



Social credit and patent quality: Evidence from China

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ABSTRACT

We combine the discredited people database disclosed by the China People's Supreme Court and the China industry business performance database from 2003 to 2014 and examine the effect of regional social credit on the quality of patents, measured by knowledge breadth. We find that a loss of social credit can result in a significant decline in patent quality. The result remains robust to a series of sensitivity checks, including using the alternative measures of key variables and exploiting the number of missionary universities established since the Opium War as an instrument for social credit. The possible mechanisms for the effect of social credit on patent quality are further verified, including attenuating external financing constraints and enhancing the innovation incentive.

1. Introduction

A consensus now more or less exists that innovation plays a fundamental role in driving long-term economic growth. Innovation determines a firm's viability, competitive advantage, market value, and productivity. A sizable amount of theoretical and empirical literature has confirmed that R&D investment is affected by a variety of forces, including but not limited to industrial policy, market factors, a firm's attributes, as well as formal and informal institutions, e.g., intellectual property protection, financial development, financing constraints, managerial traits, and democratic institutions.² The influence of social credit on firm innovation has also been widely studied in existing literature, but without an established body of clear, causal evidence of social credit's effects.

Based on the matched data covering the discredited people database from the Supreme Court, the patent database of the State Intellectual Property Office, and the China Industry Business Performance database, this study looks into the question of how regional social credit affects the quality of patent output. We find that the loss of social credit can result in a significant decline in corporate patent quality, as proxied by knowledge breadth. This is especially the case for non-state-owned, domestic, small-size firms, firms in inland areas, labor-intensive sectors, and during periods of economic upheaval. The result remains robust after a series of sensitivity checks, including using alternative measures of patent quality and social credit, as well as exploiting the number of missionary universities established since the Opium War as an instrument for social credit to address concerns regarding measurement error and

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² See Moser and Voena (2012); Szczygielski et al. (2017); Kim et al. (2012); Paunov (2012); Acemoglu (2010); Hashmi et al. (2013); Cornaggia et al. (2015); Coad et al. (2016); Aghion et al. (2013); Kim and Weisbach (2008); Talke et al. (2010); Malmendier et al. (2011).

reverse causality for identification.

Our study contributes to the relevant literature that examines the impact of social credit on patent quality in the following aspects³: firstly, existing literature measures credit based on questionnaires, such as the world value survey (WVS). The potential inconsistency may bring about measurement bias between interviewees' answers and actual behaviors. Beugelsdijk et al. (2004) cautioned that the selection error caused by a relatively small sample is much more serious than missing values. Secondly, most existing literature measures social credit from aspects of social capital or trust⁴. To address the above issues, we directly proxy for social credit by using the number of discredited people disclosed by the Supreme Court of China. These data come from a large sample and can reduce the adverse effects of measurement error bias, thus improving the credibility of the research.

More broadly, this study also adds to the literature that investigates the influence of culture and informal institutions on corporate innovation behaviors. For example, the emphasis on learning consciousness, the concept of cooperation, a culture of organizational trust, individualism, tolerance of failure, and cultural diversity can all significantly improve innovation (Stacey, 1995; Mcallister, 1995; Chua et al., 2008; Wang et al., 2011; Hofstede, 2001; Qian, 2013).

The remainder of this paper is structured as follows: Section 2 introduces the background of China's social credit and the quality of patent output. Section 3 presents the theoretical hypotheses with regard to social credit and corporate innovation. Section 4 then introduces the data, econometric model, variables and methodology. Section 5 describes the baseline empirical results and examines their robustness. Section 6 reports the channel testing results of social credit culture's impacts on firm-level patent quality. Section 7 concludes the paper and presents some potential research policy implications on top of our findings.

2. Research background

With the development of China's economy, social credit issues such as the "wage arrears of migrant workers" and "triangle debt" have become more and more prominent over the last few decades. By 15 April 2019, the number of discredited people had risen to 13.6227 million, accounting for 9.76% of the total population. According to a report from the Chinese Corporate Credit Survey, the economic loss caused by lacking social credit now exceeds more than 600 billion yuan a year. Fig. 1 depicts the dynamics in the number of discredited natural people in the years from 2004 to 2018. The number of discredited people grew steadily before 2010, increased more rapidly from 2011 to 2016, and started to decline in the last two years (2017–2018). To reduce the negative impact of social credit deficiency on economic growth and effectively improve the credit environment, financial sectors most sensitive to credit loss firstly began a constructive and beneficial exploration to build a credit supervision and punishment system.

In 2006, the People's Bank of China established a national basic database of credit information; the database included more than 16 million legal and 650 million naturalized people. On July 1, 2013, the Judicial Committee of the Supreme People's Court of China considered and passed the document "Several Provisions Concerning the Disclosure of Information on the Blacklist of Discredited People" and decided to add those who were deemed to have the ability to perform but who had failed in the execution of the statutory obligations stipulated in legal documents into China's national blacklist of discredited people. On October 8, the "Information Publication and Inquiry on the Blacklist of Discredited People" platform was opened to the public. On the platform, everyone from all walks of life can obtain information published by all courts (excluding military courts) related to discredited people. Meanwhile, to promote the construction of the social credit system and to prompt people to fulfill obligations within the timeframe stipulated in the legal documents, the executive court confirmed that consumption restriction measures would be taken against the discredited people. In essence, high-consumption and non-essential consumption activities will be strictly supervised and prohibited by law.⁵

In addition, as China's economic aggregate expanded rapidly, the input and output of corporate innovation have also substantially increased over the past few decades. Fig. 2 reflects the dynamic increases in the number of patent applications in both China and the U.S. over the period from 2003 to 2018. The number of patent outputs in China grew faster than in the U.S., and China surpassed the U.S. in 2011. In 2018, the number of patent outputs in China rose to 1.542 million, becoming nearly three times the number of U.S. patent outputs. According to a report from the World Intellectual Property Organization (WIPO), China produced almost half of the world's patent applications in 2018, equivalent to the combined sum of the countries ranking second to eleventh. What's confusing, though, is that China has long lagged behind the U.S. in technology innovation in many fields. Fig. 3 indicates that a big gap still exists in the global innovation index between the U.S. and China, further reinforcing this anomaly. As a matter of fact, during the R&D process of China's companies, for a long time, more attention has been paid to "quantity" rather than "quality" of patent output. The result of this

³ See e.g., Guiso et al. (2015); Knack and Keefer (1997); Zak and Knack (2001); Beugelsdijk et al. (2004); Akcomak & Weel (2006); Dincer and Uslaner (2010).

⁴ For example, Akcomak & Weel (2006) focused on 102 European regions, from 1990 to 2002, and found that social capital can indirectly drive economic growth by strengthening corporate innovation ability. Xie et al. (2017) employed the industrial databases of 42 nations, from 1991 to 2008, and verified that social trust could improve innovation performance and productivity.

⁵ When the discredited person is naturalized, according to the consumption restriction orders, the following high consumption and consumption activities not necessary for life and work shall not be allowed: (1) To take an airplane, take the soft berth of a train, or take the second-class or above berth of a steamship; (2) to have high consumption activities at one star and above hotels, nightclubs and golf courses; (3) to purchase real estate, or build or expand high-end houses; (4) to lease high-end office buildings, hotels, apartments and other places; (5) to purchase non-operational vehicles; (6) to take a trip or vacation; (7) to let children attend high-fee private schools; (8) to pay high premiums to purchase insurance and wealth-management products; (9) to take G-head MU trains and first-class or above seats of other MU trains. When the discredited is a legal entity, then the legal representative, the principal responsible person, the responsible persons directly influencing debt repayment, and the actual controller shall not carry out the above-mentioned acts.

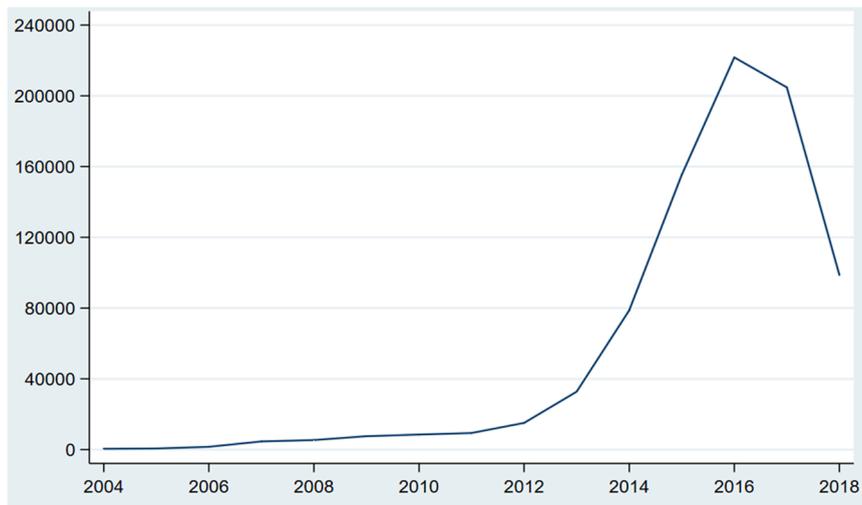


Fig. 1. The dynamic changes in the number of discredited naturalized people.

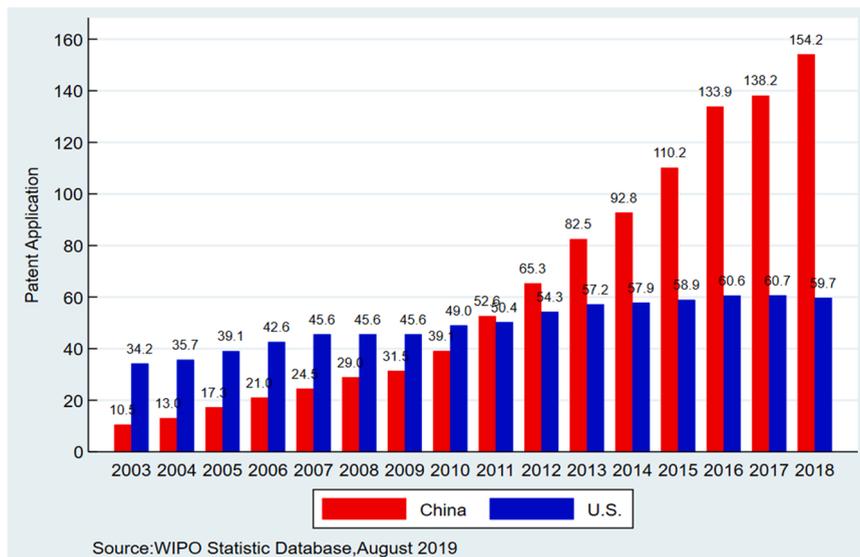


Fig. 2. The dynamic changes in patent applications between China and the U.S.

approach has been many ineffective (and few knowledge-intensive) patents. The low quality of patents may be a persuasive explanation for the abnormal phenomenon described above.

Based on the analysis above, we are aware that social credit deficiency and low patent quality have coexisted for several decades in China. This article attempts to link the two economic phenomena and identify the causal relationship between social credit and the quality of patent output. We find that social credit can make a valuable contribution towards elevating corporate innovation ability. Firms located in favorable credit circumstances tend to produce more high-quality patents.

3. Hypothesis discussion

The standard economic rationale for the low quality of patent output is the result of two types of market failure: 1) externality or the imperfect appropriability conditions of innovation, and 2) the underinvestment in R&D activity induced by information asymmetry (David et al., 2000; Hall, 2002).

As argued in the pioneering studies of Nelson (1959) and Arrow (1962), the nature of public good and the imperfect appropriability of innovative activity means that private returns will be lower than social returns. Consequently, R&D investment is likely to be below the socially optimal level, which in turn causes the low quality of patent output. A property right protection system is the fundamental formal institution used to support the modern economy. Kanwar and Evenson (2003) provided unambiguous evidence indicating the

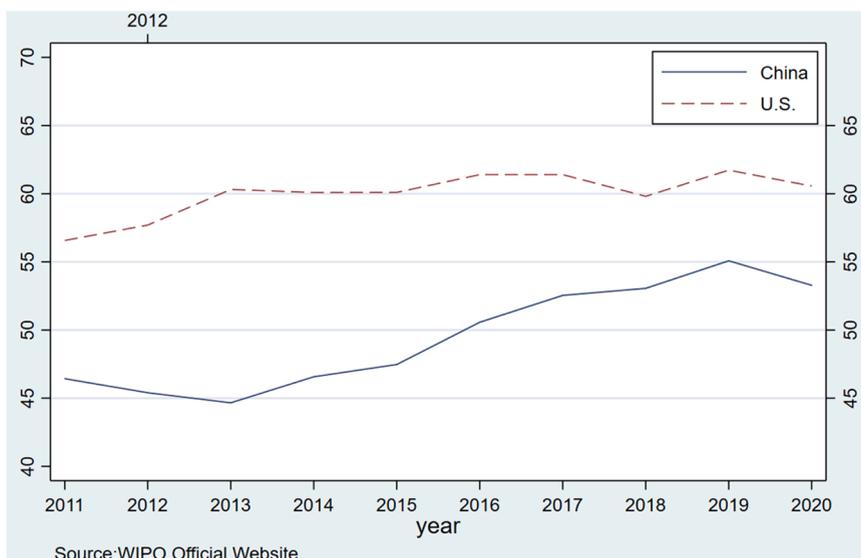


Fig. 3. The dynamic changes in the global innovation index of the US and China.

significance of intellectual property rights as incentives for spurring innovation. However, the incomplete intellectual property protection system used in China today undoubtedly triggers illegal technology plagiarism, thereby amplifying the spillover effects and obliging firms to cut down the number of original innovation projects.

Beyond the law, social credit, as an informal institution containing business morality, will force companies to strengthen their own self-discipline and will also curb opportunistic behaviors (Dikolli et al., 2012). This “soft” binding force of the credit environment reduces the adverse influence of the absence of a formal system on the private returns of patent outputs. When social credit starts to deteriorate, the corporate psychological costs of copying and stealing patents will gradually decrease (Pruckner & Sausgruber, 2013). The “free-rider” phenomenon will become increasingly common, thus eroding innovators’ incentives and eventually reducing the quality of patent outputs.

Further, R&D investments have been frequently shown to be financially constrained, due to information asymmetries. Social credit can significantly improve informational asymmetry (Grieser et al., 2017) and reduce the potential for opportunistic behaviors, such as deceit and tax evasion (Mazar & Ariely, 2006; Dikolli et al., 2012). A paper by Gosling and Huang (2009) pointed out that the increase of information asymmetry caused by credit loss would elevate transaction costs and lower trading efficiency.

To figure out how social credit affects transaction costs, according to the transaction cost theory proposed by Williamson (1987), this study considers anticipation and afterward costs. Due to the vigilance required to prevent possible deceptions and defaults, both parties have to spend more on information collection and negotiation costs, and may even have to arrange contractual and structural defenses to protect their interests. This can signal that local firms are rich in the contract spirit and credibility needed to create a good credit environment. Severe credit deficiencies may incur “collective punishment” against all local companies from external investors and consumers, eventually leading to an increase in marketing activities and advertising expenses. Hence, social credit loss can amplify ex-ante transaction costs.

In the matter of ex-post costs, the moral restriction of social credit can lift the executive efficiency of contracts and decrease monitoring costs. In regions with good credit culture, in order to sell products as quickly as possible, trading partners often allow delayed payment, rather than insisting on payment immediately after obtaining goods. That is, they provide commercial credit for each other (Fabri & Menichini, 2010; Giannetti & Simonov, 2004). Such practices will not only contribute to improving the efficiency of exchanges, but will also reduce the demand for corporate preventive cash. For R&D, the innovator commonly has more and better information about the nature and economic potential of the project than do the prospective financiers. The increasing likelihood of corporate misconduct caused by credit loss will further augment this informational asymmetry. As a result, the lemon’s premium for R&D will be especially high (Akerlof, 1970). In summary, social credit deficiency may increase transaction costs and enlarge corporate R&D funding gaps.

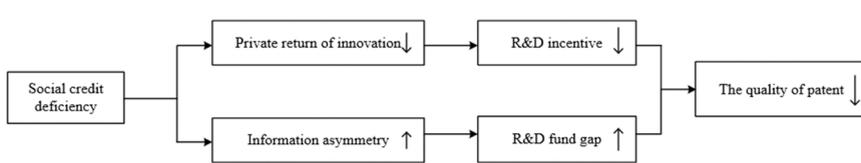


Fig. 4. Theoretical mechanism showing how social credit affects patent quality.

The arguments presented above lead to the following hypothesis: Social credit, as a kind of morality capital, can advance the quality of patent outputs by relaxing financial constraints and strengthening the innovation incentive (Fig. 4).

4. Empirical framework

4.1. Data

We combine data from several sources to look into the causal link between social credit and patent quality. The first is the China Industry Business Performance database for the period spanning 2003–2014. The database includes all state-owned and above-size private industrial enterprises and contains primarily firm basic information, financial conditions, and employee information, which is the most comprehensive and systematical data source available at present reflecting the situation of corporate operation. Following the approach of Cai and Liu (2009) and Brandt et al. (2012), we clean the sample and delete outliers.

The second is the patent database from the State Intellectual Property Office (SIPO). The SIPO contains more than 14.56 million patents, which have been awarded since the implementation of the patent system in September 1985. The public can enquire about an application number, application date, public number, patent name, abstract, classification number, applicant, inventor, address, patent agency, etc., and the patent instruction can be downloaded manually.

The third is the discredited people blacklist from the “Information Publication and Inquiry on the Blacklist of Discredited People” platform on China’s Supreme Court website, which was first launched on March 30, 2009. Those who fail to comply with legal obligations or who breach the rules of the property report will be inserted into China’s national blacklist of discredited people. The information about offenders since 1988 is available to the public, including his or her name, the ID number or the institution code, and the executive court. By June 30, 2018, the courts in China had issued a cumulative list of more than 11.23 million discredited people. All other city-level data come from the China City Statistical Yearbook.

4.2. Econometric model

The main purpose of this paper is to accurately identify the causal link between social credit and the corporate quality of patent output. To test the above hypothesis, the basic econometric model is set as follows:

$$Patent_{ict} = \alpha + \beta Credit_{ct} + X' \theta + \mu_t + \gamma_h + \sigma_c + \delta_{ht} + \rho_r + \varepsilon_{it} \quad (1)$$

The subscripts i , c , t , h , and r index firm i , city c , year t , industry h and region r , respectively. The dependent variable, $Patent_{ict}$, stands for the quality of the patent output. The independent variable, $Credit_{ct}$, represents regional social credit loss. X denotes a series of city- and firm-level covariates that may affect the patent quality. μ_t , γ_h , σ_c , δ_{ht} and ρ_r signify year fixed effects, industry fixed effects, city fixed effects, the industry-year fixed effects, and region-year fixed effects, respectively. ε_{it} is the random error term. All standard errors are clustered at the two-digit industry level. The parameter β is the coefficient of interest to be estimated. If β is statistically significant and negative, that indicates, social credit loss has an inhibiting effect on the patent quality.

4.3. Variables

Dependent variable: Our main challenge is to construct a valid measure to proxy for the patent quality. In prior studies, patent citations and originality were often used (Gao et al., 2017; Hsu et al., 2014). Given that China’s patent database fails to provide accurate information on the number of patents cited, we learn from the patent breadth method used by Aghion et al. (2015) and Akgicig et al. (2016) and adopt the knowledge breadth approach to measure patent quality. Knowledge breadth primarily refers to the complexity and universality of knowledge embedded in a patent and overcomes the flaw of measuring firm innovation only based on the dimension of patent quantity.

To measure the quality of patents, this study employs the quantitative information of international patent classification (IPC) in the corporate patent documents of the SIPO in China. Different types of patents correspond to different classification formats. The IPC of invention and utility model patents generally adopts the form of “department - general category - subcategory - large group - subgroup” (e.g. A01B01/00). Specifically, the first letter represents the department. The second and third digits represent the general category. The next letter represents the subcategory, and the large group and subgroup are separated by “/”. The patent classification of design patents is in the format of “general category – subcategory” (e.g., 01–00). In order to better reflect the quality of patent, we make full use of the patent classification information and define the knowledge breadth. For instance, a patent has three classification numbers: “A01B02/00”, “A01B02/10” and “A01B02/20”. Another patent also has three classification numbers: “A01B02/00”, “A02B13/00” and “B35D13/20”. Despite the identical amount of patent classification, the first patent only contains the information of one large group, “A01B02”, while the second involves three separate large groups. Obviously, the knowledge breadth of the second patent is greater than that of the former, so the second patent’s quality is correspondingly higher.

We firstly define the breadth of firm patent knowledge at the large group level and correspond to 1 minus the Herfindahl concentration index (Aghion et al., 2015), that is:

$$Patent_{ii} = 1 - \sum \left(\frac{Z_{mi}}{Z_{ii}} \right)^2 \quad (2)$$

In the above formula, Z_{mti} is the cumulative amount of patent applications of firm i involving large group m by year t ; Z_{ti} is the cumulative number of large groups of firm i 's patent application by year t . The greater the value of $Patent_{it}$ is, the higher is the firm-level patent quality. Given that the classification format of design patents differs from the other two types of patents, the knowledge complexity embedded in design patents is relatively low. Therefore, this study excludes the design patents and only selects invention and utility model patents while calculating this indicator.

Independent variable: The percentage of discredited naturalized people to the total population (Credit1) measures the regional social credit in our baseline regression. In the robustness tests, we employ the ratio of the discredited naturalized people to regional GDP (Credit2) and the ratio of the discredited legal people to regional GDP (Credit3) as alternative variables.

Control variables: We incorporate a set of control variables. As a proxy for regional economic progress, we use the log of GDP per capita (ED). The regional industrial structure is proxied by the ratio of the added value of the second industry in GDP (Second). We also control for governmental scientific and technological investment by including the logarithm of scientific and educational expenditure (Fiscal). Furthermore, at the micro-level, the natural logarithm of total assets (Size) is incorporated to measure firm size. To capture the impact of corporate ownership on R&D investment, we control for the SOE dummy. Firm age is measured by subtracting the year of establishment from the current year and then taking the logarithm (Age). Some other financial indicators are also taken into consideration, such as the firm's capital intensity, measured by the ratio of fixed assets to total assets (Tang), and the firm's financial leverage, measured by the liability as a share of total assets (Leverage). As is well-known, a wide gap exists in economic conditions and economic development strategies across various regions in China. Following the National Bureau of Statistics, we classify the provinces into four parts: East, Central, West, and Northeast. We incorporate region-year fixed effects to capture any time-varying regional shocks that may affect the regional social credit culture and corporate innovative activities. Furthermore, given that those industry policies implemented over the sample period may also have impacted R&D investment, we control for the interaction terms of the year with industry dummies. Year, city, and industry fixed effects are added to the baseline regression as well. To minimize the disturbance of extreme values, we winsorize all continuous variables at the 1st and 99th percentiles. Table 1 displays the descriptive statistics of the main variables.

5. Empirical results

5.1. Baseline results

Table 2 presents the estimation results of Eq. (1). In column (1), in addition to the variable of social credit and three types of time-invariant unobservable factors, we only take the GDP per capita (ED) into consideration. The estimated coefficient on social credit is -0.16 and is statistically significant at the 1% level for a firm's patent quality. City-level characteristics are further introduced in column (2), including the regional industrial structure and fiscal investments in science and education. The point estimate turns out to be -0.22 for corporate quality of patent output and remains significant at the 1% level. In column (3), multiple micro-level controls have been added. The point estimate of the coefficient on the proportion of the discredited naturalized people becomes -0.13 for firms' patent quality and remains statistically significant at the 1% level. In column (4), we control for two combination fixed effects mentioned in Section 4.3 and find that the estimated coefficient on social credit loss is -0.18 and negative significantly at the 1% level. Generally, from column (1) to column (4), the point estimate of the coefficient on the proportion of regional discredited naturalized people barely changes, indicating that social credit loss is negatively related to a firm's patent quality. Column (4) is regarded as this study's preferred baseline results.

In summary, this study finds that social credit loss in a city is negatively associated with firm patent quality. The baseline results are robust after controlling for several firm-level variables and city-level variables, as well as including region-year and industry-year fixed effects. However, endogeneity trouble may also undermine the causal link between regional credit and firm innovation. In the remainder of this section, several different empirical exercises are employed to address the potential endogeneity issue and confirm the robustness check.

Table 1
Variables and Descriptive statistics.

Types of variables	Variables	Observations	Mean	Std. Dev	Min	Max
Dependent variable	Patent	171,480	0.574	0.369	0.000	0.996
Independent variable	Credit1	171,480	0.021	0.034	0.000	0.191
City level controls	ED	171,480	11.120	0.599	8.142	13.056
	Fiscal	171,480	0.192	0.546	9.516	12.480
Firm level controls	Second	171,480	0.500	0.096	0.171	0.910
	Size	171,480	11.615	1.689	0.693	20.672
	Tang	171,480	0.285	0.201	0.004	0.901
	Leverage	171,480	0.537	0.239	0.032	1.195
	Age	171,480	2.252	0.701	0.693	4.060
	SOE	171,480	0.121	0.326	0.000	1.000

Table 2
Social credit and corporate quality of patent output.

Variables	(1)	(2)	(3)	(4)
Credit1	-0.164 *** (0.055)	-0.224 *** (0.056)	-0.133 *** (0.042)	-0.180 *** (0.043)
ED	0.040 *** (0.005)	0.040 *** (0.005)	0.017 *** (0.004)	0.013 *** (0.003)
Second		-0.162 *** (0.016)	-0.046 *** (0.011)	-0.045 *** (0.011)
Fiscal		0.023 (0.039)	0.029 (0.024)	-0.050 (0.030)
Size			0.072 *** (0.001)	0.072 *** (0.001)
Age			0.063 *** (0.002)	0.062 *** (0.002)
Leverage			-0.016 (0.010)	-0.016 (0.010)
Tang			-0.055 *** (0.009)	-0.054 *** (0.009)
SOE			0.016 *** (0.004)	0.018 *** (0.005)
Constant	0.133 ** (0.052)	0.211 *** (0.059)	-0.548 *** (0.048)	-0.494 *** (0.046)
Year fixed effect	Yes	Yes	Yes	Yes
City fixed effect	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes
Year-industry fixed effect	No	No	No	Yes
Year-region fixed effect	No	No	No	Yes
Observations	171,478	171,478	171,478	171,478
R-squared	0.134	0.135	0.267	0.273

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level.

5.2. Endogeneity issues

Endogeneity can lead to bias and inconsistency of estimations. The endogeneity of social credit mainly originates from two aspects. One is the risk of reverse causality (social credit favors innovation, but innovation can also improve social credit by facilitating regional economic development). The other is the potential omitted variable bias, which may result in endogeneity. In this section, we pursue two strategies to assess whether the links documented to this point are causal. Firstly, we use selection on observable variables to evaluate the likelihood that our estimates are being driven by unobserved factors. Secondly, we gauge the number of missionary universities since the first opium war as an instrument for credit loss.

The strategy that we employ exploits the insight from [Altonji et al. \(2005\)](#) that selection on observables can be used to assess the latent bias from unobservable variables. To figure out how this measure is calculated, consider two regressions: one with a restricted set of covariates, and one with a full set of controls. Denote the coefficient for the variable of interest from the first regression β^R , and the estimated coefficient from the second regression β^F . Then, the ratio can be calculated as: $|\beta^F / (\beta^R - \beta^F)|$. The bigger the ratio, the less likelihood that our estimates are driven by unobserved factors.

In the baseline regression of [Table 2](#), we consider three sets of restricted covariates: the first one with industry-, year- and city-level time-invariant unobservable factors and GDP per capita as presented in column (1), the second including further city-level characteristics shown in column (2) and the third adding micro-level corporate traits shown in column (3). The full set of controls incorporates all city- and firm-level covariates in column (4). The ratios are shown in [Table 3](#). The ratios range from 3.75 to 11.25, with a mean value of 6.36, which indicate that selections on unobservable variables would have to be at least 3.75 times greater than selection on observables and, on average, over 6.36 times greater. These results make it less likely that the estimated effect of social credit loss is driven by unobservable factors.

Our second strategy is the use of an instrumental variable. To deal with endogeneity issues, scholars often seek instrumental variables that are based on religious traits ([La Porta et al., 1997](#); [Zak & Knack, 2001](#)), ethnic dispersion ([Knack & Keefer, 1997](#)), and regional history ([Tabellini, 2010](#)). In addition, western influence is often treated as a possible source of exogenous variation in the

Table 3
Assessing the bias from unobservable factors.

Control variables	Coefficients in restricted sets	Coefficients in unrestricted sets	Ratios
GDP per capita	-0.164	-0.180	11.250
All city-level covariates	-0.224	-0.180	4.091
All city-level covariates, firm age, firm size	-0.132	-0.180	3.750

social atmosphere or institutions (Acemoglu et al., 2001). The validity of this instrument relies on the premise that the more exposure there is to Western culture, the stronger the contract spirit and credit concept become.

We proxy for western influence by using the number of missionary universities founded by Christian and Catholic churches since the first opium war. This choice is premised on the reasoning that church universities play a significant role in preaching western values, leading local people to pay more attention to the spirit of the contract and credit concepts. Accordingly, we hold that the number of regional missionary universities is strongly associated with social credit. Meanwhile, after the nationwide readjustment of colleges and universities in 1952, all church universities were canceled, renamed, or merged with others, suggesting they have no direct link to current corporate behaviors. Based on such an analysis, this study follows Nunn and Qian (2014) and interacts the year dummy with the number of church universities as the instrument for social credit.

Before turning to the instrumental variable estimation, a reduced-form estimation is employed. This is achieved by directly examining the effect of missionary universities on the quality of patent output in column (1) of Table 4. After controlling for relevant variables and fixed effects, the result shows that missionary universities can significantly elevate corporate patent quality. The instrumented results are reported in columns (2) and (3) of Table 4. The first-stage regression results show that the number of church universities is negatively and statistically significantly associated with credit loss. Meanwhile, the Kleibergen-Paap F-statistic is greater than Staiger and Stock (1997) rule-of-thumb value of 10, indicating that a church university is by no means a weak instrument of social credit. The estimated coefficient on credit deficiency is -0.87 and statistically significant at the 1% level for the patent quality. All the regressions reinforce the validity of this study's OLS findings.

There remain some reasons why the exclusion restriction may not be satisfied. Firstly, the number of historical church universities may be associated with human capital accumulation, which would play a supportive role in technological progress. Secondly, church universities may have a persisting effect on the regional institutional environment and exert influence on transaction costs. To block the plausible channels, we follow Nunn and Wantchekon (2011) and control for two additional proxy variables of human capital and institutional atmosphere. Table 5 reports IV estimates with additional controls. The regional human capital stock (HC) is measured by the logarithm of the average years of schooling. We proxy for the institutional environment (IE) using the provincial closing rate of economic cases used by Yu and Pan (2008). The estimates are similar to Table 4 when controlling for these additional factors: they remain negative and significant at the 1% level.

5.3. Robustness checks

To verify further the robustness of the baseline results, alternative measures of the dependent variable are needed to re-examine the effect of social credit loss on patent quality. Zhang and Zheng (2018) measured the knowledge breadth for each patent at a large group level. The calculating formula is as follows: $1 - \sum \alpha^2$, where α represents the proportion of each large group in patent classification. Firm-level knowledge breadth can be obtained by calculating the mean value of this indicator. Column (1) of Table 5 illustrates the results when the mean value of patent-level knowledge breadth is employed. In column (2), the dependent variable is the number of invention patents granted, expressed in terms of a natural logarithm. The results again confirm that the inhibition effect of social credit loss on patent quality is convincing.

Columns (3) and (4) of Table 5 show the results when we employ the ratio of the discredited naturalized people to regional GDP (Credit2) and the ratio of the discredited legal people to regional GDP (Credit3) as alternative credit loss measures. One can see that the estimated impacts of credit loss remain almost the same, that is, negative and statistically significant. The result shows that credit deficiency will significantly reduce the quality of patent output, following the baseline results.

To address serial correlation and heteroscedasticity, we cluster the standard error at the two-digit industry level in Table 2. Column (1) to (3) in Table 6 displays the results with heteroscedasticity robust standard error and standard error clustered at the firm and the city level, respectively. The magnitude of the coefficient hardly changes and keeps significantly negative, which is consistent with the baseline result.

Table 4
Social credit and patent quality by IV method.

Variables	(1) Reduced-form	(2) First-stage regression	(3) 2SLS
Credit1			-0.871 *** (0.245)
Church	0.000519 *** (0.000140)	-0.000596 *** (0.000047)	
Constant	-0.488 *** (0.043)		
Observations	171,480	171,480	171,480
Kleibergen-Paap F-statistic		163.28	

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level. All specifications include the city-level and firm-level controlling variables and fixed effects in column (4) of Table 2.

Table 5
Social credit and patent quality by IV method, with additional controls.

Variables	(1) Reduced-form	(2) First-stage regression	(3) 2SLS
Credit1			-1.486 ** (0.677)
Church	0.000343 ** (0.000142)	-0.000199 *** (0.000055)	
HC	0.042 ** (0.020)	-0.076 *** (0.004)	-0.070 (0.058)
IE	-0.027 (0.018)	-0.078 *** (0.009)	-0.133 ** (0.049)
Constant	-0.535 *** (0.069)		
Observations	171,480	171,480	171,480
Kleibergen-Paap F-statistic		13.309	

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level. All specifications include the city- and firm-level controlling variables and fixed effects in column (4) of Table 2.

Table 6
Results with alternative measures of patent quality and social credit.

Variables	(1)	(2)	(3)	(4)
Credit1	-0.060 ** (0.022)	-0.359 ** (0.145)		
Credit2			-0.412 ** (0.079)	
Credit3				-2.336 ** (1.002)
Constant	0.172 *** (0.025)	-0.865 ** (0.323)	-0.441 *** (0.049)	-0.440 *** (0.052)
Observations	171,480	171,480	171,480	159,441
R-squared	0.117	0.165	0.273	0.268

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level. All specifications include the city-level and firm-level controlling variables and fixed effects in column (4) of Table 2.

5.4. Heterogeneous effects

It has proved that a lack of social credit can significantly restrain the corporate quality of patent output. Considering that the influence of social credit deficiency may differ due to some firm, regional and industrial characteristics on corporate innovation activities, we develop a heterogeneity analysis of the relationship between social credit and patent quality.

(1) SOEs versus private enterprises. From the aspect of firm ownership, SOEs have more access to bank credit resources and less market competition pressure (Guariglia et al., 2011), due to political connections between state-owned companies and local governments. Social credit deficiency can increase information asymmetry, deepen commercial banks' suspicion of non-state companies' solvency and then worsen corporate financing predicaments. Hence, we expect that a lack of social credit has a more negative effect on non-state firms' quality of patent output than that of SOEs. The results estimating the differential impact on the two groups are reported in columns (1) and (2) of Table 7. The coefficient on credit deficiency is negative and statistically significant at the 1% level for the patent quality of private enterprises. Meanwhile, the coefficient for SOEs is not significantly different from 0. As expected, the result implies that fund shortages caused by a social discredited environment will compel private firms to abandon superior innovative programs and eventually lower the quality of their patent output. The lack of credit has almost no influence on SOEs' R&D behaviors.

(2) Foreign versus domestic enterprises. Social credit may also have diverse impacts on R&D investment between foreign and

Table 7
Results with alternative standard error rectification.

Variables	(1)	(2)	(3)
Credit1	-0.180 *** (0.028)	-0.180 *** (0.032)	-0.180 *** (0.039)
Constant	-0.494 *** (0.023)	-0.494 *** (0.028)	-0.494 *** (0.037)
Observations	171,480	171,480	171,480
R-squared	0.273	0.273	0.273

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. All specifications include the city-level and firm-level controlling variables and fixed effects in column (4) of Table 2.

domestic enterprises. Compared with domestic-funded companies, foreign firms have more access to overseas product sales markets, which may in turn advance the commercialization process of new technology. A social credit deficiency has a smaller inhibitory effect on the product sales of foreign-funded companies. Besides, [Aghion et al. \(2015\)](#) pointed out that local governments in China were inclined to provide more low interest loans to attract more foreign direct investments and induced significant variations in the interest rates being charged. Domestic enterprises were facing an effective interest rate that was almost double that borne by foreign firms between 1998 and 2007. Accordingly, we expect that a lack of social credit will have a greater hindrance function on the patent quality of domestic firms than on foreign ones. In columns (3) and (4) of [Table 7](#), the coefficient on regional credit loss is -0.22 and significant at the 1% level for domestic firms' patent quality. This result indicates that a social credit deficiency has a more negative effect on the patent quality of domestic firms than on foreign companies, a finding which is consistent with the above analysis.

(3) Large firms versus small firms. The signal role of firm size represents solvency and profitability to a certain degree, conducive to overcoming asymmetric information exacerbated by social credit deficiency ([Wu, 2017](#)). This long-standing size discrimination in capital markets implies SMEs (small and medium-sized enterprises) face more difficulty with financing, as well as higher loan costs than large-size enterprises do. As a result, we expect that the influence of credit loss on patent quality may vary due to firm size. To investigate whether firm size determines the effect of social credit or not, this study sorts the firms into two groups, based on whether their total assets are above or below the yearly sample median. The differential impacts between large and smaller firms are presented in columns (1) and (2) in [Table 8](#). These results indicate that small firms suffer more from social credit deficiency than large ones, consistent with our expectation.

(4) Coastal versus inland areas. Given the huge gaps in regional economic development among regions in China, the more perfect financial system present in coastal areas can effectively smooth external financing channels and reduce financing costs ([Tian & Wang, 2014](#)). Meanwhile, the more developed property trading market may result in the higher market value of new technologies, and loosen the insufficient R&D incentives. Firms located in inland areas may have been more likely to be damaged by social credit deficiency. Therefore, we guess credit shortage may trigger more low-quality patents in inland areas than in coastal lands. To verify whether the geographic location is a key influencing factor, the full samples are divided into two groups, according to whether the firm in question is located in a coastal province or province-level municipality. Columns (3) and (4) in [Table 8](#) report the relevant results. The coefficients on social credit are -0.24 and -0.39 and are significant for the patent quality located in coastal and inland areas. This finding implies that, in inland areas, the negative impact of credit loss on elevating patent quality is significantly greater than in coastal provinces.

(5) Capital-intensive versus labor-intensive industries. Labor-intensive sectors are characterized by less investment and low capital-labor ratios ([Feenstra et al., 2014](#)). The negative effect of social credit loss on firms' external financing would further deepen the funding gap in R&D for firms in labor-intensive sectors. Sufficient internal capital assists capital-intensive companies to mitigate the shock of social credit deterioration. Therefore, we expect that credit loss has a more inhibitory role on patent quality in labor-intensive sectors than in capital-intensive sectors. In columns (1) and (2) of [Table 9](#), the estimated coefficients on social credit are -0.32 and -0.12 and are statistically significant for patent quality in labor- and capital-intensive sectors under our expectations.

(6) Economic downturn versus economic upturn. The procyclicality of credit supply makes obtaining external funding during an economic downturn more difficult for innovative firms ([Aghion et al., 2012](#)). The loan shrinkage is the aftermath of the prevailing pessimistic expectation other than social credit deficiency. Therefore, we surmise that social credit may play a more critical role in patent quality during an economic upturn period, while its effect will become weaker in a period of economic decline. This study adopts [Hodrick and Prescott \(1997\)](#) HP filter method and calculates the business cycle value with a smoothing parameter (λ) equaling 100, based on the panel data of city-level real GDP. Based on whether or not this value is greater than 0, we divide the sample period into two categories: economic upward and economic downward. In columns (3) and (4) of [Table 9](#), regardless of which periods, a loss of social credit significantly lessens patent quality. In contrast such an effect is more significant during economic upward.

5.5. Mechanism tests

According to the theoretical analysis proposed in [Section 3](#), financial constraints in R&D and the incomplete appropriability of

Table 8
Results of the heterogeneity analysis on firm ownership.

Variables	(1)	(2)	(3)	(4)
	SOEs	NSOEs	Foreign firms	Domestic firms
Credit1	-0.106 (0.127)	-0.192 * ** (0.043)	-0.134 (0.097)	-0.221 * ** (0.047)
Constant	-0.346 * ** (0.080)	-0.511 * ** (0.050)	-0.333 * ** (0.091)	-0.548 * ** (0.047)
Observations	20,777	150,673	28,149	143,301
R-squared	0.265	0.265	0.247	0.281
Empirical p-values	0.000 * **		0.002 * **	

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level. All specifications include the city-level and firm-level controlling variables and fixed effects in column (4) of [Table 2](#). The empirical p-values are determined using the Fisher's permutation test. They are based on the null hypothesis that the coefficients are equal for the two groups under consideration.

Table 9
Results of the heterogeneity analysis on firm size and location.

Variables	(1)	(2)	(3)	(4)
	Large firms	Small firms	Coastal area	Inland area
Credit1	-0.139 ** (0.059)	-0.259 *** (0.053)	-0.243 *** (0.045)	-0.392 ** (0.188)
Constant	-0.228 *** (0.057)	-0.657 *** (0.055)	-0.372 *** (0.052)	-0.598 *** (0.045)
Observations	85,269	86,187	122,576	48,872
R-squared	0.165	0.213	0.270	0.298
Empirical p-values	0.002 ***		0.002 ***	

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level. All specifications include the city-level and firm-level controlling variables and fixed effects in column (4) of Table 2. The empirical p-values are determined using the Fisher's permutation test. They are based on the null hypothesis that the coefficients are equal for the two groups under consideration.

innovation are the two primary causes of the low-quality patent output. On the supply side, the soft binding force of social credit can reduce corporate opportunism, thereby relaxing informational asymmetry and narrowing the funding gap. On the demand side, as a kind of informal institution, social credit can also make up for the absence of a property protection system and enhance profitability, and advance the commercialization of new technology.

To verify the effect of credit loss on financial constraints, this study introduces the size-age (SA) index to measure the comprehensive situation of financing constraints in column (1) of Table 10. The calculating formula was provided by Hadlock and Pierce (2010); $SA\ Index = -0.737 * Size + 0.043 * Size^2 - 0.04 * Age$, Size and Age denote firm total assets (in logs) and years of establishment (in logs), respectively. As an important informal approach to obtain low-cost external financing, trade credit is measured by the ratio of accounts payable to total assets in column (2). Referring to Feenstra et al. (2011), in column (3), this study incorporates the ratio of financial expense to total debts as a measure of the financial cost. To capture the effect of social credit on corporate loans, we use the approach proposed by Aghion et al. (2015) and proxy for the effective interest on loan obligations by including the ratio of interest paid to total liabilities in column (4). Generally speaking, as financing constraint increases, the SA index, financial expense, and interest paid will rise, and trade credit will decline.

The related results are reported in Table 10. The estimated coefficient in column (1) is statistically significant and positive, indicating that social credit loss can increase financial constraints, expressed by the SA index. The coefficient in column (2) is equal to -1.06 , illustrating that social credit is unequivocally associated with obtaining accounts payables from business partners. In columns (3) and (4), the results show that credit loss will result in the rise of firm financial expenses and interest rates. In summary, the regression results in Table 10 clearly state that as a type of morality capital, social credit has an inhibitory effect on firm opportunistic behaviors, thereby leading the punitive interest rates and financing expenses to decrease. Social credit also causes an increase in commercial credit, narrows the gap in R&D, and lifts the quality of patents. Table 11.

Based on the differentiation made by Schumpeter (1939) between invention and innovation, we realize that invention is the creation of new technology, whereas innovation is the commercialization or introduction of that technology into the market. Many inventions are patented, but most never reach the point of commercialization (Carlino and Kerr, 2015). Credit deficiency triggers more opportunistic behaviors such as copying and even stealing of patents (Kanwar & Evenson, 2003), thereby amplifying the spillover effect of new technology and dampening the enthusiasm for R&D investment (Grieser et al., 2017). Therefore, we expect that social credit deficiency can weaken corporate profitability and curb the incentive for R&D investment.

In summary, as a kind of morality capital, the soft binding force of social credit can curb opportunism, and thus lead to the decline of informational asymmetry and the relaxation of firm financial constraints in R&D. Meanwhile, on the demand side, the reduction of misdeeds may elevate the market values of high-quality patents and innovation incentive. This may in turn motivate firms to devote more resources to innovative projects and yield more high-quality patents.

6. Conclusions

To explore the deep-seated factors behind the anomaly of the high number of patent applications and inadequate technological innovation in China, this study attempts to investigate the association between social credit deficiency and patent quality. Combining the database of the discredited people blacklist from the Supreme Court, the patent database of the State Intellectual Property Office, and the China Industry Business Performance database, we probe the average effect of regional social credit loss on patent quality between 2003 and 2014.

The results indicate that social credit deficiency, as measured by the ratio of discredited naturalized people to the total population, has a significant inhibitory effect on the quality of patents, proxied by firm-level knowledge breadth. This is especially the case for non-state-owned, domestic-funded, and small-size firms, as well as firms located in inland areas, in labor-intensive industries, and during periods of economic upward. The baseline result is still robust after using alternative measures of social credit and patent quality and exploiting the number of missionary universities established since the Opium War as an instrument for social credit. The latter was done to deal with concerns of measurement error and reverse causality. The mechanism tests show the loss of social credit can, on the one hand, result in the rise of effective interest rates, higher firm financial expenses, and a decline in business credit. This amplifies and

Table 10
Results of the heterogeneity analysis on industry trait and economic wave.

Variables	(1)	(2)	(3)	(4)
	Labor-intensive	Capital-intensive	Economic upturn	Economic downturn
Credit1	-0.321 *** (0.105)	-0.116 ** (0.048)	-0.213 *** (0.045)	-0.127 *** (0.038)
Constant	-0.666 *** (0.056)	-0.412 *** (0.055)	-0.435 *** (0.032)	-0.597 *** (0.034)
Observations	44,926	122,641	96,060	74,634
R-squared	0.288	0.245	0.255	0.298
Empirical p-values	0.000 ***		0.037 **	

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level. All specifications include the city-level and firm-level controlling variables and fixed effects in column (4) of Table 2. The empirical p-values are determined using the Fisher's permutation test. They are based on the null hypothesis that the coefficients are equal for the two groups under consideration.

Table 11
Mechanism tests.

Variables	(1)	(2)	(3)	(4)
Cedit1	0.050 *** (0.017)	-1.057 *** (0.208)	3.153 *** (0.205)	3.315 *** (0.217)
Constant	5.913 *** (0.085)	-6.896 *** (0.280)	-2.338 *** (0.202)	-1.072 *** (0.239)
Observations	171,478	149,886	141,289	121,699
R-squared	0.900	0.219	0.089	0.097

Notes: *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. Robust standard errors in parentheses are clustered at the two-industry level. All specifications include the city-level and firm-level controlling variables and fixed effects in column (4) of Table 2.

expands the corporate fund gap in R&D and reduces patent quality. On the other hand, credit loss can weaken the positive influence of high-quality patents on firm returns, which will then dampen the innovation incentive and eventually inhibit patent quality.

Therefore, based on the above empirical results, the following implications may be drawn: firstly, government sectors (especially those responsible for developing transitional economies where formal property protection institutions are not yet perfect) should advance the construction of social credit laws and strengthen the existing credit disciplinary mechanisms. These steps should be taken to narrow the financial gap in R&D input and then promote corporate high-quality innovative programs. Secondly, financial sector entities, such as banks, should strengthen cooperation with guarantee institutions and third-party rating agencies, thus reducing information asymmetry between financial institutions and enterprises. Thirdly, firms should fully recognize the importance of credit culture to corporate financing and investing activities, and conscientiously abide by credit contracts.

Conflict of interest

All the authors have no conflict of interest and make equal contribution to this article.

Data availability

Data will be made available on request.

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