(3.860)**	**(4.876)**	**(6.017)**	**(4.158)**	**(2.895)**	**(1.770)**	**(0.955)**
RD	0.402**	1.197***	1.856***	2.665***	3.392***	4.295***	4.892***	6.725***	10.546***
	(2.449)	(7.850)	(9.909)	(10.948)	(11.796)	(8.767)	(7.789)	(7.323)	(11.942)
population	0.145*	0.122	0.151*	0.137	0.077	0.048	-0.020	-0.117	0.035
	(1.821)	(1.639)	(1.660)	(1.159)	(0.551)	(0.202)	(-0.065)	(-0.262)	(0.081)
employment density	0.125**	0.117**	0.172***	0.242***	0.380***	0.706***	1.764***	3.194***	4.035***
	(2.442)	(2.455)	(2.934)	(3.178)	(4.226)	(4.605)	(8.976)	(11.115)	(14.601)
education	0.238***	0.213***	0.209***	0.303***	0.361***	0.282**	0.165	-0.197	0.037
	(5.056)	(4.850)	(3.875)	(4.334)	(4.362)	(2.003)	(0.914)	(-0.746)	(0.146)
manufacturing	0.030	0.019	0.005	0.004	-0.007	-0.028	-0.098	-0.143	-0.201
	(1.067)	(0.722)	(0.146)	(0.099)	(-0.144)	(-0.336)	(-0.921)	(-0.918)	(-1.342)
pollution	0.021	-0.002	-0.020	-0.035	-0.052*	-0.075	-0.100	-0.150	-0.163*
	(1.299)	(-0.112)	(-1.041)	(-1.429)	(-1.812)	(-1.518)	(-1.591)	(-1.628)	(-1.845)
GDP per capita	0.538***	0.940***	1.234***	1.426***	1.399***	1.707***	2.263***	2.246***	2.021***
	(5.023)	(9.455)	(10.098)	(8.980)	(7.460)	(5.343)	(5.523)	(3.750)	(3.508)
constant	-4.520***	-4.595***	-5.240***	-6.174***	-5.586***	-5.666***	-5.336**	-2.319	-2.727
	(-7.064)	(-7.728)	(-7.172)	(-6.505)	(-4.981)	(-2.966)	(-2.179)	(-0.648)	(-0.792)
Observations	804	804	804	804	804	804	804	804	804
Pseudo R2	0.1156	0.1623	0.2053	0.2475	0.2930	0.3409	0.3999	0.4840	0.5968

t statistics in parentheses.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$.

Table 3
Robustness check result: controlling for confounding policies.

	(1)	(2)	(3)
	Hausman-Taylor	Fixed effects	Hausman-Taylor
reform	**3.464****	**8.992*****	**3.925*****
	(2.572)	**(5.138)**	**(2.686)**
RD	-0.207	1.364***	-0.186
	(-0.649)	(3.687)	(-0.560)
population	1.254	22.497***	1.381
	(1.161)	(5.858)	(1.201)
employment density	1.359***	2.392***	1.337***
	(5.943)	(9.476)	(5.609)
education	3.622***	6.230***	3.693***
	(10.705)	(10.364)	(10.049)
manufacturing	0.042	0.333***	0.056
	(0.600)	(3.307)	(0.732)
pollution	-0.080	-0.263**	-0.082
	(-1.016)	(-2.348)	(-0.990)
GDP per capita	0.917***	-0.181	0.929***
	(5.609)	(-0.727)	(5.445)
Anti-corruption efforts	-0.562**		-0.568**
	(-2.242)		(-2.209)
Economic and Technological Development Zones		-0.166	-0.139
		(-0.488)	(-0.568)
constant	-17.107***	-125.684***	-17.749***
	(-3.095)	(-8.152)	(-2.965)
City FE	No	Yes	No
Year FE	No	Yes	No
Observations	614	740	566
R-squared		0.931	
F	57.794	52.874	48.077

t statistics in parentheses.
Note: As the *fight against corruption* variable remains constant over time, we employ a Hausman-Taylor (HT) regression with the inclusion of the said variable. The HT estimation facilitates the computation of coefficients for variables that remain unchanged over time, alongside those that vary across time. Additionally, it employs the remaining regressors as instruments to calculate the coefficients for the time-invariant variables within a panel analysis.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$.

R&D investment and innovation (Crescenzi et al., 2012; Zhang et al., 2020). Employment density's positive and significant coefficient across regressions underscores the increased likelihood of innovation in denser regions, echoing the principles of the New Economic Geography (e.g., Duranton and Puga, 2003; Fujita and Mori, 2005; Krugman, 2011). The educational level of workers shows a strong association with innovation across fixed effects regressions, although its significance varies under endogeneity consideration, suggesting a correlation with another economic variable not captured directly. Moreover, the relationship between patenting activities and local manufacturing employment emphasises the interconnectedness of a city's innovative potential with its specific industrial activities. However, adverse air quality, as indicated by the negative coefficient for air pollution, presents a hurdle to innovation, highlighting the importance of environmental enhancements for regional progress. Lastly, the positive and significant association of GDP per capita with innovation in most regressions —except in random and DID estimations (Columns 3 and 5 of Table 1)— indicates that economic prosperity is conducive to greater innovative output.

5.3. Region-specific results

The pronounced differences in economic, social, and institutional conditions across Chinese city-regions, particularly between more and less developed areas, demand a closer look at how institutional reform impacts innovation based on the region's development level. To this end, we employ quantile regressions, which offer the advantage of recognising the diverse capacities of regions to innovate at varying stages of development. This approach allows for estimating the effects of institutional reform across different points in the innovation distribution.

Table 2 outlines the results of these quantile regressions, examining the relationship between institutional reform and innovative capacity across regions situated at the 10%, 20%, and continuing through to 90% of the regional innovation distribution, as shown in Columns (1)-(9). The findings reveal that the government institutional reform variable is positive and significant across all regressions, except for the top 10% of the most innovative regions (as seen in Column 9, Table 2). This indicates the reform's broad effectiveness in enhancing regional innovation for the majority of Chinese regions. Notably, the benefit derived from the reform intensifies as we progress up the regional innovation ladder, peaking for regions around the 60% quantile (Column 6, Table 2). However, its impact diminishes for regions in the higher 70% and 80% innovation distribution quantiles, suggesting that institutional reform yields the most substantial benefits for regions within the middle spectrum of regional innovation. This trend underscores that regions with a second-tier innovative status gain the most from institutional reform. This is due to the presence of more efficient innovation systems in China's wealthier and more innovative city-regions, which better exploit reform initiatives. In contrast, the top 10% quantile of highly innovative regions shows no significant benefit from institutional reform, possibly because these technologically frontier regions can already maximise investment and economic resources without being hindered by weak institutions. This hypothesis is supported by the observation that other economic drivers, such as R&D input, density, and economic wealth, exert the most significant influence in the top quantile (Column 9, Table 2), indicating that innovation at the technological frontier is predominantly driven by R&D investment, agglomeration effects, and economic resources. Meanwhile, regions not at the technological forefront depend, to a far greater extent, on enhancing government institutional quality, alongside R&D investments and economic resources, to boost their innovation capabilities — as was also found in the case of Europe (Rodríguez-Pose and Di Cataldo, 2015).

The significance of other innovation drivers varies between more and less developed regions. While variables like R&D investment, density, air quality, and wealth maintain high significance across all regressions, their impact grows in regions with higher innovation levels. Additionally, the education variable is significant only for the less innovative regions (Columns 1–6), suggesting these areas rely more on human capital to foster innovation. The population size variable's insignificance in the first 60% of the innovation quantile range indicates that more innovative regions depend less on agglomeration economies for innovation. Instead, factors like R&D investment, density, air quality, and economic wealth play a more crucial role in their innovation dynamics.

In summary, institutional reform significantly boosts innovation across most Chinese regions, except for the most innovative ones. The impact is particularly pronounced in mid-to-highly innovative regions. Furthermore, the drivers of innovation differ between more and less innovative city-regions, with the former driven by R&D input, density, human capital, and manufacturing activities, and the latter relying more on worker education, agglomeration effects, and economic wealth.

5.4. Robustness Tests

5.4.1. Controlling for Potential Confounding Policies

To mitigate the risk of overstating the impact of institutional reform on innovation, we account for the influence of other policies aimed at enhancing government effectiveness. Consequently, the analysis includes and adjusts for two distinct policies enacted between 2009 and 2016. The first of these policies pertains to the anti-corruption

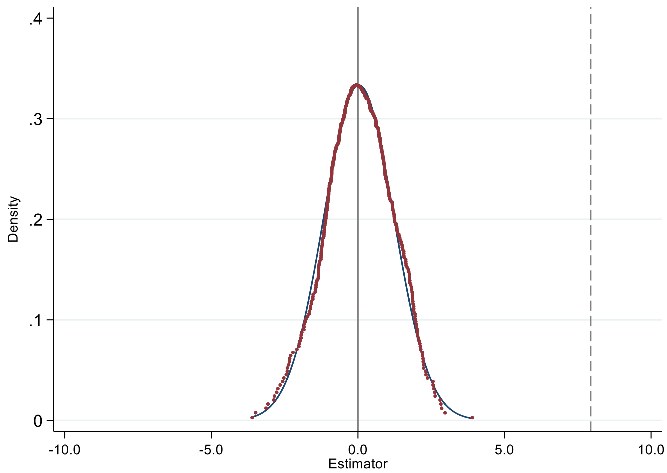

Fig. 7. Estimated coefficient distribution of the *reform* variable by 500 repetitions.

campaign led by the Chinese government, also recognised in the scholarly literature for creating an environment that supports innovation (e.g., Xu and Yano, 2017; Fang et al., 2018). Beginning in 2013, Chinese authorities initiated significant anti-corruption measures at the local level, targeting, among other goals, the enhancement of the business environment nationwide. The vigour of these anti-corruption initiatives varied across regions, facilitated by an official website launched in December 2013 for reporting corruption cases involving civil servants on a monthly basis. Drawing on established methodologies in corruption research (Boylan and Long, 2003; Cordis and Milyo, 2016), we use the count of corruption cases prosecuted in each city-region from December 2013 to December 2016 as an indicator of the local authorities' commitment to combating corruption.

Additionally, during the period of analysis, local Chinese governments initiated Economic and Technological Development Zones (ETDZs) to improve the efficiency of government agencies. These zones, designated to attract investment, encourage entrepreneurial activity, and foster regional economic growth, offer companies benefits such as reduced factor costs (e.g., land, energy), R&D subsidies, legal incentives (e.g., fiscal and tax exemptions), and access to established infrastructure (e.g., ports, laboratories, service providers) (Yan et al., 2021). The creation and operationalisation of ETDZs have been instrumental in driving economic growth and innovation, as they draw in capital, investment, production, and businesses. The establishment of ETDZs, endorsed by the central government, has been a priority for governments at various levels. Between 2009 and 2016, 169 provincial ETDZs and 57 national ETDZs were established and became operational. Therefore, our model includes the presence of ETDZs as another confounding policy variable for a more comprehensive analysis.

Table 3 outlines the regression results, factoring in the two aforementioned policies. Notably, the coefficient for anti-corruption efforts is significant and negative in Columns 1 and 3 of Table 3, suggesting a negative correlation between anti-corruption measures and city-regional innovative performance. This could reflect the local levels of corruption (Zheng and Xiao, 2020), which may inhibit innovation activities (Lee et al., 2020). Furthermore, the lack of a significant impact of ETDZs on innovation implies that the preferential policies offered within these special economic zones may not be as critical in overcoming innovation bottlenecks as previously thought. Despite these additional policy influences, the institutional reform variable consistently exhibits a positive and significant effect across all regression models in Table 3. This underlines the strong association between effective government institutions and enhanced innovation capacity within Chinese city-regions, thereby confirming our primary conclusions.

5.4.2. Placebo Test: Mixing Up Treatment and Control Group and Changing Policy Time

To further substantiate our findings, we undertake two placebo tests. The first involves re-running the regressions with cities randomly allocated to the treatment and control groups. During this process, city-regions are arbitrarily designated as either treatment or control, and the post-period is factored in to produce an artificial estimated coefficient. Fig. 7 illustrates the distribution of these fictitious estimated coefficients after conducting the procedure 500 times. Notably, the average of these spurious coefficient values is near zero and follows a normal distribution. This result highlights the expected normative impact of reform on innovation, lending additional credibility to the significant and positive influence of government agency reform on the innovative capabilities of Chinese city-regions.

Table 4
Placebo test with changed policy time.

Dep. var	(1)	(2)	(3)	(4)	(5)	(6)
innovation	T-3	T-2	T-1	T	T+1	T+2
reform	**0.980**	**1.100**	**0.985**	**7.939*** **	**10.639*** **	**9.656*** **
	(1.138)	**(1.275)**	**(1.139)**	**(4.992)**	**(5.983)**	**(4.110)**
RD	1.268***	1.269***	1.266***	1.347***	1.318***	1.287***
	(5.311)	(5.318)	(5.305)	(3.801)	(3.756)	(3.619)
population	4.769***	4.753***	4.758***	23.232***	23.034***	23.974***
	(3.636)	(3.623)	(3.626)	(6.329)	(6.332)	(6.511)
employment density	0.882***	0.881***	0.881***	2.397***	2.413***	2.423***
	(6.972)	(6.963)	(6.963)	(9.870)	(10.018)	(9.928)
education	6.302***	6.306***	6.304***	6.233***	6.271***	6.249***
	(17.694)	(17.705)	(17.694)	(10.935)	(11.086)	(10.901)
manufacturing	0.203***	0.204***	0.203***	0.285***	0.289***	0.263***
	(3.436)	(3.447)	(3.434)	(3.071)	(3.142)	(2.831)
pollution	-0.159***	-0.160***	-0.159***	-0.246**	-0.284***	-0.246**
	(-2.795)	(-2.807)	(-2.796)	(-2.326)	(-2.691)	(-2.312)
GDP per capita	0.620***	0.615***	0.616***	-0.142	-0.190	-0.152
	(3.471)	(3.439)	(3.441)	(-0.599)	(-0.805)	(-0.637)
N	2114	2114	2114	804	804	804
R-squared	0.896	0.896	0.896	0.931	0.932	0.930
F	78.240	78.295	78.240	64.758	67.065	63.053

t statistics in parentheses.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$.

We conduct a second placebo test. This test implies creating fictitious policy timings. Drawing upon existing literature (Abadie and Dermisi, 2008; Callaway, Sant'Anna, 2021), we set the time points three years before and two years after the actual reform as the artificial treatment time. Consequently, the 'post' dummy variable is redefined based on these fictional treatment timings. Eq. (1) is re-estimated using this altered policy timing framework. Table 4 highlights the outcomes of this test. In Columns 1–3, the coefficient of the interaction term *reform*(*treated*post)* is not statistically significant, indicating an absence of a notable effect prior to the actual reform. Conversely, the significant coefficient for the reform variable in Columns 4–6 reveals that it is precisely the measures enacted at the actual reform time and subsequently that have had a significant impact on the innovative performance of regions. This implies that once implemented, institutional reforms exert a lasting positive influence on innovation. The outcomes of this second placebo test validate that our dataset satisfies the parallel trend assumption, confirming the suitability of the DID model for our analysis.

Overall, these placebo tests not only reinforce the validity of our primary findings but also emphasise the methodological soundness of employing the DID approach in examining the effects of institutional reforms on regional innovation in China.

6. Conclusion

In this paper we have conducted an empirical analysis of the influence of government reform on innovation. We leverage early adopters of a reform aimed at improving the local business ecosystem —particularly affecting the rule of law, corruption control, and market regulations as a source of exogenous variations in local government institutional quality. The reform, implemented from 2009 onwards on a voluntary basis, mostly led to improvements in institutional quality which, in turn, we expect to have led to increases in Chinese city-region's innovation performance.

The findings of the analysis reveal that the implementation of the reform has, indeed, notably increased innovation in the early-adopters. Improvements in government institutional quality as a result of reforms thus shape the regional innovative capacity of city-regions in China. In addition to improvements in institutional quality, factors such as R&D input, human capital, economic prosperity, employment density, manufacturing activities, and environmental quality also contribute to explain variations in innovation among Chinese city-regions. Moreover, the impact of the institutional reform on innovation increases in the regions placed around 60% of the Chinese city-region innovation distribution, suggesting that it is these places at the medium and high levels of innovation which have reaped the highest benefits from the institutional reform. By contrast, institutional reforms have had limited impact on the overall innovation of the top 10% most innovative city-regions in China.

Beyond the institutional dimension, disparities in innovation dynamics between more and less developed regions extend to conventional factors. In the context of more innovative regions, increasing R&D, density, and creating a more amenable environment, emerge as key drivers of innovation. In contrast, constraints posed by an underdeveloped economy, along with limited human capital and population, appear to hinder the ability to harness the potential of R&D investments, particularly in less innovative city regions. Our core findings withstand rigorous testing employing a historical government quality indicator (*chongfanpinan*) from the Qing dynasty as an instrument, accounting for potential confounding policies, and conducting placebo tests.

The implications of our findings extend to policy formulation for China and places elsewhere aiming to harness innovation's potential for economic growth. As we emphasise the crucial role of institutional reform in fostering an innovative economy, China must persist in reforming its government institutions to align more effectively with market dynamics. Priority should be given to dismantling institutional barriers for market entry, bolstering intellectual property rights protection, curbing corruption, and enacting appropriate regulations. This particularly pertinent for China's second tier innovative city-regions, which have benefited the most from more effective governance and nurturing a more favourable business environment. But the least and less innovative Chinese city-regions also stand to benefit from institutional reform, provided they improve institutional quality in conjunction with increasing R&D investment, agglomeration and fostering economic development as a prerequisite for innovation in these contexts.

Our research comes with some limitations. Patents, employed as proxies for innovation, have been criticised as an indicator of innovation for, among other factors, including a notable share of non-innovative filings (Hu et al., 2017). The lower quality of indigenous Chinese patents linked to 'strategic play' patenting has also been a source of criticism (Thoma, 2013). Furthermore, patent statistics in China may overstate innovation indicators due to patent subsidies (Dang and Motohashi, 2015). In addition, our work does not delve into the channels through which institutional reform impacts innovation, paving the way for future micro-level investigations.

Notwithstanding these caveats, the analysis shows that institutional reform is crucial for innovation at the local level in China, particularly for middle-of-the-range and less innovative city-regions. The removal of institutional bottlenecks and barriers holds critical significance for Chinese city-regions. Bold institutional reforms can thus provide a path for addressing long-term innovation problems and making sure that regions in China and elsewhere overcome some of the barriers their firms, research centres, and other socio-economic actors face when trying to innovate.

CRediT authorship contribution statement

Min Zhang: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Andrés Rodríguez-Pose:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

For the manuscript titled "Government Reform and Innovation Performance in China," submitted to *Papers in Regional Science*, we, the authors, declare that there are no conflicts of interest. This includes any potential conflict of interest regarding the funding, research, and authorship of this paper. This submission is exclusively the result of our own original research and has not been influenced by any external interests.

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Appendix

Table A1
Definition and source of variables

Name	Definition	Source
innovation	number of patent applications per 10,000 inhabitants	State Intellectual Property Office of the P.R.C(SIPO)
reform	whether the local government has successfully carried out the transformation of the government agency (from AIC to MAS) by establishing the Market Supervisory Authority agency.	Self-calculated from Yearbook of Industry and Commerce Administration of China
RD	local investment in R&D as a share of GDP (%)	China City Statistical Yearbook
education	workers with a bachelor's degree or higher as a share of total employment (aged 25–64 years old), %	
population	population size at year end (1 million inhabitants)	
employment density	employment density (100 persons per square kilometer) in urban areas	
manufacturing	employment share of manufacturing industries (%)	
GDPpc	GDP per capita at year end. 10, 000 Yuan/person	
pm25	average concentration of PM2.5 (μg/m3)	Van Donkelaar et al.(2016)
chongfanpinan	*chongfanpinan* hierarchy in Qing Dynasty	Veritable Records of the Qing Emperors (Qingshilu)
fight against corruption	number of corruption cases exposed between 2015.7 and 2016.12, prefectural city level	http://www.ccdi.gov.cn/; authors' calculation
Economic and Technological Development Zones	number of provincial Economic and Technological Development Zones (ETDZs) established for region *i* till year *t*	The Ministry of Science and Technology of the People's Republic of China; authors' calculation

Table A2
Descriptive statistics for the main variables

Variable	Obs	Mean	Std. Dev.	Min	Max
innovation	864	14.440	31.727	0.021	337.621
reform	864	0.094	0.292	0	1
RD	864	1.667	1.619	0.000	20.683
population	864	4.050	3.822	0.195	33.920
employment density	805	3.984	5.364	0.113	46.388
education	864	6.834	6.062	0.721	39.285
manufacturing	850	14.894	9.377	0.346	59.702
pm25	864	35.175	15.397	4.676	82.793
GDP per capita	863	4.659	3.246	0.449	46.775
chongfanpinan	856	2.698	0.949	0.000	4.000
fight against corruption	648	12.130	16.656	0.000	130.000
Economic and Technological Development Zones	800	5.589	5.873	0.000	43.000

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