Democracy and Innovation

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Abstract

We study the effect of increased democracy on innovation using novel provincial panel data on political pluralism in China from 1980 to 2012. We find higher diversity and more non-communist members in the provincial congresses positively affect innovation. An instrumental variable approach using the 1965 (pre-cultural revolution) provincial congress compositions confirms our results. Consistent with Acemoglu and Robinson's (2012) proposition that more 'inclusive' political institution leads to less extractive economic institution, we find provinces with higher congress diversity and non-communist members tend to have higher R&D expenditure, earlier initiative to attract highly skilled emigrants, and earlier patent promotion policies. To establish causality, we examine the staggered adoption of secret ballot voting method in provincial congresses and an intra-communist party democracy experiment at county level to reform the tenure system of party congress. Finally we find crackdowns on corruption among holders of high political offices in a province positively affect subsequent innovations. Overall, our results suggest in a single party authoritarian country like China, a little bit more democracy could have significant impact on innovation.

JEL classification: 053, 034, 031, K00, G21, G24, G28

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Does democracy inspire innovation? Though it is widely accepted that innovation is fundamental for economic growth, and a country's innovative performance is associated with a wide range of economic institutions, we know little about whether democracies or autocracies promote better innovation.[1]

At some level it is obvious that democracy matters. History is full of examples where great technological advances were made in nations that established 'inclusive' political institutions (Acemoglu and Robinson 2012).[2] Witness, for example, the dazzling civilization of the Roman Republic (509 to 27 BC) was founded on its form of government with modern democratic ideologies (Greene 2000, Glower 2009). The British industrial revolution was accompanied by important political advances including the enhanced voting rights of adult males, increasingly representative political system, and high quality political debate in newspapers and in both houses of parliament in the 18th century (Evans 2001, Harvie and Matthew 2005, Williams 2004, Atterbury 2009). In Asia, the massive technology advancements and expansion of Japan in the late 19th and early 20th century owed much to the Meiji Reform which initiated series of anti-monarchy constitutions and advocated democracy revolutions (Norman 2000). On the other hand, Acemoglu and Robinson (2000) describe how non-democracies in the Russian and Austro-Hungarian Empire tried to hold back the Industrial Revolution. In Islamic lands, religious leaders forbade the printing press as a source of blasphemy and

[1] For example, the literature has documented the association between innovation and property rights (Arrow 1962; Dass, Nanda and Xiao 2014), quality of law (Djankov et al. 2002; Brown, Martinsson and Petersen 2013), financial market development (Rajan and Zingales 1998; Hsu, Tian and Yu 2014; Cornaggia et al. 2015), cultural settings (Huang and Xu 1999), and human capital development (Khan 2015), etc.

[2] Acemoglu and Robinson (2012) make the distinction between 'inclusive' and 'extractive' political institutions. The authors define inclusive political institutions as those "sufficiently centralized and pluralistic' (pp.95), and those encourage participation and a level playing field for the majority of its people. They argue inclusive political institution promotes innovations and long term economic growth.

heresy; according to Landes (1998) this is the main reason why the Islamic world started to lag behind the West in economic development.[3]

Empirically, however, we lack reliable estimates on the effect of democracy on innovation. Countries can be different for a number of reasons that generate differences in both political institutions (autocracy versus democracy) and innovation. On the other hand, rapid expansions in political opportunities can create political instability and violence, which are hardly conducive for innovation (Friedman *et al*. 2011). It is also possible that the effect is running from innovation to political environment.[4]

In this paper, we ask when a country starts from a single-party authoritarian, whether a little bit more political pluralism will do more good than harm for innovative activity? Our focus is on China, the country where communist authoritarianism is perhaps the most entrenched. To illustrate, in 2014 China ranked 144 (out of 167) in the world's Democracy Index, 175 (out of 180) in the Press Freedom Index, and 100 (out of 175) in the Corruption Perception Index. After over 30 years of rapid economic development, the future growth of the country depends crucially on innovation and creativity. [5] On the other hand, due to the Chinese Communist Party (CCP)'s determination to monopolize political power, the country's political development lags far behind its economic reform. Acemoglu and Robinson (2012) conjecture that China's politically extractive growth model is not sustainable, for powers are concentrated in the hands of narrow elite who will structure the economic institutions to extract resources

[3] Note, however, history is also full of examples of great innovations emerging from autocratic, even oppressive, countries and organizations. Striking examples are Nazi Germany and Soviet Union that produced a number of pioneering inventions in different fields, ranging from medicine to aeronautic engineering.
[4] For example, technological change can alter the balance of political power and lead to political and other types of reforms. In line with this view, Rajan and Zingales (2003) suggests that financial market deregulation occurred in the US thanks to major innovations that eroded the political support of the regulations.
[5] See, for example, the World Bank (2013) report on "China 2030: Building a Modern, Harmonious and Creative Society", available at: http://www.worldbank.org/content/dam/Worldbank/document/China-2030-complete.pdf

from the rest of the society. Boldrin, Levine and Modi (2012) argue that extractive institutions can also deliver growth but only when the economy is distant from the technological frontier. They will ultimately fail when innovations and 'creative destruction' are needed to push the frontier.

We investigate the effect of democracy on innovation using a unique provincial level panel dataset on political pluralism in China from 1980 to 2012. In the aftermath of the decade-long cultural revolution (1966-1976) in China, the provincial human capital and economic resources were reshuffled in a mass scale, and it was not until the death of Mao Zedong and in the 5th National People's Congress in 1978 did the CCP decided to shift the national priority from previous power struggle to economic development. We exploit the fact that when the People's Congress system was resumed in 1978, there were significant variations on provincial level political pluralism, and these variations in congress composition change every five years following the quinquennial election of the provincial congress members. These both cross-sectional and time series variations allow us to use a panel-based fixed effects identification approach to associate provincial politics with innovation. To establish causality, we use an instrumental variable approach, and examine the effect of staggered adoption of two rare democracy experiments (both in the congress system and within the CCP) in a difference-in-differences setup.

Using multiple measures of political pluralism as well as innovation, we find robust evidence that congressional political pluralism positively affect both the quantity and quality of innovations in a province. A one standard-deviation increase in provincial congress diversification is associated with 39.6% increase in incidence rate ratio of

patent applications filed domestically in China over the province-year. The proportion of non-communist members and 'intellectuals' class members are also found positively associated with innovation.

Three pieces of evidence suggest that the positive association between political pluralism and innovation is supported by deliberate policy. In a two-staged test, we first find high political-pluralism provinces tend to have higher public R&D expenditure, earlier policy to attract highly skilled emigrants, and earlier policy for patent promotion. We next show these pro-innovation policies have positive effect on innovation. These results are consistent with our working hypothesis that more inclusive political institution reduces regulatory capture by vesting powers broadly, resulting in pro-innovation policies and economic institutions.

We employ multiple identification strategies to test the effect of democracy on innovation: Our baseline result is strengthened by a 2SLS test using the 1965 (pre-cultural revolution) provincial congress composition as instrument of the post-1980 political pluralism. In a difference-in-differences setup we find strong evidence that staggered adoption of the secret ballot voting methods at provincial congresses improves levels of innovation.

One doubt about our empirical results is that despite the pluralistic trends that we document at China's provincial congresses, China's politics is still a de-facto single party authoritarian by the CCP. For this reason we exploit a unique, county level intra-CCP democracy experiment to reform the tenure system of party congress. In 1988 the Central Organization Department of the CCP almost randomly chose 12 counties and prefectures in five provinces to experiment the effect of enhanced power of party

congress deputies in supervising party appointed local cadres (the ‘tenure system of party congress’). Over the years the Central Organization Department of the CCP has expanded its approval on this experiment to 132 counties and prefectures. We adopt a “twin-city” difference-in-differences approach by finding the control group of the county / prefecture that are immediate neighbors of the experimenting county / prefecture in the same province. We find the county / prefecture level innovation was enhanced as a result of enhanced intra-party democracy. Finally, using a hand-collected dataset of 92 crackdowns on corruption among Party cadres of high political offices which form a staggered set of exogenous shocks to the risk of being held accountable for self-serving behavior among politicians, we find anti-corruption crackdowns in a province positively affect subsequent innovations.

Overall, our empirical evidences suggest a positive and causal relationship from political pluralism to innovation in a single-party authoritarian state. This finding has implications on many non-democracies that wish to drive economic development through innovation. Murphy, Shleifer and Vishny (1993) find innovators usually have high demand for government-supplied goods yet the distribution of resources in a society is an inherently conflictual, therefore political, decision. Unlike the political elites (incumbents), innovators have no established lobbies and they are often credit-constrained thus cannot as easily find the cash to pay bribes. An inclusive political environment helps innovators by vesting the power broadly and protects against regulatory capture (Laffont 2005). A non-extractive political environment also encourages true innovators, for entrepreneurs face less expropriation risk thus can

channel their efforts more on productive activities such as innovation than unproductive activities such as rent seeking (Baumol 1990).

Our paper belongs to the literature that emphasizes the role of institutions on innovation and economic outcomes (see Acemoglu, Johnson and Robinson 2005 for a survey). Prior studies have identified the association between innovations and property rights (Dass, Nanda and Xiao 2014), legal and financial institutions (Rajan and Zingales 1998, Brown, Martinsson and Petersen 2013; Hsu, Tian and Yu 2014; Cornaggia *et al*. 2015), cultural settings (Huang and Xu, 1999) and political preferences (Acemoglu and Robinson 2000, Bhattacharya *et al*. 2014). At firm level, it is found that corporate innovations are positively associated with investor's risk tolerance (Manso 2011, Lerner, Sorensen and Strömberg 2011, Tian and Wang 2014), whilst the overall evidence on the relationship between corporate governance and innovation is a mixed bag (Hirshleifer, Low and Teoh 2012, O'Connor and Rafferty 2012, Atanassov 2013, Edrer and Manso 2013, Aghion, Reenen and Zingales 2013, Sapra, Subramanian and Subramanian 2015). We add to this literature by providing the first empirical investigation on the link between political pluralism and innovation, using rare evidence from Communist China. In interpreting the results, however, one should be careful that the democracy in China is at a rudimentary state. Hence our results do not suggest that more democracy would always be a boon for innovation, but rather that if a country starts from an authoritarian political regime, a little bit more political pluralism will do more good than harm for innovative activity.

Our paper also contributes to the literature on economics of diversity. The issue of diversity has been at the forefront of many fields, including economics, management,

and social psychology (for a review, see Williams and O'Reilly 1998).[6] The insight from this literature is that diversity within a team gives rise to knowledge diffusion and accumulation of universally applicable human capital, which reduces group thinking, enhances creativity, and enables better deliberation in decision making (Galunic and Rodan 1998; Lazear, 1999; Pelled, Eisenhardt, and Xin 1999). However, too much diversity might hinder cooperation and trust between individuals, which is detrimental to the value creation of a society (Fukuyama 1995; Ashraf and Galor 2013). We add to this literature by showing higher diversity in the political market lead to more pro-innovation economic policies, such as higher level of R&D expenditure, earlier policy to attract highly skilled emigrants, and earlier policy for patent promotion.

Finally, we shed light on the economic history of China and in particular the famous "Needham Question" (Needham 1954-) by offering a political-based explanation. Mote and Twitchett (1988) estimate China's total technological inventions from *Qin* to *Ming* Dynasty (B.C. 221 to A.D. 1644) accounted for about 2/3 that of the world in the same period. According to Needham (1964), the puzzle is that "*between the first century BC and the fifteenth century AD, Chinese civilization was much more efficient than occidental in applying human natural knowledge to practical human needs"* (pp.385). but "*Why, modern science (as we know it since the seventeenth century, the time of Galileo) had not developed in Chinese civilization* (or. *Indian*)*but only in Europe*?" (pp. 385) Prior work attempts this question by offering economic, legal, and philosophical-based explanations (Webber 1951, Graham 1973, Needham 1982, Alford 1995, Elvin

[6] For example, research shows in a team setting, gender diversity matters for males and females differ in risk appetite and work attitude (Adams and Ferreira 2009; Anderson *et al*. 2011). Ethnic diversity also matters for different ethnic groups differ in beliefs and cognitive functioning, which could provide a broader view and more alternative solutions to the questions (Carter *et al*., 2003). Diversity in educational and professional backgrounds can provide a diverse range of expertise, which enhances problem solving capability (Rodan and Galunic 2004).

2004). We argue that autocratic and extractive political system might contribute to this puzzle. To illustrate, since *Ming* dynasty (1368-1644), the "Three Departments and Six Ministries" political institution established in *Tang* dynasty that provides checks and balances gradually eroded (Hucker 1958; Qian 1982). Instead, power was vested upon the land holding classes, corruption became prevalent, and domination by the eunuchs became political reality (Ebrey 1999). Eventually in 17th century the Ming Empire, caught between fruitless efforts to defeat the Manchu raiders from the north and huge peasant revolts in the provinces, essentially fell apart. The subsequent *Qing* dynasty (1644-1912) was under the political reign of Manchu who viewed the majority Han ethnic group as a political threat (Rhoads 2000). In early 20th century, following the demise of China's two thousand years of imperial governance, leaders of China's New Cultural Movement called for "Mr. Confucius" to be replaced by "Mr. Science" and "Mr. Democracy" [7], reflecting the desire to borrow these two closely related assets to modernize the nation (Gu 2001).

The next section discusses our measures on political pluralism and innovation, and quantifies their association based on a panel data identification strategy. Section 3 presents empirical results based on instrumental variable approach, and tests on two mechanisms through which politics affects innovation. Section 4 employs three identification strategies based on staggered shocks and political experiments to establish causality. Section 5 concludes.

[7] In the word of Chen Duxiu, one of the leaders of the New Culture Movement, who personified Science and Democracy as Mr. Science (Sai xiansheng) and Mr. Democracy (De xiansheng), and claim that "only these two gentlemen can save China from the political, moral, academic, and intellectual darkness in which it finds itself". Quoted from Edward X. Gu., 2001,"Who was Mr Democracy? The May Fourth Discourse of Populist Democracy and the Radicalization of Chinese Intellectuals (1915-1922), *Modern Asian Studies* 35: 589-621, at 589.

2. Data, Empirical Strategy, and Baseline Result

Our panel data consists of 31 provinces in mainland China, with all the variables measured at the province-year level during the period 1980-2012.[8] We first introduce our measures for innovative activities and measures for political pluralism and control variables, then proceed to discuss identification strategies in the baseline model along with empirical results.

2.1 Innovation variables

Appendix A provides details on all variables. Following the standard in the innovation literature we use patents, citation and R&D activities to capture innovation (Aghion, Reenen and Zingales 2013; Tian and Wang 2014). All Chinese patent applications need to be filed centrally at the Chinese Patent Office (CPO) in Beijing. The CPO grants three types of patent: invention patent (IP), utility model (UM) and exterior design (ED). Among the three, "invention patent" represents substantive levels of innovation, is hardest to obtain, and has a protection period of 20 years. The level of innovation in 'utility model' and 'exterior design' is lower and their protection period is 10 years. Thus, our first two measures of innovation include: (i) count of total patents (IP+UM+ED); and (ii) count of invention patents filed domestically in China at province-year level. Data of patent count are taken from China Statistics Yearbook from 1980 to 2012.

Our third innovation measure is the count of Chinese patents filed in the U.S. or European Patent Office aggregated at province-year level ('Patent US&EP'). We

[8] China has 22 provinces, 5 autonomous regions, and 4 municipalities (Beijing, Chongqing, Tianjin, and Shanghai). The municipalities are directly governed by the central government and enjoy the same status as provinces and autonomous regions.

choose these two patent offices because data show that Chinese patents filed at these two patent offices account for 99.75% of the total Chinese patents that are filed overseas during 1991-2010. We expect these patents to have higher quality due to: (1) (potentially) more stringent patent assessment in US and European Patent Offices; and (2) higher commercial value globally. To identify this sub-sample of patents and aggregate them into province-year we use the European Patent Office Worldwide Patent Statistical (EPO PATSTAT) Database and analyze the postal address of its China-domiciled applicants.[9] Table B-2 and Appendix B provides the details.

Our forth measure of innovation is the citation-weighted count of patents ('CW Patent US&EP') built upon an estimation of citation age profile (Jaffe and Trajtenberg 2002, Hall *et al*. 2002, Caballero and Jaffe 2002). Citation-weighted patent count is calculated as the sum of total predicted life-long citations per province-year unit of the observations. Following Mehta *et al.* (2010), we calculate total predicted life-long citations per patent as the total observed citation since grant year of the cited patent divided by the predicted proportion of citations in the patent age profile estimated from the Poisson model. We provide the details in constructing this measure in Appendix B. Similar to our third measure of innovation, data used to calculate this variable come from the EPO PATSTAT database.

Finally, we use R&D expenditures to GDP ratio as our fifth measure of innovation. As Hsu, Tian, and Xu (2014) argued, R&D expenditure is an important measure of innovation activities, as it directly affects the innovation output such as patents and innovative products. Our definition of total R&D expenditures are the

[9] If the applicant is an individual, the address is his / her registered postal address. If the applicant is a company, the address is the company's registered postal address.

amount of R&D investment made by all corporations and the research institutions, aggregated at the province-year level, based on the reports by China Science and Technology Statistical Bureau.

2.2 China Politics and Political Pluralism Variables

Our objective is to capture the variations in China's provincial political institutions. Xu (2011) characterizes China's fundamental institution as a "regionally decentralized authoritarian system". To illustrate, the highest power of China politics lies in the National People's Congress (NPC), whose over 3,000 members are elected from the Provincial People's Congresses. Members of the provincial congresses are in turn elected by lower level congresses, with a series of layers that ends with popularly elected basic level congresses. Despite this, China's Constitution also provides that the People's Congress system must be operated under the leadership of the Communist Party of China (CPC), which dominates China's political power since 1949 after defeating the Kuomingtang (KMT) in the post-Japanese invasion civil war during 1946-1948. Every five years the CPC will hold its *Party Congress* to make key personnel decisions shortly before the People's Congress. The People's Congress will then officially endorse these key decisions in the name of all voters in China. During the interval of the five year period, the power of the Party or People Congresses is exercised by a much smaller Standing Committee whose members meet every a few months.

Note that despite the CPC dominance in China politics, it is not the only political party in China. Other than the CPC, there are eight non-communist political parties in China and they represent the interest of private businesses, intellectuals, and emigrant

overseas Chinese.[10] Unlike the western politics, these minority parties are not opposition parties and their role in Chinese politics is mainly to be 'consulted' on important political and economic matters.

Reflected in political representation, in recent years, approximately one-third of the seats in national and sub-national People's Congresses have informally been reserved for members of minority political parties and other independent members, and there exists significant variations among provinces. Other than the party differences, there are differences in the composition of different interest groups in provincial congresses. Our data come from the provincial statistical yearbooks which disclose the compositions of male and female congress members, and the distribution of congress members from six 'classes' including peasants, workers, cadres, military officers, intellectuals, and others). It is these variations among Chinese provinces that we are investigating.

Even within the CPC, the composition of its members also shows pluralist trends. In 2002, following the call by the then CCP Party Secretary Jiang Zemin for the Party to '*represent the development trends of advanced productive forces*', the Charter of the CCP was revised to allow private entrepreneurs to join the Party. Formerly dominated by the proletariat (army men, peasants and workers), the elite group of CCP now consists an increasing number of technocrats and private entrepreneurs (Dickson 2003; Chen and Dickson 2008). The presence of diversified interest groups both within the Party and in the People's Congress system enhances the level of deliberation in the

[10] The eight Non-Communist Parties in China are: Revolutionary Committee of the Kuomintang (founded in 1948, 80,000+ members); China Democratic League (founded in 1941, 180,000+ members); China Democratic National Construction Association (founded in 1945, 100,000+ members); China Association for the Promotion of Democracy (founded in 1945, nearly 100,000 members); Chinese Peasants and Workers' Democratic Party (founded in 1930, 90,000+ members); China Zhi Gong Party (founded in 1925, nearly 20,000 members); Jiusan Society (founded in 1944, nearly 100,000 members); Taiwan Democratic Self-government League (founded in 1947, 2100+ members).

decision making process. Literature documents in recent years the People's Congresses have increasingly become forums for debate and consensus-building over a wide range of issues (Hasan *et al*. 2009). For example, several milestone legislations that protects private property rights and levels the play field for state and private owned businesses (e.g. the Property Law of 2007, Bankruptcy Law of 2006, and Anti-monopoly Law of 2008) were products out of a decade or longer deliberation and re-drafting process before passed by the National People's Congress.

Based on the above discussions, we construct three measures of political pluralism. The first measure is congress diversity, measured by one minus the Herfindahl Hirschman Index (HHI) provincial congress based on the sum of squares of the proportions of each of these five types of members in the congress: farmers and workers, military officers, cadres, intellectuals, and others. In the banking and corporate finance literature, Herfindahl Hirschman Index has been widely used as an inverse indicators of diversification (e.g., see Acharya et al. 2006), and by construction, the HHI ranges from 1/n (n = number of categories, 5 in this case) to 1, with a higher value of the index indicating more focus (less diversification). Therefore, we have:

$$\text{Congress diversity} = 1 - \sum_{i=1}^{5} (component\%)^2 \qquad \text{... (1)}$$

Our second measure is the proportion of non-Communist Party members in the provincial congress (*% Non CCP*), and the third measure is the proportion of the class of "intellectuals" in the provincial congress (*% Intellectuals*). One data advantage is that there are large variations both cross-sectionally and over the years in these measures

of provincial level political pluralism, and these variations enable us to employ a panel data identification strategy employed in the baseline model.[11]

2.3 Control variables

The baseline models of innovation require us to include the local economic environment, financial resources, as well as human resources that are commonly found in economic and innovation studies. We therefore control for the following variables at the province-year level. 'Real GDP per capita', defined as the GDP per capita in real term with price level adjusted to year 1980, provides control of regional economic development momentum and environment. We also control for the 'unemployment rate' in urban area. 'Wage differential', defined as the percentage differentials between the average wage in state sector vs. non-state sector in urban area, captures the effects of job market competition. In addition, we control for the effects of the human resources by including 'logged population' and 'college education' measured by the ratio of population with college degrees and above to total population above age six. GDP, unemployment, wage differentials, education and other macroeconomic data for the provinces are collected from the annual issues of the Statistics Yearbook of China. The population data are obtained from the National Bureau of Statistics of China and the annual issues of China Statistics Yearbooks. China conducted population censuses in 1982, 1990 and 2000 and 'semi censuses' in 1987 and 1995. In addition, annual population surveys have been conducted since 1983 in all regions of the nation, with the sampling ratio varying slightly around 0.1%.

[11] Note since China's provincial congress members change only every five years, so our political pluralism variable also change every five years.

Hsu, Tian, and Xu (2014) show that financial development and resources are crucial for innovation. To capture the financial development in a province we control for the 'banking sector depth' by the ratio of total long-term bank loans to GDP of that province. We also include 'capital market activity', measured by the total IPO proceeds raised by public firms from a given province to GDP of that province. Long-term bank loans data are obtained from the annual issues of the *Almanac of China's Finance and Banking* (ACFB), and the equity issuance data are collected by summarizing the equity issuance data from the statistical yearbooks of the Shanghai and Shenzhen Stock Exchanges.

2.4 Baseline Model and results

To analyze how political pluralism in a province's congress affects the quantity and quality of innovations in that province, our baseline model adopts a panel-based fixed effects identification approach. When our dependent variable is a continuous variable (such as ratio of R&D expenditure), we use a standard linear panel data estimation model with province and year fixed effects. When we use a count variable (such as count of patents) as our dependent variable y_{it}, we make assumptions that y_{it} has a negative binomial distribution, which can be regarded as a generalization of the Poisson distribution with an additional parameter allowing the variance to exceed the mean. There are several different ways to parameterize the negative binomial distribution, and we use the NB2 model termed by Cameron and Trivedi (1998), which specifies the mass function for a single y_{it} is given by:

$$f(y_{it} \mid \mu_{it}, \lambda_i) = \frac{\Gamma(\lambda_i + y_{it})}{\Gamma(\lambda_i)\Gamma(y_{it}+1)} \left(\frac{\mu_{it}}{\mu_{it}+\lambda_i}\right)^{y_{it}} \left(\frac{\lambda_i}{\mu_{it}+\lambda_i}\right)^{\lambda_i} \quad \text{... (2)}$$

Where the mean is allowed to vary with time, but the overdispersion parameter λ_i is assumed to be constant for each individual:

$$E(y_{it}) = \mu_{it}, \text{ and } \sigma(y_{it}) = \mu_{it}(1 + \mu_{it} / \lambda_i) \quad \text{... (3)}$$

To model dependence on covariates, we let:

$$\ln \mu_{it} = \delta_i + \beta \cdot x_{it} \quad \text{... (4)}$$

This panel-based approach captures both time series and cross-sectional dynamics between y_{it} and x_{it}, and yields consistent statistical inferences under the assumptions of the model.

Table 2 presents the baseline results based on the panel negative binomial regression with province and year fixed effects specified in equation (2) to (4) for count dependent variables (i) to (iv), and a standard linear panel fixed effects model for continuous dependent variable (v). For the interest of compactness, the statistics on control variables defined in Table 1 are not reported in this and following tables though they are included in all regressions. Besides those specified in equation (2) to (4), three notable features (or statistics) are specified differently in our negative binomial model from the linear models: (a) exponentiated coefficients (i.e., exp(b)) are presented, as they have the interpretation of incidence-rate ratios; (b) standard error are derived from asymptotic theory; (c) log likelihood ratios are reported in the last column instead of adjusted R-squared.

Table 2 shows that all our political pluralism variables are positively and significantly associated with innovation, and the magnitude of the association is also economically large. For regressions (i) to (iv), all the regression coefficients are shown in terms of incidence rate ratio coefficients for the negative binomial models. The

incidence rate ratio is a relative difference measure used to compare the incidence rates of events occurring at any given point in time, and it equals to the ratio of incidence rate 1 to incidence rate 2, where incidence rate 1 is the occurrence of patent applications over province-year, and incident rate 2 is occurrence of no patents (i.e., patent application does not occur) within the province-year in the context of our paper. Therefore, the coefficients in the regressions (i) to (iv) can be interpreted as the estimated changes in the incidence rate ratio of the dependent variable *y* associated with a one unit change in the *x* variable, given the other variables being held constant in the model. For example, for regression (i), the first regression slope coefficient for *congress diversity* regressor is 6.309, and it means that one standard deviation increase in provincial congress diversification is associated with 0.396 (=6.309∗0.063) increase in incidence rate ratio of patent applications filed domestically in China over the province-year. Moreover, the magnitude or significance of congress diversity stay relatively stable in the model with or without adding the other two pluralism variables. The regression coefficient on the second political pluralism variable, % Non-CP, is also statistically significant, though its magnitude is slightly smaller than that of the congress diversity. Among the three political variables, % intellectuals is the least significant regressor, which indicate a weaker association between innovation and the proportion of representatives of intellectuals in the congress, compared to the other two political measures. This result points to the possibility that the representation of intellectuals in the congress and the relative power of this group is not necessarily the main channel that congress affects innovation. Rather, the overall congress diversity and the non-CP

members play a much bigger role in affecting innovation, indicating a more political driven mechanisms rather than an intellectual driven channel.

3. Instrumental Variable Approach and Channels of Influence

To identify an unbiased estimate, the fixed effects models employed in Section 2 crucially rely on the assumption that the unobservable factors that simultaneously affect the regressors and dependent variables are time-invariant. When this assumption is violated, the fixed effects model yields biased estimates and alternative identification strategy is needed to obtain unbiased results. In this section, we first present empirical results based on an instrumental variable approach. We then show evidence on two possible channels through which political pluralism affects innovation.

3.1 Instrumental Variable Approach

Our instrument for the potentially endogenous political pluralism variables is the three political pluralism measures in the Provincial People's Congresses in the year of 1965 (i.e., one year before the outbreak of the Culture Revolution).

China's Cultural Revolution, formally the Great Proletarian Cultural Revolution, was one of the most chaotic periods in modern Chinese history. It took place in the China from 1966 until 1976. The Revolution was launched in May 1966, when the CPC leader Mao Zedong claimed that bourgeois "virus" had penetrated the government and society, and advocate violent class struggle to defend against capitalism. In response to Mao's appeal, China's youth formed Red Guard groups around the country (MacFarquhar and Schoenhals 2006). The movement veered out of control and spread

into the military, urban workers, and the CPC itself. Millions of people were persecuted in the violent struggles that ensued across the country, and suffered a wide range of abuses including public humiliation, arbitrary imprisonment, torture, sustained harassment, and seizure of property. In particular to the science community, Mao and the "Gang of Four" shut down universities, dismantled scientific institutes, and punished intellectuals for elitist, bourgeois inclinations. During the "Down to the Countryside" movement, millions of scientists and students were forcibly displaced to the countryside to spend wasted years being 're-educated' by peasants (Cao 2013).

We use the 1965 level of political pluralism in provincial congresses to instrument the provincial political pluralism in the post-1980s. The rationale behind this instrument is that compared with economic changes, the distribution of political power in a country or region is more "sticky", for the leadership, once elected, would entrench itself in power, undermining the democratic principle of a level playing field (Mechels 1911, on "the iron law of oligarchy"). Dal Bó, Dal Bó and Snyder (2009) test the presence of political dynasty and find political power in the U.S. is self-perpetuating. Therefore it is reasonable to expect the political composition in the 1965 and post 1980s congresses in the same province to be correlated in a nontrivial manner. On the other hand, the decade long Culture Revolution has completely paralyzed the country's economic institutions and education system. Economic activity was halted, schools and universities were closed, and urban intellectuals were forcefully displaced, with "revolution" being the primary objective of the country (Andreas 2009). This instrument therefore satisfies the exclusion restriction in that, given the local human capital and economic resources were largely reshuffled in a mass scale during the Culture

Revolution, it is unlikely the 1965 political pluralism level in the provincial congress has any impact on the post-1980 innovation activities of that province, except through the political channel itself.

We use three political pluralism measures in the year of 1965 (i.e., one year before the outbreak of the Culture Revolution), with each instrumenting the corresponding pluralism measured from 1980 to 2012. Table 3 presents the IV results on the pooled estimation with year fixed effects. Province fixed effects are not included because our IVs are purely cross-sectional. Consistent with the economic motivation behind the instrument construction, the coefficient estimates for the IVs in the 1965 level are positive and significant at the 1% level for the first stage regressions. In addition, the values of F-statistics for the test of joint significance of the instruments in the first regressions are statistically large (>20 in all cases; not reported in Table 3). We also conduct the Stock and Yogo (2005) weak instrument test and report in the last column of Table 3. The Wald F-statistics are much larger than their critical values for the Stock and Yogo (2005) weak instrument test based on 2SLS size. Therefore, we reject the null hypothesis that the instruments are weak.[12] Taken together, the results in Table 3 confirm the baseline results in Table 2 that political pluralism measures such as congress diversity and the proportion of non-CP members in the congress are significantly and positively associated with innovation, while the proportion of intellectuals in the congress are less significant, confirming a political driven channel rather than an intellectual driven channel.

[12] Because the model is just-identified, we cannot provide over-identification test.

3.2 Two Possible Channels

Prior work on innovation has shown the patenting activities are promoted by a country's human capital stock and intellectual property protection environment. For example, Moser, Voena and Waldinger (2014) find that the post-World War II Jewish emigrants from Nazi Germany to the U.S. substantially increased the U.S. inventions in their relevant fields. Saxenian (2002) surveyed foreign-born professionals in the Silicon Valley and shows 43% were from India and 30% from China. These immigrants have a wide range of professional ties to their native countries. Many return to their home countries regularly for business purposes and exchange technology and labor market information with colleagues and friends. Some also advise companies, invest in start-ups and venture funds, and meet with government officials in their native country. Giannetti, Liao and Yu (2014) find China's staggered provincial policy to attract overseas Chinese talents has caused an increase in the supply of higher skilled Chinese individual with foreign experience in corporate boards, leading to better corporate performance. Inspired by this 'brain gain' channel as an important source of innovation, we design a two-stage test. The first stage examines whether provincial political pluralism is associated with earlier adoption of policy to attract highly skilled emigrants (HSE policy) in that province. In the second stage, we test whether the adoption of HSE policy will positively affect that province's innovation. The timing of the provincial adoption of the HSE policy is taken from Giannetti, Liao and Yu (2014).[13]

[13] The authors extract the data on the timing of provincial adoption of HSE policy from Wang, Wanlong, Xiangang Zeng, and Weida Pu, 2011, Guidelines for Overseas Returnees to Set Up Ventures in China (in Chinese) (China Machine Press, Beijing, China), and verified through internet and news searches. It is also found that an earlier adoption of the policies is not necessarily related to higher economic development: While the highly developed Beijing and Guangdong were early adopters (in 2000 and 1999, respectively), so were the far less developed Inner Mongolia and Yunnan (in 2001). The highly developed Shanghai, on the other hand, implemented similar policies only in 2005.

On the other hand, Dass, Nanda and Xiao (2014) show enhanced intellectual property protection, such as TRIPS is followed by enhanced subsequent patenting. Follow China's accession to the WTO in 2001, the country level Patent Law was promulgated in the same year. Subsequently different provinces in China were promulgating their own Patent Protection and Promotion (PPP) rules at different time. These policies aimed at promoting the patenting activities through enhanced financial support on innovative activities, strengthened administrative and legal sanctions of patent infringement activities, and fiscal policies that reward corporate R&D investments. Similar to the HSE channel, we design a two stage test. The first stage examines whether provincial political pluralism is associated with earlier adoption of patent protection and promotion (PPP) rules in that province. In the second stage, we test whether the adoption of PPP rules will positively affect that province's innovation. Data come from the public disclosure of regulations promulgated by the Standing Committees of the provincial congresses.

We use the following model:

Equation 1: $adoption_{i,t} = f(political\ pluralism_{i,t}, controls_{i,t})$ … (5)

Equation 2: $innovation_{i,t} = f(instrumented\ adoption_{i,t}, controls_{i,t})$ ... (6)

where adoption is an indicator variable and it equals to 1 if the policy is adopted in year *t* by province *i*, and 0 otherwise. The pluralism, innovation, and control variables are the same used in the baseline models.

Table 4-A presents the results of the first-stage regressions of HSE and PPP policies, respectively. We use both the pre- or post-Revolution political pluralism measures as predictors of the adoption of these policies. It shows that the provincial

congress diversification and non-Communist Party member proportion are positively and strongly associated with the provincial adoption of the HSE and PPP Policy. In sum, it suggests that high political pluralism provinces are more likely to implement policies to attract the highly skilled emigrants from overseas earlier than their counterparts. The proportion of intellectuals is significant and positively associated with the adoption when post-Revolution pluralism measures were used, and not significant otherwise.

Table 4-B presents the second-stage regression results. It shows that provinces that adopt the HSE and PPP policy have positive effect on innovation. Taking these two tables together, our results are suggestive of two possible channels that political pluralism affects innovation: the 'brain gain' channel through policies attracting highly skilled emigrants, and the 'patent protection and promotion' channel through corresponding policies. These results are consistent with the argument that more inclusive political institution result in less extractive economic institutions. Indeed, for highly skilled emigrants, one of the important considerations on whether to set up businesses in their home country is whether they perceive the local government as a "helping or grabbing hand" (Shleifer and Vishny 1998). Due to the risky nature of innovation, these projects are particularly vulnerable to rent-seeking. Thus if a project succeeds, the returns are expropriated, whereas if it fails, the innovator bears the cost. Political pluralism mitigates this problem by vesting the power broadly, thus uproot economic institutions that allow great mass of people take advantage of economic opportunities. The reduced fear of expropriation will encourage corporations to invest more in R&D, and attract innovators as opposed to rent-seekers.

4. Identification through Natural Experiments

This section employs more careful identification strategy to establish causality from democracy to innovation, based on three separate natural experiment settings. First, we investigate whether and how the staggered adoption of 'secret ballot' voting method (changing from 'raising hands') at provincial congresses affects innovation. Second, we examine how a rare natural experiment of democracy reform that occurred within the Communist Party system, i.e., the county-level tenure system reform of party congress, affects innovation. Finally, we look into the incidence of corruption crackdowns and examine how it affects innovation.

4.1 Difference-in-difference approach based on a voting method reform: From 'raising hands' to 'secret ballot'

Voting system is essential component of democracy. The CPC rules on decision making stipulated that ''bills or proposals shall be passed by *ballot*, by a *show of hands*, or by *any other means* as may be decided by the Presidium".[14] However, until the 1990s almost all the decisions or nominations were passed by 'applauded in consensus' or 'raising hands'. These are not voting in the sense that voter's political privacy is not respected and the fear of retaliation would prevent opposition opinions. In contrast, secret ballot does not need voters to reveal their underlying preferences. It is particularly important for decisions on controversial issues such as government work reports, the appointment and removal of key personnel government officials, etc. Starting from the late 1990s, many local People's Congresses have started to abandon

[14] The 1989 Rules for the Procedures of the National Party's Congress Article 53.

the old ‘applause’ or ‘show of hands’ voting method and implemented ‘secret ballot’ voting method, which allow us to observe the number of vetoes and abstaining votes.

Our empirical model to examine the effects of voting method switching on innovation is based on the following:

$$Innovation_{i,t} = \alpha + \beta_1 * Post\ ballot\ voting_{i,t} + \beta_2 * Treatment_{i,t} + \beta_3 * Post\ ballot\ voting_{i,t} * Treatment_{i,t} + controls_{i,t} + year\ fixed\ effects_{i,t} + province\ fixed\ effects_{i,t} + error\ term_{i,t} \quad ... (7)$$

Where *i* indexes the provinces, and *t* indexes years. $Post\ ballot\ voting_{i,t}$ is a dummy variable which equals 1 if year *t* is after the ballot voting-adoption year for provincial *i*’s congress (we exclude the year immediately before or after the adoption year from the sample), and 0 otherwise. Treatment is a dummy variable and it equals to 1 if province *i* has adopted the ballot voting within [-3, 3] year window at year *t*. The information about the voting mechanisms of the provincial people’s congress is hand-collected by reading the statements associated with meetings of each individual provincial congresses and their standing committee in the official or local newspapers, and in the government documents. The key variable in the model is the interaction term, *post ballot voting*∗*treatment*. All the control variables defined in Table 1 are added in the model.

Table 5 presents the results. For all measures of innovation, the interaction term (post ballot∗treatment) is positively significant, indicating that a switching from ‘show of hands’ to ballot voting method is associated with more innovation. This evidence is consistent with our baseline results more democratic political environment is associated with more innovation.

4.2 Twin-city tests based on a county-level natural experiment of the Permanent System of Party Congress (PSPC)

We have shown that political pluralism in provincial congresses positively affects innovation outcomes. Despite this, there is no doubt that China's politics is still dominated by the CPC who make key personnel decisions, and the People's Congresses system at national and sub-national level tend to provide legitimacy of the CPC's decisions at corresponding levels. Thus to establish that democracy matters innovation, we need a *within-CPC* democracy experiment. This section exploits a county-level democracy experiment *within* the CPC: the *Permanent System of Party Congress* (PSPC), and our "twin-city" difference-in-differences empirical design.[15]

The CPC is the world's largest political party with over 80 million registered members by 2014.[16] The CPC's charter provides that the highest power of the party should vest in its party congresses at national and sub-national level. The party congresses were held once every five years to select party cadres and a standing committee. However, in the past, the party congress system was 'symbolic' at best. The Party Congress Members (*dangdaibiao*) is appointed rather than elected. It is an honorary title with no power derived from their representativeness. Every five years a group of honorary party congress members were called upon to provide rubber-stamp on the decisions made by party cadres, and their duty ends as long as the party congress ends. According to the report by the US Congressional Executive Commission

[15] For a description on the institutional background of the CPC's inner-party democracy and the PSPC experiment, see Joseph Fewsmith, 2010. Inner-party democracy: Development and Limitations, China Leadership Monitor 31 (Winter 2010), available at http://media.hoover.org/sites/default/files/documents/CLM31JF.pdf

[16] Bloomberg, "China's Communist Party Reports First New Member Drop in Decade". Bloomberg BusinessWeek. Bloomberg L.P. 30 June 2014. Retrieved 30 June 2013.

on China (2006), the concentration of CPC's powers in the hands of the a few cadres leads to corruption and other abuses of power. It caused tensions within the Party and grievance among ordinary Party members, which threatened the legitimacy of the Party.[17]

The CCP's 13th National Party's Congress in 1987 identified 'intra-party democracy' as the entry point for China's political reform. This became a top-down boost for regional experiments. The objective was to make the party congresses a 'permanent system' by elevating the power and accountability of Party Congress members. In other words, by setting up "parliament within the party", the PSPC would rely on party members to constrain the powers of Party cadres. This objective is achieved through letting Party Congress members face *competitive election* from their peers (He 2006), and request give each elected Party Congress member to serve the entire five-year terms, and meet on an annual basis. At annual meetings, Party congress members are given right to suggest agenda items, elect and assess party cadres; to ask the presidium of party congresses or relevant party organizations to explain hot issues of concern to party members; and to put forward proposals for dismissing the party officials who have violated Party disciplines and laws.[18]

[17] Note the CPC called "inner called the intra-party democracy the "lifeblood of the Party" in its 16th Party Congress in 2002.

[18] For example, the Jiaojiang district in Taizhou in southern Zhejiang province was one of the county level congresses selected for PSPC in 1988, and by far the most successful. In Jiaojiang, party congress members were elected by their peers and the number of electing units was increased so that candidates are better known to their 'constituents'. The total number of Party Congress members was cut by a third, from 300 to 200, creating a competitive environment. Once elected, they are divided into 'interest groups' based on locality or functional group. The function of the interest groups is to run the discussion, think about personnel selection, and to propose resolutions. Annual meetings of party congress members were conducted to listen to work reports by the local party cadres and discipline inspection committee. In Jiaojiang's case, before the experiment the leading cadres at a given level normally made up 70 to 80 percent of the delegates. This percentage significantly declined after the experiment.

Importantly, given the political sensitivity of this experiment the Party has been careful by implementing the PSPC at *prefecture and county level*.[19] Starting in 1988 the Central Organization Department of CPC chose 12 counties and prefectures in five provinces to conduct the first round of experiments.[20] Although the selection criteria for the initial 12 sites were nowhere disclosed in the archival documentations of the Party, Tao (2006) finds that the selection of counties and prefectures for PSPC is quasi-random. The initial 12 counties and prefectures selected to experiment the PSPC are located in both developed and coastal regions like Zhejiang, developing regions like Heilongjiang and Hebei, and less-developed in-land regions like Shaanxi. Importantly, since the PSPC serves to constrain the power of local cadres, local cadres have little incentive to propose the experimentation of PSPC in their jurisdiction. Our interview with a chief-editor of *Xinhua* (one of the Party Newspapers) also confirms that whether a county or prefecture shall pilot the PSPC is a top-down political mandate by the Central or Provincial Organization Department of the CPC, rather than a choice of that county or prefecture.

Over the years some counties suspended their experiment, but more counties and prefectures were added to pilot the PSPC. A large wave of experimentation occurred after 2002 following a decision at the 16th National Party's Congress 'to *enlarge the scale of the Permanent System of Party Congress in counties and prefectures, and actively pursue the means to exercise the rights of the Party members*'.

[19] The reason for the CCP to conduct PSPC at county / prefecture instead of provincial level party's congresses follows China's favored reform approach of "regional experimentation" (Xu 2011). The advantage of this approach is that it reduces the political risk of advancing a reform, especially sensitive ones such as intra-party democracy. Moreover, as the experiment is conducted at lower level, it weakens the political oppositions within the party that are foreseeable at higher level.

[20] These 12 counties, municipals and prefectures include Jiaojiang, Shaoxing, Yongjia, Rui'an of Zhejiang Province, Lindian, zhaodong of Heilongjiang Province, Datong, Hongdong, Yuci, Hesheng of Shaanxi Province, Xinji of Hebei Province, and Hengshan of Henan Province.

By the end of 2011, 132 counties and prefectures in China (among the over 3,000) are implementing this experiment.

To establish causality, we design a twin-city difference-in-differences approach by finding a "twin county or prefecture" in the same province that did not pilot the PSPC, but is a neighbor of the PSPC county or prefecture. We argue the "twin-city" provides an ideal control group to test the effect of PSPC, for neighboring counties or prefecture level cities within the same province share similarities in factor endowments and economic institutions.[21] Figure 1 illustrates the location of the treated county and each of its match in the map of China.

Take the prefecture and county level PSPC as a treatment, our approach measures the difference in the differences between the treatment and control group over time. More specifically, the effect of the PSPC natural experiment on innovation is tested by the following specification based on a difference-in-difference approach:

$$Innovation_{i,t} = \alpha + \beta_1 * Post1_{i,t} + \beta_2 * Treatment_{i,t} + \beta_3 * Post1_{i,t} * Treatment_{i,t} + Controls_{i,t} + error\ term_{i,t} \quad \ldots (8)$$

Where $Post1_{i,t}$ is a dummy variable that equals to 1 for county *i* if year *t* is the year after the experiment year, and 0 if it is the year before the experiment year. Besides, we also replace *Post1* by alternative specifications: $Post2_{i,t}$ is a dummy variable that equals to 1 for county *i* if year *t* is within the subsequent two years after the experiment year, and 0 if it is within the preceding two years before the experiment year; and $Post3_{i,t}$ is a dummy variable that equals to 1 for county *i* if year *t* is within the

[21] Note China's sub-national administrative hierarchy has four levels: provincial level, prefecture level, county level, and township level. Given the four municipalities directly under the central government (Beijing, Shanghai, Tianjin and Chongqing) have equivalent administrative level of a province, the districts under the jurisdiction of these municipalities are at prefecture-level.

subsequent three years after the experiment year, and 0 if it is within the preceding three years before the experiment year. *Treat* is a dummy variable and it equals to 1 if a county is treated, i.e., if it is a county that conducted the experimental reform, and 0 for the neighboring county that did not conduct the experiment. See Appendix A.2 for the definition of dependent variables and control variables in the model.

In the model, all the dependent variables and control variables are measured at the county-level or prefecture-level variables (depending on whether the experiment is at the county or prefecture level). More specifically, the county-level patent counts are constructed by aggregating all the patents applied (or granted) to China Patent Office by individuals, firms, and institutions located at the county, based on the entire patent database provided by China Patent Office.

The results of this test is shown in Table 6. Our main variable of interest is the interaction term, *Post∗Treatment*, and the coefficients on this interaction term represent the differences in the differences of pre- versus post-level of innovation between the treated county versus its matched control county. The positive and significant coefficients of this interaction term in the regressions indicate that the adoption of this PSPC experiment increases innovation, with other factors potentially affecting innovation being controlled. It shows that though the effects of the experiment on innovation is not significant in the first year that immediately follows the experiment year, the effect becomes much more significant after 2 or 3 years of the experiment. Given the pro-democracy nature of the PSPC experiment, we interpret Table 6 as a piece of strong evidence that more democracy in the political environment (even if it is an intra-

party political experiment) is innovation friendly, i.e., democracy promotes innovative activities.

4.3 Propensity score matching-based test on top-down crack-down on corruptive provincial high ranked officials

Our last test is based on a natural experiment on the local political environment by identifying the events when the central government cracks down the corruptive provincial highly ranked officials. While corruption itself can be highly endogenously of local economic development etc., the corruption crack-down by the central government is arguably more exogenously as the crack-downs are often more motivated by the within-party political power competition at the central government instead of driven by the local economic environment. Nevertheless, to accommodate the possibilities that the incidence of crack-downs could be partially driven by local (i.e., provincial-level) economic conditions, we use the 'Propensity Score Matching' (PSM) described in Hillion and Vermaelen (2004) to find the matched (i.e., untreated) province that does not experience the crack-downs within the same time frame. In economics and finance, the PSM is becoming increasingly popular in the construction of suitable control groups. We use a simple version of PSM known as the nearest-match method. For each treated province (i.e., the province that experienced the crack-down within a time window), we find its nearest matched province by looking for the nearest predicted propensity score estimated upon a vector of variables that helps to predict the tendency that the province will conduct the experiment, while those variables themselves are exogenous to the experiment choices.

After identifying the control provinces based on PSM, we estimate a model similar to Equation 8, where $Post1_{i,t}$ is a dummy variable that equals to 1 for province *i* if year *t* is the year after the experiment year, and 0 if it is the year before the experiment year. $Post2_{i,t}$ is a dummy variable that equals to 1 for province *i* if year *t* is the second year after the experiment year, and 0 if it is the year before the experiment year. $Post3_{i,t}$ is a dummy variable that equals to 1 for province *i* if year *t* is the third year after the experiment year, and 0 if it is the year before the experiment year. *Treat* is a dummy variable and it equals to 1 if a province is treated, i.e., if it is a province that experienced the crack-down, and 0 for the PSM-matched province that did not experience the crack-down.

We follow Tu (2011), who tracks China's corruption crackdowns at party cadres of deputy ministry and above level the over the period 2002-2011, supplemented with information from a Wikipedia entry dedicated to tracking corruption cases in China (http://tinyurl.com/kv2tjq7) to identify 92 cases of province level crackdowns on political officeholders over our sample period. These form a staggered set of exogenous shocks to the risk of being held accountable for self-serving behavior among politicians.

The results of this test are presented in Table 7. Based on the coefficients of the interaction terms (Post∗Treatment), it suggests that there are more innovative activities after 2 or 3 years after the corruption crack-downs, after removing the predicted changes in the level of innovation based on the observables. If one assumes that the political environment after corruption crack-down incidences are in general more pluralism prone (as the incidence is also coupled with appointment of new provincial leaders who have less local influence or monopolistic political power, power reshuffling

in the provincial party congress, and more public monitoring of the party officials after a crack-down), then the results in Table 7 can be interpreted as a piece of supporting evidence of more political pluralism promotes innovative activities.

5. Conclusion

Almost 40% of the world's population still lives under authoritarian political regimes, with a large share of these being from China (The Economist 2007). We study the effect of political pluralism on innovation in the Communist People's Republic of China by exploiting heterogeneities in the provincial-level political institutions and innovation from 1980 to 2012. We find more diversified interest groups, higher proportion of non-communist members as well as intellectuals in the provincial congresses positively affects the province's innovation performance. To establish causality we use the pre-culture revolution political pluralism as instrumental variable, and we examine the effect of staggered adoption of two significant democracy reforms: the change to secret ballot voting method at the provincial level people's congresses, as well as a county-level experiment to reform the CPC congress system. Our results are robust to these identification strategies. Finally, using propensity-score matching, we find anti-corruption crackdowns against holders of high political offices in a province positively affect subsequent innovations.

Our results are consistent with the proposition of Acemoglu and Robinson (2012) that a more pluralistic (thereby 'inclusive') political institution will vest the power of the state broadly in the society, as opposed to the hands of a narrow elite who will structure the economic institutions to extract resources from the rest of the society. A more pluralistic political institution also reduces corruption, encourages participation and

levels the playing field of incumbents and innovators. As we document, “higher political pluralism” provinces are also found to have higher of R&D expenditure, earlier policy to attract highly skilled emigrants, and earlier policy for patent promotion, contributing to their higher innovation outputs.

China’s economic growth in the past three decades without democracy is often taken as an outlier in the growth literature and attracts alternative explanations. As China is now the second largest economy in the world and in many aspects reached the technological frontier, the country’s future growth momentum will depend crucially on ‘innovation and creativity’ (World Bank 2013). Nevertheless, the present incumbents-dominated political institution and administratively directed resource allocation are widely seen as the ‘bottleneck’ for the country’s science and technology to push the frontier. We show empirically that higher political pluralism provinces have both higher quantity and quality of innovation represented by international standards.

To be sure, our results do not suggest that more political pluralism is always good for innovation. Instead, we suggest when a country starts from an extractive authoritarian political regime, a little bit more political pluralism will do more good than harm to innovation. This proposition has bearings on China, as well as other non-democracies such as Russia, Cuba, North Korea, Vietnam, Egypt, and many African countries.

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Appendix A. Variable Definitions

A.1 Variables at the provincial level (used in the all tables except Table 6)

A.1.1 Five measures of innovation

(a) *Patent domestic*: provincial-level aggregated counts (in thousands) of patent applications filed domestically in China, based on the China Statistical Yearbook.

(b) *Invention patent domestic*: provincial-level aggregated counts (in thousands) of invention patent applications filed domestically in China, based on the China Statistical Yearbook.

(c) *Patent US&EP*: provincial-level aggregated counts (in thousands) of Chinese patents filed in U.S. and European Patent Office (EPO), based on the EPO PATSTAT Database.

(d) *CW patent US&EP*: provincial-level aggregated, citation-weighted counts (in thousands) of patent applications built upon an estimation of citation age profile. Following Mehta et al. (2010), we calculate total predicted life-long citations per patent as the total observed citation since grant year of the cited patent divided by the predicted proportion of citations in the patent age profile estimated from the Poisson model. Data source: EPO PATSTAT Database.

(e) *R&D/GDP*: provincial-level R&D expenditure to GDP ratio. Our definition of total R&D expenditures are the amount of R&D investment made by all corporations and the research institutions, aggregated at the province-year level, based on the reports by China Science and Technology Statistical Bureau.

A.1.2 Three measures of political pluralism

(f) *Congress diversity*: diversification of provincial congress based on (1-HHI index) of five components of congress members: farmers and workers, military officers, cadres, intellectuals, and others;

(g) *% Non-CP*: Congress the proportion of non-Communist Party members in the provincial congress;

(h) *% Intellectuals*: proportion of intellectuals in the provincial congress.

These political pluralism measures are hand-collected from provincial yearbooks of People's Congress, provincial statistical yearbook, and provincial congresses' official website.

A.1.3 Control variables

(i) GDP per capita (at 1980 price level);

(j) logged population;

(k) proportion of college degree holders in the population;

(l) unemployment rate;

(m) wage differentials between state and non-state sector;

(n) long-term bank loans to GDP;

(o) IPO gross proceeds to GDP.

All measures of control variables are at the provincial-year level. Unless otherwise specified, the monetary terms are measured in units of RMB.
The data source for these control variables are China Statistical Yearbooks.

A.2 Variables at the county level (used in Table 6)

(p) Number of patent applications (invention type, in thousands) is the total counts (in thousands) of invention type patent applications by individuals, corporations, and other institutions at the China Patent Office, aggregated at the county-year level.

(q) Number of patent publications (invention type, in thousands) is the total counts (in thousands) of invention type patent applications by individuals, corporations, and other institutions at the China Patent Office, aggregated at the county-year level.

(r) Number of patent applications (utility model type, in thousands) is the total counts (in thousands) of invention type patent applications by individuals, corporations, and other institutions at the China Patent Office, aggregated at the county-year level.

(s) Number of patent publications (utility model type, in thousands) is the total counts (in thousands) of invention type patent applications by individuals, corporations, and other institutions at the China Patent Office, aggregated at the county-year level.

The data source of the above four measures of innovation at the county level is the China Patent Database provided by China Patent Office.

Besides, Table 6 includes the following county-level variables as controls: GDP per capita, logged population, Outstanding bank loans to GDP, registered urban unemployed population to total population, capital expenditure to GDP, proportion of college students in the population. All the control variables at the county level are obtained from the CEIC database.

Appendix B. Citation age Profile estimations

In the studies by Jaffe and Trajtenberg 2002, Hall *et al*. 2002, Caballero and Jaffe 2002), the citation age-profile is meant to reflect the process of an idea diffusing across the economy and then becoming obsolete as the technological frontier builds past it. In the EPO PATSTAT database, we take all patents where the country of the patent applicants is China and where the address information is not missing so that we can identify the provincial association for the patents. We also observe each patent's identification number, application year, grant year, and technology class. In the search of the set of all patents that cited a particular Chinese patent, we do not have any country limitations (so that the citations could be from any country), and we observe the dates of those citations by searching the database appropriately. We keep all citations made by patents granted in 1991 or later, and we drop any patents that apply before 1991, or patents whose application year is post 2010.[22] This original dataset has 1,431,415 patent-citation observations. Then we re-organize this original dataset into a "compressed" dataset, in which the counts of citations are aggregated by the cohorts of cited patents' application year, grant year, technology class, and the citing patents' application year. This "compressed" dataset includes 28,329 cohort observations. We further drop 3,563 observations from the "compressed" dataset where the application year of the citations is prior to the grant year of the cited patent, and we drop another 1,537 observations where the patent review process took longer than five years, as that

[22] We drop observations based on the application date instead of the grant date because if we drop patents that were granted before 1991, we would observe only a selection of patents that applied before 1991. We select 1991 as the starting year as we observe a much smaller number of Chinese patents that applied prior to 1991.

would be very unusual. The final "compressed" dataset for age profile estimations have 23,229 cohort observations, which corresponds to 1,047,883 patent-citation observations from 1991 to 2010.

Because Johnson and Popp (2003) and Mehta *et al*. (2010) provide strong evidence in favor of using the grant date (as opposed to the application date) as the start of the age process, we define "age" as the difference between the grant year of the cited patent and the application year of the citing patent. Then we estimate the citation age profile following the method used in Mehta *et al*. (2010). In the count data model, we take each patent-year as a separate observation and our dependent variable is the citation count. We categorize patents as in Hall *et al*. (2002) and Mehta *et al*. (2010) so that the six potential categories for a patent application are: Chemicals (excluding Drugs), Communications and Computers, Drugs and Medical, Electrical and Electronics, Optics and Nuclear, Mechanical, and Other. The base category are patents that fall into the 'Other' category. The Poisson regression results of the age profile of citations are presented in Table B-1.

Based on the estimation of patent age profile, we calculate the predicted life-time citation for each patent (assuming that the life-time is 19 years for all patents based on our sample year range), and then match the predicted citations back to the cited patent dataset dataset that has 46,285 observations at the cited patent-province level with 44,280 unique patents.[23] In this dataset, we find that 46,277 observations are identified as "Patent of Invention" (99.98% of the sample) and 8 observations as "Utility Model" for the IPR type based on the "Kind of Publication" code. Further, we find that the majority

[23] There are more patent-province observations than unique patent observations because in some cases, the same patent is associated with multiple provinces.

of the patents' authorities are either the United States (US, 75.47% of the sample) or European Patent Office (EP, 24.28% of the sample), as show in Table B-2. The extremely small number of observations of patents in the other authorities casts doubt on the completeness of the coverage by the EPO database in these countries, and therefore, we drop 102 observations of patents whose application authority is not US or EP, and leaving our sample to 46183 patent-province observations (44185 unique patents).

Table B-3 presents descriptive statistics of the total predicted life-long citations per patent, and the citation-weighted patent count by year, and Table B-4 presents the tabulation by the inventor province, based on our final sample of yearly Chinese patents filing for US and European protection during 1991-2010. In Table B-4, we observe that the number of patents filed for US and EP protection steadily increased over the period of 1991-2008, and then significantly dropped in 2009 and 2010, while similar pattern is also observed in the citation-weighted patent count.

We observe large variation of number of patents and citation-weighted patent count across provinces. In particular, three provinces (or municipalities) stand out from the sample as the "most innovative" regions in China, based on the number of patents that filed internationally in U.S. and Europe from 1991-2010: Guangdong (17,983 patents, or 38.94% of the sample), Beijing (9,973 patents, 21.60%), and Shanghai (8,782, 19.02%). Regarding the significant drop of patents in 2009 and 2010, it may due to the fact that typically the contents of the patent application in the EPO are published 18 months after the priority date, and our EPO PATSTAT database version is April 12, 2011. Therefore, in the following regression analysis based on the internationally filed

patents, we truncate the last application year of patent to year 2009 to avoid the bias introduced by the limited coverage in 2010.

Figure 1 Map of Twin-city (county) Test of PSPC Experiment

Table 1: Descriptive statistics

This table shows the descriptive statistics of the dependent variables (measures of innovation), political pluralism variables, and control variables used in the regression analysis. The statistics are based on our sample of provincial level panel data of 31 Chinese provinces (including 4 municipalities) from year 1980 to 2012. Our five measures of innovation are: (i) provincial-level aggregated counts (in thousands) of patent applications filed domestically in China (*patent domestic*); (ii) provincial-level aggregated counts (in thousands) of invention patent applications filed domestically in China (*invention patent domestic*); (iii) provincial-level aggregated counts (in thousands) of Chinese patents filed in U.S. and European Patent Office (*patent US&EP*); (iv) provincial-level aggregated, citation-weighted counts (in thousands) of patent applications built upon an estimation of citation age profile following Mehta *et al*. (2010) (*CW patent US&EP*); (v) provincial-level R&D expenditure to GDP ratio (*R&D/GDP*). Our three measures of political pluralism are: (a) diversification of provincial congress based on (1-HHI index) of five components of congress members: farmers and workers, military officers, cadres, intellectuals, and others; (b) the proportion of non-Communist Party members in the provincial congress; (c) proportion of intellectuals in the provincial congress. Our control variables include: GDP per capita (at 1980 price level), logged population, proportion of college degree holders in the population, unemployment rate, wage differentials between state and non-state sector, long-term bank loans to GDP, and IPO gross proceeds to GDP. All measures of control variables are at the provincial-year level. Unless otherwise specified, the monetary terms are measured in units of RMB. Finally, note that for the statistics for citation-weighted patents applications filed in US and EP are different from Table B-3 and B-4 due to three reasons: (i) the citation-weighted patent counts are aggregated at the provincial level here instead of at the individual patent level; (ii) it is scaled in thousands in this table; (iii) in all regressions where citation-weighted patent count is used as the dependent variable, we drop the observations in 2010 due to the lags of EPO patents reports.

	Variables	Obs	Mean	Median	Std.	Min	Max
Measures of innovation	Patent domestic	1017	9.0720	1.5100	29.2795	0.0000	472.6560
	Invention patent domestic	1011	2.2701	0.2850	7.3214	0.0000	110.0910
	Patent US&EP	837	0.0768	0.0040	0.3610	0.0000	3.7960
	CW Patent US&EP	837	0.0502	0.0017	0.2052	0.0000	2.2036
	R&D /GDP	867	0.0083	0.0053	0.0098	0.0006	0.0701
Measures of political pluralism	Provincial congress diversification	1015	0.8920	0.9025	0.0627	0.6615	0.9656
	Non-Communist Party % in provincial congress	1015	0.3195	0.3280	0.0641	0.1380	0.5100
	Intellectuals % in provincial congress	1015	0.1923	0.2000	0.0629	0.0720	0.3510
Control variables	GDP per capita, at 1980 price level	1011	0.2344	0.1309	0.2519	0.0270	1.6823
	ln(population)	1011	17.1631	17.3907	0.9168	14.4532	18.5543
	College degree holder % in population	1012	0.0425	0.0301	0.0462	0.0009	0.3735
	Unemployment rate	985	0.0313	0.0324	0.0126	0.0020	0.0770
	Wage differential between state and non-state sector	1008	0.0017	-0.0217	0.2386	-0.6094	1.1047
	Long-term bank loans/GDP	850	0.3423	0.2597	0.2721	0.0129	1.8550
	IPO proceeds/GDP	1022	0.0054	0.0004	0.0169	0.0000	0.2733

Table 2: Baseline results

This table presents the panel negative binomial regression with fixed effects specified in equation (2) to (4) for count dependent variables (i) to (iv), and a standard linear panel fixed effects model for continuous dependent variable (v). All the regressions include both the province and year fixed effects. Note three different treatment (or statistics) for the negative binomial model from the linear model: (a) exponentiated coefficients (i.e., exp(b)) are presented, as they have the interpretation of incidence-rate ratios; (b) standard error are derived from asymptotic theory; (c) log likelihood ratios are reported in the last column instead of adjusted R-squared. See Appendix A.1 for the definitions of variables used in the table. All the control variables defined in Appendix A.1 are added in the model. T-statistics are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Dependent Variable	Congress Diversity		% Non-CP		% Intellectuals		N	ll
Panel Data Fixed Effects Negative Binomial Model Estimations								
(i) Dep.Var.: Patent domestic	6.309***	[7.68]					829	-1401.50
			1.700**	[1.99]			829	-1426.96
					6.014***	[4.69]	829	-1417.19
	6.169***	[7.37]	0.669	[1.47]			829	-1401.20
			1.173**	[2.34]	5.801	[1.50]	829	-1416.28
	5.923***	[5.64]	0.652*	[1.75]	0.602	[0.39]	829	-1401.12
(ii) Dep.Var.: Invention patent domestic	5.673***	[3.92]					829	-701.17
			0.847**	[2.51]			829	-709.12
					5.449**	[2.31]	829	-706.52
	5.681***	[3.90]	0.073**	[2.04]			829	-701.17
			0.458	[0.28]	5.384	[1.27]	829	-706.27
	6.139***	[3.21]	0.063**	[2.04]	1.164	[0.37]	829	-701.10
(iii) Dep.Var.: Patent US&EP	9.245***	[5.67]					787	-620.27
			1.477***	[5.13]			787	-612.29
					2.374**	[2.15]	787	-602.23
	9.456**	[4.76]	1.563**	[2.34]			787	-630.74
			1.489**	[2.20]	2.055	[0.46]	787	-635.58
	10.386**	[2.23]	0.987*	[1.87]	2.071	[0.11]	787	-639.07
(iv) Dep.Var.: CW Patent US&EP	2.669**	[2.14]					760	-466.76
			2.240***	[5.74]			760	-487.55
					10.252	[0.31]	760	-57.41
	3.275**	[2.17]	2.646**	[2.18]			760	-557.58
			2.772*	[1.78]	10.460	[0.49]	760	-457.47
	2.347**	[2.38]	3.915**	[2.25]	13.669	[0.58]	760	-557.36
Panel Data Fixed Effects Linear Model Estimations							N	Adj. R2
(v) Dep.Var.: R&D/GDP	0.007**	[2.06]					796	0.957
			0.009**	[2.01]			796	0.957
					0.006*	[1.86]	796	0.957
	0.006**	[2.05]	0.008**	[2.51]			796	0.957
			0.008**	[2.35]	0.006	[0.53]	796	0.957
	0.008**	[2.02]	0.008**	[2.37]	0.008	[0.68]	796	0.957

Table 3: Instrumental variable estimation based on the pre-Revolution pluralism

This table presents the 2nd stage IV results based on the pooled sample linear regression with year fixed effects. See Appendix A.1 for the definitions of variables used in the table. All the control variables defined in Appendix A.1 are added in the model. Weak identification is tested by the Cragg-Donald Wald F-statistic, and this statistic needs to be compared to Stock-Yogo weak ID test critical values. Based on the Stock-Yogo Stock-Yogo (2005), the weak ID test critical values are 16.38 at 10% maximal IV size, 8.96 at 15% maximal IV size, 6.66 at 20% maximal IV size, 5.53 at 25% maximal IV size. The R-squared for the first stage regressions ranges between 0.18 to 0.45, and the first-stage F-statistics ranges from 16.89 to 22.39. t-statistics are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Dependent Variabl	Congress Diversity		% Non-CP		% Intellectuals		N	R2	Wald F
(i) Dep.Var.: Patent domestic	4.066**	[2.03]					942	0.137	735.504
			2.744*	[1.82]			942	0.134	216.296
					3.018	[1.46]	942	0.036	821.377
	3.669*	[1.92]	3.43	[0.92]	5.536*	[1.65]	942	0.126	55.201
(ii) Dep.Var.: Invention patent domestic	2.363**	[2.16]					932	0.133	722.896
			2.550*	[1.79]			932	0.130	215.287
					2.806	[1.38]	932	0.033	803.173
	4.158	[1.07]	3.021*	[1.84]	5.584*	[1.70]	932	0.121	55.718
(iii) Dep.Var.: Patent US&EP	1.460**	[1.99]					595	0.154	271.866
			1.151**	[2.09]			595	0.152	125.522
					0.591	[0.52]	595	0.054	372.920
	1.609	[0.77]	1.659*	[1.74]	0.352	[0.23]	595	0.152	22.534
(iv) Dep.Var.: CW patent US&EP	5.136	[0.56]					493	0.082	112.617
			10.259*	[1.94]			493	0.114	196.970
					1.068	[0.19]	493	0.085	255.806
	5.873	[0.56]	16.453*	[1.66]	3.768	[0.56]	493	0.132	160.280
(v) R&D/GDP	0.013*	[1.90]					806	0.253	681.086
			0.006	[0.79]			806	0.237	158.922
					0.043***	[6.47]	806	0.249	641.686
	0.031***	[2.83]	0.006	[0.69]	0.062***	[6.24]	806	0.246	370.540

Table 4-A: Fist-stage regressions of the test of two channels

This table presents the first-stage regressions for the test of two channels through which political pluralism affects innovation: the HSE policy channel, and the PPP policy channel. See equation 5 and 6 for the model specifications. HSE policy and PPP policy refer to, respectively, the Highly Skilled Emigrants policy and the Patent Protection and Promotion policy adopted by each province at different time points. We use two sets of measures of political pluralism in the model, namely, the pre-Revolution political pluralism (left two columns), and the post-Revolution political pluralism (right two columns). See Appendix A.1 for the definitions of variables used in the table. All the control variables defined in Appendix A.1 are added in the model. T-statistics are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

	Regressions using pre-Revolution political pluralism		Regressions using post-Revolution political pluralism	
	HSE Policy	PPP Policy	HSE Policy	PPP Policy
Congress diversification	0.444**	0.414**	0.550***	0.566***
	[2.54]	[2.38]	[2.91]	[2.61]
% Non-CP	0.033	0.447***	0.198	0.581***
	[1.26]	[3.35]	[1.23]	[3.36]
% Intellectuals	0.185	0.027	0.435**	0.502***
	[1.52]	[0.22]	[2.37]	[2.63]
N	813	788	844	794
Adj R2	0.731	0.647	0.740	0.651
F	65.74	43.442	71.48	44.526

Table 4-B: Second-stage regressions of the test of mechanism

This table presents the second-stage regressions for the test of two channels through which political pluralism affects innovation: the HSE policy channel, and the PPP policy channel. See equation 5 and 6 for the model specifications. HSE policy and PPP policy refer to, respectively, the Highly Skilled Emigrants policy and the Patent Protection and Promotion policy adopted by each province at different time points. We use two sets of measures of political pluralism in the model, namely, the pre-Revolution political pluralism (left panel), and the post-Revolution political pluralism (right panel). See Appendix A.1 for the definitions of variables used in the table. All the control variables defined in Appendix A.1 are added in the model. T-statistics are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Dependent Variable	Regressions using pre-Revolution political pluralism				N	ll	Wald F	Regressions using post-Revolution political pluralism				N	ll	Wald F
	HSE Policy		PPP Policy					HSE Policy		PPP Policy				
(i) Dep.Var.: Patent domestic	3.696*	[1.81]			916	-2246.72	22.17	0.545**	[2.20]			946	-2228.09	24.95
			2.709*	[1.89]	884	-2128.72	24.49			0.496**	[2.18]	890	-2115.68	25.45
(ii) Dep.Var.: Invention patent Domestic	4.308	[0.95]			910	-2224.47	21.16	0.31	[1.12]			940	-2176.39	14.95
			1.955*	[1.67]	878	-2072.10	24.49			0.803**	[2.31]	884	-2070.64	25.48
(iii) Dep.Var.: Patents US&EP	1.007**	[2.20]			595	-827.20	22.48	0.581*	[1.67]			613	-841.27	25.21
			0.134	[0.14]	575	-741.14	23.28			0.518	[0.65]	578	-752.96	15.02
(iv) Dep.Var.: CW patents US&EP	3.001*	[1.69]			493	-1340.73	22.66	1.086**	[2.34]			500	-1349.25	24.86
			5.804	[1.13]	477	-1330.19	20.53			0.054	[0.02]	480	-1290.97	16.40
(v) Dep.Var.: R&D/GDP	0.097**	[2.41]			813	-1791.94	22.24	0.051***	[3.02]			844	-2290.36	24.82
			0.048***	[2.89]	788	-2136.41	24.74			0.065***	[3.60]	794	-1997.22	26.10

Table 5: Difference−in−difference estimations of Ballot Voting

This table presents the difference-in-difference estimations of the effects of switching to ballot voting from hand showing on innovation. See equation 7 for the model specification. In addition, negative binomial models are used for dependent variable (i) to (iv), and linear model is used for dependent variable (v). *Post ballot voting*$_{i,t}$ is a dummy variable which equals 1 if year *t* is after the ballot voting-adoption year for provincial *i*'s congress (we exclude the year immediately before or after the adoption year from the sample), and 0 otherwise. Treatment is a dummy variable and it equals to 1 if province *i* has adopted the ballot voting within [-3, 3] year window at year *t*. See Appendix A.1 for the definitions of variables used in the table. All the control variables defined in Appendix A.1 are added in the model. The year and province fixed effects are also added to the model. T-statistics are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Dependent Variable	Post Ballot Voting		Treatment		Post Ballot∗Treatment		N	ll
Difference-in-Difference Estimations based on Panel Data FE Negative Binomial Model								
(i) Dep.Var.: Patent domestic	0.019**	[2.14]					801	-1365.73
			0.006**	[2.10]			832	-1428.94
	0.008**	[2.21]	0.004	[0.12]	0.026***	[3.16]	801	-1365.71
(ii) Dep.Var.: Invention patent domestic	0.135**	[2.48]					801	-675.22
			-0.102	[-0.98]			832	-708.82
	0.057	[1.35]	-0.073	[0.62]	0.158***	[4.14]	801	-673.91
(iii) Dep.Var.: Patent US&EP	0.175*	[1.91]					759	-380.79
			-0.060	[-0.09]			789	-62.29
	-0.264	[0.27]	0.026	[0.67]	0.366***	[3.67]	759	-457.16
(iv) Dep.Var.: CW Patent US&EP	0.055	[0.02]					733	-52.89
			0.042	[0.06]			762	-57.60
	0.028	[0.25]	0.014	[0.28]	0.067**	[5.32]	733	-520.48
Difference-in-Difference Estimations based on Panel Data FE Linear Model Estimations							N	Adj R2
(v) Dep.Var.: R&D/GDP	-0.001	[0.23]					765	0.957
			-0.003	[-0.27]			796	0.957
	-0.001	[0.88]	-0.001	[0.76]	0.002**	[2.34]	765	0.957

Table 6: Difference-in-difference Test of County Level Party Congress System Experimental Reform

This table presents the difference-in-difference test of the effects of county level party congress system experimental reform on innovation. See equation 8 for the model specifications. $Post1_{i,t}$ is a dummy variable that equals to 1 for county *i* if year *t* is the year after the experiment year, and 0 if it is the year before the experiment year. $Post2_{i,t}$ is a dummy variable that equals to 1 for county *i* if year *t* within the subsequent two years after the experiment year, and 0 if it is within the preceding two years before the experiment year. $Post3_{i,t}$ is a dummy variable that equals to 1 for county *i* if year *t* within the subsequent three years after the experiment year, and 0 if it is within the preceding three years before the experiment year. *Treat* is a dummy variable and it equals to 1 if a county is treated, i.e., if it is a county that conducted the experimental reform, and 0 for the neighboring county that did not conduct the experiment. See Appendix A.2 for the variable definitions. All the regressions include GDP per capita, logged population, outstanding bank loans to GDP, registered urban unemployed population to total population, capital expenditure to GDP, proportion of college students in the population.as control variables. t-statistics are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Dependent Variable	Treat	Post1	Treat∗Post1	Post2	Treat∗Post2	Post3	Treat∗Post3	N	pseudo R2	ll
Number of Application (Invention, in thousands)	0.572	-0.021	0.109					213	0.336	-27.71
	[0.48]	[-0.02]	[0.08]							
	0.690			0.230	0.006**			414	0.348	-56.17
	[0.77]			[0.26]	[2.01]					
	0.713					0.426	0.095***	601	0.371	-91.74
	[0.90]					[0.56]	[3.11]			
Number of Publications (Invention, in thousands)	0.706	-0.209	0.050					213	0.333	-25.01
	[0.58]	[-0.16]	[0.03]							
	0.876			0.052	0.102			414	0.349	-52.03
	[0.95]			[0.05]	[0.09]					
	0.862					0.290	0.082*	601	0.368	-81.85
	[1.04]					[0.35]	[1.89]			
Number of Applications (Utility Model, in thousands)	0.608	0.158	0.080*					240	0.289	-81.14
	[1.09]	[0.29]	[1.72]							
	0.632			0.267	0.043**			467	0.301	-163.95
	[1.50]			[0.65]	[2.09]					
	0.616*					0.448	0.046*	683	0.326	-248.62
	[1.65]					[1.27]	[1.91]			
Number of Publications (Utility Model, in thousands)	0.748	0.119	0.194					240	0.275	-71.36
	[1.24]	[0.19]	[0.26]							
	0.735			0.251	0.145**			467	0.284	-148.45
	[1.64]			[0.56]	[2.27]					
	0.681*					0.399	0.122**	683	0.308	-223.86
	[1.73]					[1.05]	[2.18]			

Table 7: Propensity Score Matching-based Pairwise Difference-in-Difference Approach for Corruption Crack-down Tests

See Appendix A for the variable definitions. All the regressions include the control variables defined in Appendix A. t-statistics are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Dependent Variable	Treat	Post1	Treat∗Post1	Post2	Treat∗post2	Post3	Treat∗post3	N	pseudo R2	ll
PSM-Pairwise Difference-in-Difference Estimations based on Negative Binomial Model										
Dep.Var.: Patent domestic	0.112	0.011	0.087					62	0.381	-129.429
	[0.62]	[0.05]	[0.40]							
	0.329			-0.077	0.043**			63	0.334	-149.162
	[1.49]			[-0.32]	[2.16]					
	0.342					-0.002	0.187*	63	0.337	-155.114
	[1.50]					[-0.01]	[1.68]			
Dep.Var.: Invention patent domestic	-0.020	0.091	0.073					62	0.437	-70.915
	[-0.05]	[0.21]	[0.16]							
	0.274			-0.030	0.003			63	0.415	-81.582
	[0.75]			[-0.08]	[0.01]					
	0.340					0.162	0.271*	63	0.412	-88.200
	[0.95]					[0.43]	[1.67]			
Dep.Var.: Patent US&EP	0.327	0.154	0.005					62	0.502	-7.220
	[0.10]	[0.04]	[0.00]							
	0.715			-0.634	0.131**			63	0.489	-7.624
	[0.23]			[-0.18]	[2.03]					
	0.709					-0.640	0.081	63	0.422	-7.837
	[0.23]					[-0.18]	[0.02]			
Dep.Var.: CW Patent US&EP	1.921	1.079	0.849					62	0.572	-4.931
	[0.31]	[0.15]	[0.11]							
	2.068			-0.189	0.901**			63	0.537	-4.820
	[0.34]			[-0.03]	[2.12]					
	1.817					-0.173	0.288**	63	0.534	-4.361
	[0.30]					[-0.02]	[2.04]			
PSM-Pairwise Difference-in-Difference Estimations based on Linear Model Estimations								N	Adj R2	ll
Dep.Var.: R&D/GDP	-0.003	-0.003	0.003					62	0.422	252.327
	[-1.03]	[-1.19]	[1.02]							
	-0.003			-0.004	0.004*			63	0.411	254.778
	[-0.96]			[-1.60]	[1.73]					
	-0.002					-0.004	0.004*	63	0.432	254.759
	[-0.84]					[-1.41]	[1.80]			

Tables for Appendix B

Table B-1: Patent Age Profile Estimation Main Results

This table presents the patent age profile estimations with the specification of Poisson regression following Mehta *et al*. (2010), based on Chinese patents filed international protection during 1991 to 2010. Total observation: 1,047,883, Log pseudo likelihood = -709,559.64, Pseudo R-squared = 0.154. Standard errors are in parentheses.

	Application Year		**Citing Year**		**Age Since Grant**		
	Coeff.	**S.E.**	**Coeff.**	**S.E.**	**Age**	**Coeff.**	**S.E.**
1992	-0.637	(0.042)	13.095	(2.282)	1	1.989	(0.020)
1993	-0.377	(0.045)	13.294	(6.318)	2	2.924	(0.021)
1994	-0.331	(0.049)	13.774	(5.156)	3	3.215	(0.023)
1995	-0.293	(0.052)	14.012	(8.055)	4	3.386	(0.025)
1996	-0.137	(0.056)	13.984	(4.495)	5	3.504	(0.028)
1997	-0.246	(0.057)	14.053	(8.841)	6	3.541	(0.032)
1998	-0.222	(0.060)	14.231	(7.337)	7	3.521	(0.037)
1999	-0.147	(0.061)	14.242	(7.945)	8	3.440	(0.041)
2000	-0.143	(0.065)	14.303	(8.674)	9	3.357	(0.050)
2001	-0.026	(0.067)	14.390	(10.419)	10	3.219	(0.055)
2002	-0.028	(0.070)	14.371	(9.349)	11	3.343	(0.064)
2003	-0.174	(0.074)	14.248	(8.073)	12	3.315	(0.069)
2004	-0.207	(0.077)	14.161	(10.349)	13	3.312	(0.082)
2005	-0.341	(0.079)	13.980	(9.133)	14	3.377	(0.090)
2006	-0.543	(0.082)	14.071	(11.804)	15	3.243	(0.104)
2007	-0.532	(0.085)	14.046	(6.897)	16	3.259	(0.130)
2008	-0.713	(0.088)	14.034	(12.553)	17	3.076	(0.159)
2009	-0.968	(0.096)	14.091	(9.944)	18	2.264	(0.199)
2010	-3.122	(0.303)	14.256	(8.546)	19	3.659	(0.371)
	Technological Field						
Category	**Coeff.**	**S.E.**					
Chemicals excl. drugs	0.040	(0.011)					
Communications and Computers	0.050	(0.011)					
Drugs and Medical	0.026	(0.012)					
Electrical and Electronics	0.048	(0.011)					
Mechanical	0.043	(0.011)					
Constant	-17.909	(8.255)					

Table B-2: Chinese patents that filed international protection during 1991-2010, tabulated by patent authority country

This table presents the patent authority-based tabulation of our sample of Chinese patents that filed international protection during 1991-2010. This table is constructed before we drop other authorities than the European Patent Office (EP) and United States (US) from the sample.

Patent Authority	Counts	Percent
Canada (CA)	18	0.04%
China (CN)	1	0.00%
Estonia (EE)	4	0.01%
European Patent Office (EP)	11,236	24.28%
Finland (FI)	59	0.13%
United Kingdom (GB)	10	0.02%
Ireland (IE)	2	0.00%
United States (US)	34,931	75.47%
World Intellectual Property Organization (WO)	24	0.05%
Total observations	46,285	100.00%

Table B-3: Chinese patents that filed for US and EP protection during 1991-2010, tabulated by patent application year

This table presents the number of patents, descriptive statistics of total predicted life-long citations per patent, and the citation-weighted patent count, based on our final sample of Chinese patents filing for international protection during 1991-2010 by year. The predicted life-long citations are calculated based on the patent age profile estimated from the full model of Poisson regression in Mehta *et al*. (2010), and the citation-weighted patent counts are calculated as the sum of total predicted life-long citations per province-year unit of the observations.

Application	Number of	Total Predicted Life-long Citations per patent			Citation-weighted Patent Count		
Year	Patents	Mean	Median	S.D.	Mean	Median	S.D.
1991	102	3.513	1.151	12.157	37.778	24.000	33.808
1992	91	1.884	1.021	2.528	28.697	25.364	23.590
1993	136	2.397	1.606	3.241	49.017	29.652	41.506
1994	116	2.533	1.326	3.997	84.790	42.431	78.120
1995	135	2.478	1.705	2.807	60.155	58.546	42.455
1996	162	2.711	1.378	4.183	96.068	65.961	76.367
1997	199	3.144	0.994	5.763	104.998	147.052	83.152
1998	238	3.005	1.085	7.521	190.443	99.837	177.177
1999	357	3.710	1.515	7.574	207.331	255.910	157.166
2000	552	3.576	1.296	6.881	432.067	327.404	373.834
2001	839	2.767	1.034	5.052	481.364	578.732	353.487
2002	1127	2.583	0.835	4.563	602.439	752.900	319.907
2003	1737	1.744	0.576	3.131	625.492	731.659	330.381
2004	3160	1.478	0.000	2.981	1003.185	1331.696	544.643
2005	4785	1.238	0.000	4.357	1378.935	1645.530	660.514
2006	7067	0.751	0.000	2.976	1381.080	1115.022	787.251
2007	8090	0.558	0.000	2.510	1258.842	960.995	844.480
2008	8953	0.244	0.000	1.856	692.493	482.486	533.749
2009	6482	0.109	0.000	0.970	249.403	408.140	170.328
2010	1855	0.001	0.000	0.023	0.168	0.000	0.374
Total	46183	0.826	0.000	3.124	868.803	750.624	753.888

Table B-4: Chinese patents that filed for US and EP protection during 1991-2010, tabulated by patent inventor province

This table presents the number of patents, descriptive statistics of total predicted life-long citations per patent, and the citation-weighted patent counts by the inventor province, based on our final sample of Chinese patents filing for US and EP protection during 1991-2010 by year. The predicted life-long citations are calculated based on the patent age profile estimated from the full model of Poisson regression in Mehta *et al*. (2010), and the citation-weighted patent counts are calculated as the sum of total predicted life-long citations per province-year unit of the observations.

Inventor Province	Number of Patents	Total Predicted Life-long Citations per patent			Citation-weighted Patent Count		
		Mean	Median	S.D.	Mean	Median	S.D.
Anhui	250	1.706	0.000	10.645	38.946	15.705	61.115
Beijing	9973	1.077	0.000	3.729	751.825	956.885	521.904
Chongqing	187	0.513	0.000	2.502	5.947	5.228	6.589
Fujian	722	0.755	0.000	2.942	36.731	44.925	25.351
Gansu	42	1.120	0.000	2.509	5.606	1.602	8.381
Guangdong	17983	0.652	0.000	2.268	1411.710	1293.912	758.014
Guangxi	69	1.008	0.000	1.846	4.415	4.563	4.028
Guizhou	20	0.364	0.000	0.950	1.030	0.000	1.339
Hainan	22	0.214	0.000	0.564	0.214	0.000	0.564
Hebei	95	0.602	0.000	1.421	4.245	6.270	3.130
Heilongjiang	78	1.408	0.000	5.698	9.348	7.033	14.657
Henan	94	0.903	0.000	2.265	4.808	3.784	4.458
Hubei	428	1.363	0.000	4.698	31.500	16.555	39.701
Hunan	248	0.529	0.000	1.431	6.456	5.105	5.892
Inner Mongolia	2434	0.672	0.000	2.947	152.627	208.096	93.516
Jiangsu	100	0.475	0.000	1.509	4.090	1.659	4.961
Jiangxi	229	0.928	0.000	2.222	16.442	19.868	11.680
Jilin	439	0.986	0.000	2.760	22.813	15.303	19.523
Liaoning	32	0.952	0.000	3.083	8.578	0.946	10.923
Ningxia	23	0.635	0.000	1.701	1.751	0.586	3.365
Qinghai	1	0.000	0.000	.	0.000	0.000	.
Shaanxi	398	0.656	0.000	2.246	15.530	14.428	13.660
Shandong	520	0.738	0.000	4.551	39.196	29.537	42.718
Shanghai	8782	0.933	0.000	3.317	749.986	750.624	418.583
Shanxi	109	1.024	0.000	2.361	8.311	8.906	5.624
Sichuan	473	0.798	0.000	5.541	17.630	8.933	15.512
Tianjin	663	1.016	0.000	3.505	37.056	47.597	30.799
Xinjiang	28	0.670	0.000	1.197	2.486	0.481	3.641
Tibet	0	0.000	0.000		0.000	0.000	.
Yunnan	37	0.518	0.000	1.690	3.617	0.000	6.085
Zhejiang	1704	0.641	0.000	2.349	88.979	119.067	54.374
Total	46183	0.826	0.000	3.124	868.803	750.624	753.888