Innovations, Intellectual Property Protection, and Financial Markets: Cross-Province Evidence from China

Abstract

This study explores the interaction between innovations and financial markets using newly available data of China that present significant geographic variations in economic development. Empirical evidence suggests that provincial banking development encourages local innovations, and provincial intellectual property (IP) protection raises the market values of local firms. Firm-level innovations lead to higher market valuation and predict subsequent stock returns. Moreover, provincial IP piracy deteriorates the market values of innovative firms.

Keywords: banking; China; innovations; intellectual property; patents; piracy

JEL Classifications: G15; O30; R11

1. Introduction

As one of the major emerging economies, China has experienced fast development in both its financial and technological sectors, providing economists with a great opportunity to explore the bank-innovation-stock nexus from the perspective of emerging countries.[1] This paper aims to empirically examine the dynamics between innovations and financial markets using province-level data of China that feature significant geographic variations in banking development, IP protection, and patent piracy. The data allow us to not only reexamine if the relations proposed in prior studies based on developed countries also hold in emerging economies, but also provide new insights to the economics literature.

Previous studies have proposed that local banking development positively affects the innovative activities of local firms (King and Levine, 1993a; Benfratello, Schiantarelli, and Sembenelli, 2008). In China, the banking system is the primary resource of corporate financing and dominates equity markets, even for new technology-based ventures (White, Gao, and Zhang, 2005; Allen, Qian, and Qian, 2008). The geographic variation in banking development across different provinces, as suggested in Jin and Qian (1998), Che and Qian (1998), and Bao, Chang, Sachs, and Woo (2002), motivates us to test the positive bank-innovation relation in China. Our empirical study indicates that provincial banking development effectively stimulates innovations, as the provincial credit market index is positively associated with provincial patent output in the next year, even after controlling for assets, GDP, R&D expenditures, and both year and province dummies in regressions. One standard deviation rise in the credit market index increases local patent output by at least 15%. Such predictability remains when we introduce two instrumental variables, bank deposits and loans per capita, into the two-stage least squares (2SLS) regression.

[1] For a review of China's financial system, including banks and stock markets, please see Allen, Qian, and Qian (2008) and Ayyagari, Demirgüç-Kunt, and Maksimovic (2008). An overview of China's recent technological development and a brief history of its patent systems are provided in Appendix A.

We also construct a firm-level data set including the accounting and financial information of 1,775 public firms that ever issued A-shares listed in the Shanghai Stock Exchange and the Shenzhen Stock Exchange from 1991-2007. Among these firms, 839 have received at least one patent approved by China's patent office (the State Intellectual Property Office, or "SIPO") and, collectively, they account for a total of 58,608 patents. The locations of China's public firms are defined as the provinces where their headquarters sit.[2] It is noteworthy that the location choices of China's public firms can be regarded as a natural experiment because the majority of public firms used to be state-owned and cross-province population mobility remains regulated until now.

Our data allow us to inspect how China's stock markets valuate a public firm's technology capability, as a firm's market value usually consists of both physical and knowledge capital. The literature since Griliches (1981) suggests that, consistent with the efficient market hypothesis, stock markets recognize the value of knowledge capital and grant positive premiums to firms' innovations, usually measured with R&D and patent data.[3] However, most previous findings are based on the data from developed countries such as the U.S., U.K., and other European countries; thus, emerging countries' experience is called for. Our empirical evidence shows a strong, positive relation between public firms' patent capital and their market values in China, regardless of the existence of other control variables including assets, credit market index, leverage degree, sales growth, state ownership, and both year and industry dummies in regressions. One standard

[2] The literature has proposed that U.S. public firms' headquarter locations play an important role in their market values (Coval and Moskowitz, 1999; Ivkovic and Weisbenner, 2005; Christoffersen and Sarkissian, 2009), as the headquarters usually serve as the information hub and operational center and, thus, are subject to local innovations and piracy. Such a relation is reinforced by local product demand from provincial economies and top-level managers from local professionals.

[3] If stock markets operate efficiently, a public firm's market value should include discounted future profits that positively correlate with the firm's current knowledge capital generated from innovative activities. Since the pioneering work of Griliches (1981), there has been significant research working in this direction. Empirical studies based on U.S. firms include Morck and Yeung (1991), Hall (1993), Megna and Klock (1993), Lerner (1994), Lanjouw and Schankerman (2004), and Hall, Jaffe, and Trajtenberg (2005). Moreover, Blundell, Griffith, and Van Reenen (1999) and Toivanen, Stoneman, and Bosworth (2002) conduct similar investigations with British firms. A recent work by Hall, Thoma, and Torrisi (2007) conducts an international study with all valid European firms. It is also worth mentioning that Greenwood and Jovanovic (1999) and Hobijn and Jovanovic (2001) find empirical evidence that major technological revolutions change the market values of all firms to different extents.

deviation rise in patent capital increases the market value by at least 1.2%. Thus, similar to those of developed countries, China's stock markets recognize and update the value of knowledge capital expediently.

We also examine the effect of provincial IP protection on public firms' market values as we observe the geographic variation in IP protection in China (Gao, 1996; Maskus, Dougherty, and Mertha, 2005). With tighter IP protection, public firms should enjoy higher market values because their intangible assets (including, but not limited to, knowledge capital) become more valuable, thanks to less piracy and copy from less regulated, small private firms.[4] This proposition is supported by data. The provincial IP protection index, defined as the number of registered patent agents scaled by the number of scientists and engineers in each province every year, is found to significantly explain the market values of public firms located in that province. One standard deviation higher IP protection raises local firms' market values by more than 6%.

Three province-level instrumental variables–the R&D-to-patent ratio, the R&D-to-scientists and engineers ratio, and the density of patent law firms–are considered in the 2SLS regression to examine if our results are subject to endogeneity issues. The R&D-to-patent ratio reflects the price of patents and is negatively related with patent capital, while the R&D-to-scientists and engineers ratio and the density of patent law firms positively correlate with IP protection. These instrumental variables are uncorrelated with regression residuals, and their appearance in the 2SLS regression confirms the explanatory power of patent capital and IP protection for market values.

We also propose that local IP piracy deteriorates the market values of innovative firms, especially in high-tech industries. Local IP piracy is measured with the provincial infringement

[4] In the literature, Cockburn and Griliches (1988) have shown that industry-level patent protection raises the firm's market value in the U.S. Extending their argument along the geographic dimension leads to a positive effect of provincial IP protection on local firms' market values.

ratio, defined as the number of infringement disputes scaled by accumulated granted patents in each province every year. We find that the market values of innovative firms in high-tech industries significantly decrease with the provincial infringement ratio, corroborating that China's stock markets rationally depreciate public firms' intangible assets in response to IP piracy. When IP infringement rises by one standard deviation, local innovative firms' market values drop by more than 1% on average. Such a relation is further confirmed by the 2SLS regression with the provincial incorruption index and the R&D-to-scientists and engineers ratio as instrumental variables.

Lastly, we explore whether firms' innovative activities forecast their stock returns in China, as the innovation-based predictability has been extensively reported in U.S. stock markets since Pakes (1985).[5] In the pooled regressions with monthly excess stock returns as the dependent variable, the coefficients associated with each firm's patent flow in the prior year are persistently positive with both economic and statistical significance. One standard deviation rise in each firm's patent flow increases its future stock returns by 0.05%-0.10% per month. Such predictability is not affected by the existence of other firm characteristics, such as market beta, size, book-to-market ratio, momentum, investment intensity, state ownership, year effect, and industry effect, and could be attributed to both rational and behavioral reasons, including productivity improvement and temporary market under-reaction.

This paper may contribute to the literature from several perspectives. Provincial banking development and IP protection are found to effectively promote local firms' innovation and financial performance, suggesting the banking system and IP-related policies are critical components of national science and technology policies. We also find that China's stock markets

[5] Pakes' (1985) study starts this strand of the literature that includes Austin (1993), Lev and Sougiannis (1996), Chan, Lakonishok, and Sougiannis (2001), Deng, Lev, and Narin (2003), and Eberhart, Maxwell, and Siddique (2004). Recent studies by Pastor and Veronesi (2009) and Hsu (2009) also document such predictability at the aggregate level.

recognize innovation efforts and grant premiums to the market values and stock returns of innovative firms. Moreover, we reconfirm many positive relations proposed in prior studies based on developed countries' data. The rest of this paper is organized as follows. Section 2 reviews relevant literature and presents testable hypotheses. Section 3 documents the data, and Section 4 reports empirical test results. Section 5 summarizes this study.

2. Relevant literature and hypotheses development

The literature has long recognized the positive effect of banking development on real economies (e.g., King and Levine, 1993b; Rajan and Zingales, 1998). China has experienced fundamental changes and fast development towards a market-oriented system since the economic reform started in 1978, and the transition has been regarded as a success thus far.[6] Thus, the joint development between banking development and economic growth in China has received attention from researchers (e.g., Allen, Qian, and Qian, 2005, 2008), and the role of governments in this development has also been noted (Jin and Qian, 1998; Che and Qian, 1998).

King and Levine (1993a) argue that better-developed financial intermediaries can efficiently fund promising entrepreneurs and, hence, improve the society's innovation progress.[7] Benfratello, Schiantarelli, and Sembenelli (2008) empirically examine this proposition using data from Italy that reveals substantial geographic variations in banking development, and find that provincial banking development spurs local firms' innovative activities from 1991-2000. The significant variation in the development of provincial banking systems is also observed in China due to the economic reform started in 1978 (Jin and Qian, 1998; Che and Qian, 1998; Bao, Chang, Sachs,

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[6] From 1978 to 2009, the economy size measured with GDP has grown by more than 9% per year. Moreover, the prices of more than 95% of goods are determined by the market (Bao, Chang, Sachs, and Woo, 2002).

[7] Becker (2007) observes significantly more new firms started in cities with higher volume of bank deposits due to the geographic segmentation in U.S. banks. Ayyagari, Demirgüç-Kunt, and Maksimovic (2007) report that access to external finance is an important determinant for firms' innovations in emerging countries.

and Woo, 2002; Wang, Wong, and Xia, 2008; Fan, Wang, and Zhu, 2009). Moreover, researchers also note that local banks serve as the major financing source for all firms, including high-tech ventures in China (White, Gao, and Zhang, 2005; Allen, Qian, and Qian, 2008). These observations lead us to hypothesize a positive relation between banking development and innovations across all provinces in China.

Knowledge capital is commonly measured with the stock of R&D expenses and patents, and has been highly valued by developed countries' stock markets. The first work in this direction is Griliches (1981), in which R&D capital and patent capital adjusted for asset size explain the Tobin's q of 157 U.S. firms in 1968-1974. Ben-Zion (1984) uses the same data set and reports that firms' R&D and patent flow explain their market values. Several subsequent studies based on extensive U.S. and European data provide concurring results.[8] Motivated by the aforementioned studies, we hypothesize that the market values of China's public firms increase with their technology capabilities measured by patent capital.

We notice that the role of IP protection in stock market valuation is underdeveloped in the literature. Since IP protection is never perfect, the firms cannot harvest all benefits associated

[8] A thorough review of earlier literature can be found in Hall (2000). Hirschey and Weygandt (1985) find that R&D intensity measured with R&D expenses over sales has a positive effect on Tobin's q, using a bigger sample including 390 firms in 1977. Morck and Yeung (1991) find that the firm's R&D flow is positively related to its Tobin's q in their sample of 1,644 multinational firms. Moreover, Hall (1993) finds that R&D flow and capital have a positive impact on the market capitalization based upon a sample of 2,480 U.S. firms from 1973-1991. Chauvin and Hirschey (1993) find that R&D expenditures have positive and consistent influences on the market value of U.S. firms from 1988-1990. Megna and Klock (1993) report that R&D capital and patent capital explain the variation of Tobin's q in the U.S. semiconductor industry from 1972-1990. Lerner (1994) shows that patent capital affects the market values of 173 U.S. biotechnology start-up firms from 1978-1992. Lanjouw and Schankerman (2004) document that R&D capital scaled by assets significantly affects the Tobin's q's of public firms in high-tech industries from 1975-1993. Hall, Jaffe, and Trajtenberg (2005a) find that the R&D capital to assets ratio and the patents to R&D capital ratio are informative to the Tobin's q's of U.S. pubic firms from 1965-1996. Blundell, Griffith, and Van Reenen (1999) report that the patent capital is positively related with market value and Tobin's q based on 340 British manufacturing firms from 1972-1982. Toivanen, Stoneman, and Bosworth (2002) document that R&D flows and patent flows (scaled by assets) positively affect the market value of 1,519 British firms from 1988-1995. Hall, Thoma, and Torrisi (2007) find that the Tobin's q's of publicly traded European firms is positively associated with the R&D capital to assets ratio and the patent capital to R&D capital ratio from 1991-2004.

with their intangible investment (e.g., R&D, advertisement, and client relation). Cockburn and Griliches (1988) could be the first exploration in this direction. Among over 1,800 firms from the late 1960s through 1984, they find that industry-level patent protection serves as an intermediary variable that enhances stock markets' evaluation of firms' R&D capital and patent capital. Lerner (1994) also reports consistent results by showing that, in the biotechnology industry, firms' market values rise with patent protection. By extending the argument of Cockburn and Griliches (1988) along the geographic dimension, we hypothesize that firms located in the provinces with better IP protection enjoy higher market values due to the geographic variation of IP protection in China. Moreover, we propose a negative relation between local IP piracy and stock market valuation for innovative firms in high-tech industries. Specifically, firms located in the provinces with prevailing IP piracy should suffer from lower market valuation as their efforts will be rewarded to a lesser extent.

The literature also suggests that innovations lead stock returns. The pioneering work of Pakes (1985) investigates the dynamics among patent flows, R&D flows, and annual stock excess returns in a data set composed of 120 firms from 1968-1975. Austin's (1993) event study shows that the patents owned by 20 biotechnology companies indeed create positive CAPM alphas. Later, Lev and Sougiannis (1996) and Chan, Lakonishok, and Sougiannis (2001) document an interesting phenomenon that R&D intensive firms, measured with R&D flow or capital over sales or market value, provide higher subsequent stock returns. Deng, Lev, and Narin (2003) report that U.S. high-tech firms' patent flows significantly forecast stock returns. Eberhart, Maxwell, and Siddique (2004) find that an unexpected rise in R&D expenditures leads to significantly higher stock returns. Such predictability can be attributed to behavioral reasons such as slow information flow or myopia (e.g., Chan, Lakonishok, and Sougiannis, 2001; Eberhart, Maxwell, and Siddique, 2004) or rational explanations such as productivity and efficiency improvement (e.g., Lin, 2009). All these causes also exist in China due to its short history of stock markets, less sophisticated investors, and the private sector's fast adoption of latest technologies. Thus, we propose that the lead-lag relation between innovations and stock returns also exists in China and is worth empirical investigation.

3. Data

The data used for our empirical study come from several sources, and their summary statistics are reported in Table 1. Panel A includes all province-year variables. The credit market index is constructed to measure provincial banking development every year from 1999-2007, available from Wang, Wong, and Xia (2008) and Fan, Wang, and Zhu (2009).[9] We then collect the number of the patents filed in each province every year since 1991 from the SIPO, and the total R&D expenses from both public and private sectors in each province every year from 1991-2007 from the *China Science and Technology Statistical Yearbook* published by the National Science and Technology Ministry of China (2009). The provincial population and GDP data are from the *China Statistical Yearbook* published by the National Bureau of Statistics of China (2009). We also collect the total bank deposits per capita and the total bank loans per capita in each province every year from 1999-2007 from the *Almanac of China's Finance and Banking* published by the China Finance Society (2009). Moreover, we construct a provincial IP protection index, defined as the number of registered patent agents who are chartered to handle general IP issues in each province over the number of scientists and engineers in that province every year from 2001-2007; we obtain these statistics from the *China Science and Technology Statistical Yearbook*. This index is based on an assumption that more patent agents per innovation worker lead to better patent protection of IP. The density of patent law firms is defined as the annual number of registered patent law firms in every province (also collected from the same

[9] This index is available since 1999, and higher value refers to more developed credit market. The index combines two province-level indices: the percentage of total deposits taken by non-state-owned financial institutions that reflects the competition in the financial industry, and the percentage of total short-term loans to the non-state-owned firms that reflects the transition to open markets.

source), divided by the number of innovation works. We also collect the private R&D-to-patent ratio and R&D-to-scientists and engineers ratio, which measures the monetary price of each patent and the R&D expenses per innovation worker in every province in each year, respectively. A provincial patent infringement ratio, defined as the number of annual infringement cases being initiated in each province over the number of cumulative granted patents originated in that province in the same year, is constructed to measure the intensity of time-varying local patent piracy every year from 2001-2007, based on the SIPO data. The incorruption index describes the provincial corruption control every year from 2001-2007, available from Fan, Wang, and Zhu (2009).[10]

Panel B includes all firm-year variables. We first collect the financial market and accounting data of all China's public firms from the China Stock Market & Accounting Research (CSMAR) Database. In the sample period 1991-2008, a total of 1,775 domestic firms are included in our sample, as they issue A shares in the Shanghai Stock Exchange and Shenzhen Stock Exchange. The upper panel of Figure 1 illustrates the annual counts of valid sample firms. Moreover, the geographic locations of public firms are defined as the provinces where their headquarters sit (from the CSMAR database), as public firms' headquarter locations play an influential role in market valuation (Coval and Moskowitz, 1999; Ivkovic and Weisbenner, 2005; Christoffersen and Sarkissian, 2009). It is worth mentioning that the location choices of China's public firms can be regarded as a natural experiment for several reasons including: (1) the majority of public firms are state-owned, (2) the relatively short history of modern stock markets in China, and (3) the low movability of the general public across provinces.

[10] The incorruption index is the arithmetic average of two sub-indexes: the intervention of the government in business, and the level of non-tax levies (including illegal fees, apportions, and fines from local government) on enterprises.

We then collect each public firm's annual patent counts by manually searching the patent database of the SIPO.[11] A firm's patent counts in a specific year denote the number of patent applications that are filed by the firm in that year and are approved by the SIPO in later years (i.e., successful patent applications). Since the public firms in China rarely report R&D expenditures, patent data are extremely important as relevant proxies of knowledge flow and capital. Our patent search procedure generates a total of 58,608 patents owned by public firms, and these patents are categorized into three types: invention patents (49%), utility model patents (32%), and design patents (19%). Moreover, it is impressive that 839 firms (47%) out of a total of 1,775 samples own at least one patent by the end of 2007. When we restrict our sample to the end of 2000, we find that, among 1,172 firms ever listed by the end of 2000, only 160 firms (14%) have patent records. Such a comparison indicates that, similar to what happened in the U.S. in the 1980s (Hall and Ziedonis, 2001; Hall, 2005), China's companies realize how important and valuable patents are and have rapidly increased their innovations and patenting activities in the most recent decade.[12] The lower panel of Figure 1 illustrates the time series of the fraction of the sample firms with any patent count in a given year (solid line), and the fraction of sample firms with any patent count in and before a given year (dashed line). We observe very low ratios in the first few years, which then escalate during 1993-1999 and surge since 2000. The drop of the solid line in the last year is simply due to the application-approval lag (i.e., some patents may have been filed but not yet officially approved by the SIPO).

Three issues are worth mentioning before we proceed. First, following the literature, we use annual patent counts as the proxy of knowledge flow for all individual firms. Second, we record

[11] The website for the patent search in the SIPO is http://www.sipo.gov.cn/sipo2008/zljs/. By inputting the company's full name and year, we collect each firm's annual patents (invention patents, utility model patents, and design patents) by filing dates. There is a concern that the patents owned by the subsidiaries of the sample firms are not considered, due to data availability; however, in our viewpoint, it is not a major issue, given the short history of China's stock markets.

[12] The same pattern is also observed in U.S. patents originating from China. In the record of the U.S. Patent and Trademark Office (USPTO), a total 3,032 of approved patents from China are filed in 2001-2005, which is twice the total of approved patents from China (1,448) filed in the past (1963-2000).

all patents by their application dates (e.g., Hall, Jaffe, and Trajtenberg, 2005a, 2005b), as innovations start to enter into real production process once being invented. Last but not least, although the SIPO is required to publish all patent applications within 18 months after their filing dates, most patent applicants actually request early disclosure that makes their application materials available to the public in as short as 6-8 months.

In Panel B, patent flow denotes a firm's patent counts in each year, and Patent flow/S denotes the firm's patent counts over its total sales in 1,000,000 RMB. Patent capital serves as a proxy of a firm's knowledge capital and is defined as the cumulative patent counts with 15% obsolescence rate in each year, following Hall (2000) and Hall, Jaffe, and Trajtenberg (2005a), and Pat/A denotes the firm's patent capital over its total assets in 1,000,000 RMB. We also consider other important variables including logarithmic market value, logarithmic total assets, leverage ratio defined as total debt over total equity, changes in logarithmic annual sales, market beta, logarithmic book-to-market ratio, and investment intensity defined as annual capital expenditures over total assets. We also look into all public firms' major shareholder data that were required to be disclosed in annual reports since 2001, and observe that 70.6% of China's public firms' controlling (largest) shareholders are governments. This number is consistent with DeFond, Wong, and Li (2000) and Wang, Wong, and Xia (2008). We then construct a state-owned enterprise (SOE) dummy for each firm-year, which is set to be one if a public firm's controlling shareholder is the local or central government in a given year; otherwise, it equals zero. This dummy is included in all firm-level tests to control for potential SOE characteristics, if any.

Panel C contains two firm-month variables. The monthly excess return denotes a public firm's monthly stock return in excess of the three-month interest rate of bank deposits from the People's Bank of China. The momentum is defined as the accumulated monthly returns on each stock over the past 12 months.

Some limitations of our data are worth discussing. First, we recognize that the number of filed infringement cases is incomplete as most patent piracy activities remain unreported. However, such a limitation should not affect the validity of our statistical inferences, unless the unreported piracy ratio meaningfully correlates with the dependent variables of regression analyses. Second, unlike most firm-level variables reported in Panels B and C, some provincial variables and the SOE dummy are unavailable in the 1990s. When we combine all data sets for empirical tests, we let the unavailable values of those variables equal their earliest available values. For example, Province A's credit market index from 1991-1998 is set to be the same as its credit market index in 1999. Although such a setting is adopted for empirical feasibility, it does not affect our main conclusion as similar test results are obtained from a more recent subsample (2001-2007) that is untabulated due to space reason. Third, we are aware of the low creditability of financial information provided by China's public firms in the 1990s, which may bias our firm-level findings. Nevertheless, we do obtain similar test results from the 2001-2007 subsample, in which the credibility has been improved as China's government adopted a series of new regulations, such as a new set of auditing standards following the International Standards on Auditing in 1995 (DeFond, Wong, and Li, 2000). Fourth, we use the identification of the largest shareholder to define whether a financial institution or a public firm is state-owned. Such a definition may be imperfect as governments play an important role in all businesses in China.

4. Empirical tests

4.1. Local banking development and innovations

Table 2 empirically tests the first hypothesis that local banking development promotes local innovative activities. Local banking development is measured with the provincial credit market index, while local innovative activities are measured with the provincial patent flow defined as the logarithmic number of annual patents originated from each province every year (e.g., Hausman, Hall, and Griliches, 1984; Bound, Cummins, Griliches, Hall, and Jaffe, 1984). We conduct pooled ordinary least squares (OLS) regression by regressing the annual provincial patent flow on the provincial credit market index in the prior year, with and without other control variables for the sample period 1991-2007. The provincial credit market index has been standardized for interpretational purpose. Models (1) and (2) show that a higher provincial credit market index leads to significantly more provincial patents in the next year, regardless of the appearance of year and province dummies. Such a relation is confirmed in Models (3) and (4), in which we control for contemporaneous provincial R&D expenses, lagged provincial R&D expenses, and contemporaneous provincial GDP. The explanatory ability of the credit market index is also of economic significance: one standard deviation rise in the credit market index raises local patents by more than 15% per year.

We recognize the potential endogeneity issue with the positive relation reported in Panel A, and conduct the 2SLS regression with two instrumental variables (IVs) in Panel B: the provincial bank deposits and loans per capita. These two IVs reflect the use of banks in different provinces and, hence, should closely relate with the credit market index. On the other hand, they should not affect local innovations as they are unrelated with the will to innovate and R&D expenses have been included on the right hand side.[13] Panel B shows that, in the first stage, deposits per capita negatively affect the credit market index and loans per capita positively affect the credit market index. This finding is intuitive as the saving rate in China was known to be too high in the past. The second stage estimation suggests that local banking development still significantly raises local innovating activities, regardless of the existence of R&D expenses, GDP, and both year and province dummies. In the bottom of Panel B, we also report the J-statistics for the validity of IVs

[13] There are two main determinants for provincial patents: the R&D investment and the will to patent. The R&D investment has been included in the regressions, and the provincial deposits and loans per capita are unrelated with the will to patent. It may be argued that people in some provinces have higher incentives to innovate due to lower financing costs for ventures; however, such an effect should have been absorbed by the credit market index. Moreover, since both province and year fixed effects have been controlled for in Panel A, potential policy impact should not be a major concern.

(Hansen, 1982; Baum, Schaffer, and Stillman, 2003, 2007) and the C-statistics for the endogeneity of the credit market index (Baum, Schaffer, and Stillman, 2003, 2007). We find that the J-statistics do not reject the null hypothesis except Model (5), supporting that the IVs are valid as they are statistically uncorrelated with the error process. We also find that the C-statistics strongly reject the null hypothesis in all cases, confirming the exogeneity of the credit market index as the full set of orthogonality conditions are valid. Thus, the credit market index can be treated as an exogenous explanatory variable; even if it is endogenous, it still significantly explains local innovations after the introduction of two valid IVs.

In unreported tables, we obtain consistent results from other specifications, including the Poisson regression with provincial patent flow as the dependent variable (e.g., Hausman, Hall, and Griliches, 1984; Bound, Cummins, Griliches, Hall, and Jaffe, 1984) and the OLS regression with the difference in provincial patent flow (the patent flow in this year minus the patent flow in the prior year). We also conduct a similar analysis for the private sector by regressing the sum of provincial public firms' patents on the lagged credit market index, along with the contemporaneous and lagged private R&D expenses and all other control variables. The positive relation remains but is slightly weaker. All these results strongly support the distinct, positive effect of local banking development on innovations, which cannot be attributed to provincial research investment, local economic scale, business cycles, and province characteristics.

4.2. Knowledge capital, IP protection, and market value

Our second hypothesis is that knowledge capital and IP protection positively affect the market value of China's public firms. Such a positive relation is motivated by the literature and a simple model shown in Appendix B. Table 3 reports strong evidence supporting this proposition. We first employ pooled OLS regressions with each sample firm's logarithmic market value every year (i.e., stock price multiplied by the number of outstanding shares at the end of the year) as the dependent variable. There are three important explanatory variables on the right hand side: the firm's physical capital, the firm's knowledge capital, and the provincial IP protection. The physical capital is measured with the firm's total assets in logarithm. The knowledge capital is measured with the firm's patent capital defined as the accumulated patent counts with a 15% obsolescence rate following Hall (2000) and Hall, Jaffe, and Trajtenberg (2005a) and is scaled by its total assets following the literature. The provincial IP protection is measured with an index defined as the number of registered patent agents who are chartered to handle general IP issues in the province-year over the number of scientists and engineers in that province-year. We have standardized patent capital and the IP protection index (by their means and standard deviations) for interpretational purpose.

In Panel A of Table 3, we consider two sample groups for comparative purposes: the first group includes the firm-year samples with positive patent capital (Models (1) and (2)), and the second one includes all firm-year samples (Models (3) and (4)). We regress the firm's logarithmic market value on its patent capital, logarithmic total assets, and corresponding provincial IP protection index, along with other control variables including provincial credit market index, leverage degree, changes in sales, SOE dummy, year dummies, and industry dummies.[14] The coefficients associated with patent capital and the IP protection index are significantly positive based on heteroskedasticity-robust standard errors in all four models. It is also noted that one standard deviation rise in patent capital raises the firm's market value by 1.2% to 1.9%, and one standard rise in the IP protection index leads to a 6% increase in market value.

[14] The leverage degree is measured with the debt-to-equity (D/E) ratio (Toivanen, Stoneman, and Bosworth, 2002). The changes in annual logarithmic sales (d ln (S)) account for the scale effect (Hall, 1993). There are 22 industry categories defined in the CSMAR. The industry dummies permit the possibility that market valuation varies across industries due to various reasons, such as industry-specific risk, industry organization, and government policies. It is also noteworthy that we choose not to include fixed firm effects because there are over 1,000 firms in the sample. More detailed reasons are provided in Hall, Jaffe, and Trajtenberg (2005) and Hall, Thoma, and Torrisi (2007).

The estimated coefficients of all other control variables are consistent with the literature and economic intuition. First, not surprisingly, the firm's total assets significantly explain its market value. In addition, the firm's market value is positively correlated with changes in total sales, indicating that China's stock markets grant higher valuation to firms with high sales growth. We also note that SOEs receive relatively lower market valuation, echoing the finding of Sun and Tong (2003) that state ownership has negative impacts on firm performance in China. Our interpretation is that the control and inefficiency from state ownership in fact obstruct China's public firms in pursuing growth opportunities and lead to a discount in their market values.

To mitigate the potential endogeneity concern, we conduct the 2SLS regressions with three IVs: the private R&D-to-patent ratio, the R&D-to-scientists and engineers ratio, and the density of patent law firms. The private R&D-to-patent ratio measures how much a patent costs the firm on average in each province every year, and should affect the firm's incentive to invest in innovations. On the other hand, we could not think of any direct impact of the provincial private R&D-to-patent ratio on market value, especially when both physical and knowledge capital have already been controlled for. The R&D-to-scientists and engineers ratio measures the average R&D resources received by every innovation worker in each province every year, and may reflect how innovative local innovation workers are. It is expected to relate to both patent capital and the IP protection index but, again, does not directly affect market valuation. Lastly, the density of patent law firms is defined as the number of patent law firms divided by the number of innovation workers in each province. It highly correlates with the IP protection index but should not correlate with the regression errors because all of its effect on the market valuation, if any, should have been included in the IP protection index that is based on patent agents who actually handle all patent-related businesses.

The first stage estimation supports our argument: first, the private R&D-to-patent ratio has a significantly negative effect on patent capital; second, the R&D-to-scientists and engineers ratio and the density of patent law firms positively relate with the IP protection index with statistical significance. The second stage estimation confirms the positive effects of knowledge capital and IP protection on stock market valuation. The J-statistics do not reject the null hypothesis in all cases, supporting the validity of three IVs as they are statistically uncorrelated with the error process. The C-statistics strongly reject the null hypothesis in all models, suggesting the exogeneity of two main explanatory variables. Thus, patent capital and IP protection can actually be treated as exogenous explanatory variables in Panel A. Even if they are presumably endogenous, they still significantly explain public firms' market values with the consideration of three valid IVs.

In unreported tables, we find consistent results from different specifications including the Tobin's q regressions (Griliches, 1981; Hall, Jaffe, and Trajtenberg, 2005a) and nonlinear least squares regressions (Hall, Thoma, and Torrisi, 2007). As a result, we confirm the proposition that firms with higher knowledge capital or located in a region with better IP protection receive higher market valuation.

4.3. Infringement and high-tech firms' market values

When patent piracy becomes more prevailing, current firms with valuable patents in high-tech industries will be hurt, and their market prices should be devaluated by stock investors. Among 22 industry categories, we select six high-tech industries as they present intensive patent records in the SIPO's database: Chemical, Petrochemicals and Plastic (C4); Electrical and Electronic (C5); Metal and Nonmetallic (C6); Mechanical (C7); Drugs, Medical and Biotechnology (C8); and Computers and Communications (G). Table 4 empirically tests the proposed relation, as we regress the logarithmic market value of an innovative firm in a high-tech industry on the provincial infringement ratio, the firm's patent capital, provincial IP protection, and other control variables over the sample period 1991-2007.[15] The innovative firms are defined as firms with positive patent capital, and the provincial infringement ratio is defined as the number of reported patent infringement cases in each province-year over the number of all granted patents originated in that province-year. Although the patent infringement ratio is a province-level indicator, it can be regarded as an effective proxy of patent piracy as the geographic diffusion is the most important channel in knowledge distribution (e.g., Jaffe, Trajtenberg, and Henderson, 1993; Zucker, Darby, and Brewer, 1998; Fleming, King, and Juda, 2007).

Models (1) and (2) document that the market values of innovative firms significantly decrease with the provincial infringement ratio. One standard deviation rise in the infringement ratio decreases the logarithmic market value by 1.2% and 1.9%, without and with other control variables, respectively. Moreover, the estimated coefficients associated with patent capital and IP protection are consistent with Table 3 with statistical significance.

In Panel B, we conduct the 2SLS regressions with two IVs – the incorruption index and the R&D-to-scientists and engineers ratio. The incorruption index describes the corruption control in every province every year, which is negatively correlated with the infringement ratio as confirmed in the first stage regression. The R&D-to-scientists and engineers ratio reflects the research resources per innovation worker and is positively related with patent infringement in the first stage regression, concurring with the argument of Cohen and Levinthal (1989), Adams and Jaffe (1996), and Cockburn and Henderson (1998) that some firms invest in R&D in order to access newly developed technologies invented by others. The J-statistics do not reject the null hypothesis, indicating that these two IVs are valid as they are statistically uncorrelated with the error process, and the infringement ratio still has a significantly negative effect on innovative

[15] It is appropriate for us to include both the provincial infringement ratio and IP protection index in the regression because their Pearson correlation coefficient is -0.131 with a p-value of 0.040.

firms' market values. On the other hand, the C-statistics significantly reject the null hypothesis, suggesting the exogeneity of the provincial infringement ratio.

4.4. Innovations and subsequent stock returns

To examine if technological innovations lead subsequent stock returns in China, we conduct the pooled OLS regressions by regressing the monthly excess returns of an innovative firm on its patent flow and other firm characteristics in the prior year for the sample period 1991-2007. The patent flow is scaled by annual sales following Lev and Sougiannis (1996) and Chan, Lakonishok, and Sougiannis (2001) and is standardized. We use patent flow instead of capital as our main explanatory variable on the right hand side because stock markets are more sensitive to recent news, and all innovations before the prior year should have been reflected in stock prices. Other firm characteristics include market beta, size and book-to-market ratio, momentum, investment intensity, SOE dummy, year dummies, and industry dummies. [16] For statistical inferences, we use the standard errors clustered by years to solve the difference in the frequency between the monthly dependent variables and the annual explanatory variables (see Petersen, 2009).

Table 5 shows that firm-specific patent flow significantly predicts monthly stock returns of innovative firms in China. We consider two sample groups: the first group includes the firms with positive patent flow in all industries in Models (1) and (2), while the second group includes only the firms with positive patent flow in six high-tech industries in Models (3) and (4). The coefficients for standardized patent flow range from 0.082% to 0.096% for the first group, while

[16] Each stock's market beta is estimated by regressing the monthly excess returns on monthly market premiums in the whole sample. Following (Fama and French, 1992), size denotes the logarithmic value of the market value of each firm, and the book-to-market ratio denotes the logarithmic value of the book asset over market value. Momentum denotes the accumulative return from month t-1 to month t-12 (Jegadeesh and Titman, 1993). Investment intensity is defined as the annual capital expenditures over total assets (Xing, 2008).

the coefficients for standardized patent flow range from 0.054% to 0.096% for the second group. Among all other firm characteristics, the book-to-market ratio is the only explanatory variable significantly predicting stock returns.

To mitigate the potential endogeneity concern, we conduct the 2SLS regressions with three IVs used in Table 3: the private R&D-to-patent ratio, the R&D-to-scientists and engineers ratio, and the IP protection index. We argue that these three variables are related to public firms' incentives to patent but do not directly affect future stock returns. The J-statistics justify the use of these three IVs, and the second stage estimation strongly supports the positive effect of patent flow on subsequent stock returns. Nevertheless, the C-statistics reported in the bottom of Panel B in fact reject the null hypothesis and suggest that patent flow can be treated as an exogenous regressor.

We obtain similar, albeit weaker test results using patent capital as the explanatory variable in unreported tests. Such a finding is intuitive as old innovations become less informative and, thus, dilute the predictability. Moreover, consistent results are obtained when we scale patent flow and capital by market value. Our empirical analysis hence establishes a strong, positive relation between a firm's innovation performance and its expected stock returns in China. Such predictability may be attributed to behavioral reasons such as market under-reaction or myopia (Chan, Lakonishok, and Sougiannis, 2001; Eberhart, Maxwell, and Siddique, 2004) or rational explanations such as productivity and efficiency improvement (Lin, 2009). However, due to data limitations, we are not able to identify the true driving force(s) behind the predictability thus far.

5. Concluding remarks

As a representative emerging country, China has experienced fast development in both financial and patent systems since the early 1990s. Using newly available data, we examine the dynamics among banking development, innovations, IP protection, and stock market valuation in China. Some of our empirical findings are consistent with the results of prior studies based on developed countries, while others are novel to relevant literature. We report that more innovations occur in provinces with better developed credit markets. More innovative firms are granted with higher market values, and the firms located in provinces with better IP protection also earn higher market values. In addition, local patent piracy has a significantly negative impact on the market values of innovative firms in high-tech industries. Moreover, firms with more innovative activities are found to provide higher future stock returns to investors. This study therefore substantiates the positive feedback between financial and technological development, and suggests an important role of both central and local governments in the dynamics by promoting credit markets, improving patent systems, and tightening IP protection.

Appendix A. The recent development of technologies, patent system, and IP protection in China

China's technological development has demonstrated strong growth since the 1990s. According to the statistics of the World Intellectual Property Organization (WIPO, 2009), the SIPO observed an average annual growth rate of 23.9% on patent applications between 1995 and 2007. In 2009 alone, the SIPO received 976,686 filings, including 99,075 filed by foreign applicants, and approved 581,992 patents, including 80,206 for foreign assignees. Moreover, according to the WIPO, the ratios of the residents' patent filings to R&D expenses and GDP dollars are ranked in the top three and four, respectively, among all countries in 2007. The record of overseas filings is also impressive, as China-origin patents granted by the United States Patent and Trademark Office (USPTO) grew at a 27% annual rate from 2004 to 2007 (Gupta and Wang, 2009).

China's patent system was first established in 1985 and experienced two dramatic reforms in 1992 and 2000 in response to the requirements of the Patent Cooperation Treaty (PCT) and the World Trade Organization (WTO), respectively. The reform in 2000 is extremely radical and important in the sense that China promptly upgraded the patent system and associated institutes to the international standard. Such efforts turned out to effectively encourage technical innovations and patent filings since 2001. Recently, in order to further promote innovation-driven economies, the Chinese government initiated its third major reform of patent laws and regulations on October 1, 2009, further raising the standards for approved patents and IP law enforcement.

The SIPO and its local offices in provinces and cities are the administrative authorities in charge of all IP-related affairs and the coordinating authorities for foreign IP issues. By the end of

2009, the SIPO received a total of 5,822,661 patent applications and approved 3,083,260 cases.[17] The average approval rate in the SIPO ranges from 50% to 60%, which is commensurate to the historical approval rate of the USPTO. Moreover, the SIPO has received and processed a total of 17,804 patent infringement disputes in 2001-2007.

The number of registered patent law firms increased from 456 in 1990 to 676 in 2008. These firms used to be state-owned enterprises in the late 1980s, and most have transformed into private-owned status now. Similar to most developed countries, patent law firms are authorized by the government to represent clients in handling all IP affairs and dealing with government bureaus and courts. If they fail to settle the disputes for their clients in business contracts, they may request the SIPO and its local bureaus for potential administrative solutions and, if necessary, file lawsuits in the courts.[18] Each patent law firm requires at least three registered patent agents, who must have qualified scientific and technical backgrounds and have passed both regular lawyer examinations and a specific "registration examination" held by the SIPO. The examination started in 1992, and the average pass rate is around 10%. The number of registered patent agents started from 3,050 in 2003 and has climbed to 4,916 in 2008.

Moreover, the Chinese government has made significant progress in establishing special trial tribunals that are specifically responsible for investigating IP-related lawsuits within the court system. The special tribunal was first established within the Intermediate and Higher People's Courts in Beijing in 1993 and has been expanded to all provincial courts nationwide.

It is worth noting that China's patent system differs from that of the U.S. from several perspectives. First, China adopts a dual system that includes the administrative authority (the

[17] For comparison, the USPTO received a total of 14,481,966 patent filings and granted 8,061,872 patents from 1791 to 2008 (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm).

[18] Different from that of most other countries, China's patent systems provide an additional option for patent owners. Specifically, the administrative mediation and handling from the SIPO is highly efficient and simple, and is in fact popular among all parties concerned in the dispute (Gao, 1996).

SIPO) and judicial authority (the special tribunal) for legal enforcement against infringement and all other related violations. Second, China employs the first-to-file principle, while the U.S. adopts the first-to-invent principle. Third, by joining the European Patent Convention, China adopts the European system rather than U.S. system in many ways, including the definition of patentable inventions. Fourth, a legal entity in China can apply for a patent with evidence proving that an invention is created by its employees using its resources during a time of employment. On the other hand, only natural persons are qualified to apply for patents in the U.S.

Appendix B. A simple model for knowledge capital, IP protection, and market valuation

We adopt an additive separable linear specification of the market value function (e.g., Griliches, 1981; Cockburn and Griliches, 1988; Hall, 1993 and 2000). The market value of the firm *i* located in province *p,* V_i, is expressed as

$$V_i(K_i, A_i) = q_i(K_i + \lambda A_i)^{\rho}, \tag{A1}$$

i.e., the sum of physical capital K_i and knowledge capital A_i scaled by ρ and q_i assigned by the stock market. λ measures the shadow value of knowledge capital relative to the physical capital, and ρ denotes a multiplicative term allowing various returns to scale. q_i is a valuation coefficient and is set to be $q_i = exp\ (q^* + f_i + u_i + b_{IP}\ IP_p)$, in which q^* is the market's average Tobin's q, f_i denotes the fixed effect accounting for industry characteristics and business cycles, and u_i denotes transitory shocks with zero mean. It is noteworthy that we include the provincial IP protection index (IP_p) in the valuation coefficient as we argue that the market value of the firm's intangible assets increases with local IP protection. We would like to emphasize that knowledge capital is only a part of the firm's intangible capital, so the effect of the IP protection on market value is not specific to A_i.

When we take natural logarithms of both sides of equation (A1), we obtain the following representation:

$$\ln(V_i) = (q^* + f_i + u_i + b_{IP}\, IP_p) + \rho \ln(K_i) + \rho \ln(1 + \lambda A_i/K_i) \tag{A2}$$

$$\approx \left(q^* + f_i + u_i + b_{IP}\, IP_p\right) + \rho \ln(K_i) + \rho\, \lambda \frac{A_i}{K_i}, \tag{A3}$$

in which the logarithmic approximation is appropriate in empirical tests because, for almost all firms, knowledge capital measured with patent counts is relatively smaller in comparison to physical capital measured with total assets. The above log-linear approximation is first proposed in Griliches (1981) and then widely adopted in the literature due to simplicity and presentational cleanness (e.g., Blundell, Griffith, and Van Reenen, 1999; Hall, Jaffe, and Trajtenberg, 2005; Hall, Thoma, and Torrisi, 2007).

Equation (A1) also implies a positive relation between Tobin's q and knowledge capital as well as IP protection. By assuming constant return to scale (i.e. ρ=1) (e.g., Griliches, 1981; Hall, Jaffe, and Trajtenberg, 2005a; Hall, Thoma, and Torrisi, 2007), we can derive a representation for the Tobin's q of the firm *i*:

$$\ln(V_i/K_i) \approx \left(q^* + f_i + u_i + b_{IP}\, IP_p\right) + \lambda \frac{A_i}{K_i}, \tag{A4}$$

where $\ln(V_i/K_i)$ is the logarithmic Tobin's q. Equation (A4) implies positive effects of knowledge capital and IP protection on Tobin's q. Moreover, it is also noted that the above representation can also be easily derived from a Cobb-Douglas market value function (see Bloom and Van Reenen, 2002). However, as argued in Chauvin and Hirschey (1993), Equation (A3) is preferable to Equation (A4) as the latter is based on the assumption of constant return to scale and is subject to measurement errors.

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Table 1: Summary statistics

Panel A includes all province-year variables, Panel B includes all firm-year variables, and Panel C includes all firm-month variables. In Panel A, Credit denotes the provincial credit market index, ln (Pat) denotes the log number of all provincial patents filed in each year, ln (total R&D) is the logarithmic number of the total R&D expenditures in 10,000RMB in each province in every year, ln (GDP) denotes the logarithmic number of provincial GDP in 100,000,000 RMB, Deposits denotes the total bank deposits per capita in 10,000 RMB in each province every year, Loans denotes bank loans per capita in 10,000 RMB in each province every year, IP protection index is defined as the number of patent agents registered in each province in every year over the number of scientists and engineers in that province in that year, R&D/Pat is the private R&D-to-patent ratio (i.e., the accumulated R&D expenditures in 10,000 RMB from large and medium-sized enterprises over the accumulated patent counts of all public firms in every province in each year), R&D/Tech denotes the R&D-to-scientists and engineers ratio (i.e., the R&D expenditures in 10,000 RMB over the number of scientists and engineers in every province in each year), Patent law firm denotes the number of patent law firms in each province divided by the number of scientists and engineers in that province every year, Infringement ratio denotes the number of infringement cases being initiated divided by the number of all granted patents originated in each province every year, and Incorruption index describes the provincial corruption control every year. In Panel B, Patent capital (Pat) denotes the firm's accumulated patent counts with a 15% obsolescence rate, Patent flow denotes the number of the firm's patents filed every year, Pat/A denotes the patent capital over total assets in 1,000,000 RMB, Pat flow/S denotes the patent flow over total sales in 1,000,000 RMB, ln (MV) and ln (A) denotes the logarithmic numbers of the firm's market value and total assets, respectively. D/E denotes the firm's debt-to-equity ratio, d ln (S) denotes changes of logarithmic sales, Market beta denotes the coefficient from regressing the firm's monthly excess stock return on total stock market's monthly excess return, ln (B/M) denotes the logarithmic number of the firm's book-to-market ratio, Investment denotes the firm's capital expenditures over its total assets, and SOE dummy is set to be one if the firm's controlling shareholder is local or central government in the given year. In Panel C, excess stock return is the monthly return of the firm's stock in excess of the monthly risk-free rate, and momentum denotes the accumulated monthly stock returns over the past 12 months.

Panel A	Mean	Median	St. dev.	10%	90%	Sample period
Credit	5.339	5.310	2.365	2.120	8.520	1999–2007
ln (Pat)	7.806	7.898	1.484	6.100	9.514	1991–2007
ln (total R&D)	14.838	14.944	1.486	12.937	16.669	1991–2007
ln (GDP)	7.749	7.876	1.112	6.286	9.053	1991–2007
Deposits	2.153	1.223	3.077	0.542	4.110	1999–2007
Loans	1.528	0.956	1.834	0.471	3.104	1999–2007
IP protection	8.377	6.656	7.455	3.459	13.205	2001–2007
R&D/Pat	0.935	0.254	0.167	0.005	2.618	1991–2007
R&D/Tech	0.324	0.310	0.234	0.214	0.399	1991–2007
Patent law firms	0.162	0.114	0.170	0.057	0.284	2001–2007
Infringement ratio	0.004	0.002	0.007	0.000	0.010	2001–2007
Incorruption	7.687	7.000	2.906	4.065	11.805	2001–2007
Panel B	Mean	Median	St. dev.	10%	90%	Sample period
Patent flow	3.373	0.000	50.212	0.000	3.000	1991–2007
Patent capital (Pat)	9.308	0.000	127.055	0.000	10.000	1991–2007
Patent flow/S	0.002	0.000	0.020	0.000	0.003	1991–2007
Pat/A	0.003	0.000	0.013	0.000	0.006	1991–2007
ln (MV)	21.210	21.256	1.288	19.962	22.583	1991–2007
ln (A)	21.080	20.970	1.172	20.033	22.360	1991–2007
D/E	1.260	0.876	2.726	0.245	2.406	1991–2007
d ln (S)	0.110	0.122	0.549	-0.293	0.499	1991–2007
Market beta	0.997	0.988	0.239	0.746	1.242	1991–2007
ln (B/M)	-0.348	-0.343	0.753	-1.306	0.606	1991–2007
Investment	0.059	0.037	0.076	0.002	0.151	1991–2007
SOE dummy	0.706	1.000	0.456	0.000	1.000	2001–2007
Panel C	Mean	Median	St. dev.	10%	90%	Sample period
Excess stock return	0.019	-0.001	0.169	-0.131	0.184	Jan. 1991 – Dec. 2007
Momentum	0.190	0.050	0.591	-0.386	1.004	Jan. 1991 – Dec. 2007

Table 2: Provincial banking development and innovations

In this table, we regress the logarithmic number of the patents filed in each province on the provincial credit market index in the prior year and other control variables including the logarithmic number of provincial total R&D expenditures (both contemporaneous and lagged), the logarithmic number of the provincial GDP, year dummies, and 31 province dummies. The credit market index has been standardized. In the 2SLS regressions, we consider two instrumental variables: provincial deposits and loans per capita. Heteroscedasticity-consistent standard errors are shown in parentheses. For illustrative purposes, we use * and ** to denote the significance of the coefficients associated with explanatory variables at 10% and 5%, respectively. We also report the J-statistics for the validity of instrumental variables and the C-statistics for the endogeneity of the credit market index. The sample period is 1991-2007.

Panel A: OLS regression

	(1)	(2)	(3)	(4)
Dependent variable	**ln (Pat)**	**ln (Pat)**	**ln (Pat)**	**ln (Pat)**
Credit (t-1)	0.891** (0.066)	0.212** (0.040)	0.188** (0.038)	0.155** (0.036)
ln [total R&D]			0.190** (0.058)	0.060 (0.070)
ln [total R&D (t-1)]				0.112 (0.072)
ln (GDP)				0.539** (0.145)
Constant	8.012** (0.054)	7.537** (0.176)	0.842 (0.599)	1.462 (1.345)
Year dummy	No	Yes	Yes	Yes
Province dummy	No	Yes	Yes	Yes
R-square (%)	35.9	97.3	97.6	97.8
Observations	431	431	427	398

Panel B: 2SLS regression

Second stage	(5)	(6)	(7)	(8)
Dependent variable	**ln (Pat)**	**ln (Pat)**	**ln (Pat)**	**ln (Pat)**
Credit (t-1)	1.366** (0.119)	0.746** (0.112)	0.762** (0.114)	0.730** (0.161)
ln [total R&D]			0.022 (0.070)	-0.014 (0.086)
ln [total R&D (t-1)]				0.061 (0.088)
ln (GDP)				0.075 (0.257)
Constant	8.179** (0.069)	8.729** (0.244)	8.315** (1.135)	7.276** (2.754)
Year dummy	No	Yes	Yes	Yes
Province dummy	No	Yes	Yes	Yes
R-square (%)	26.2	95.5	95.5	95.7
Observations	400	400	397	396
First stage (credit)				
Deposits	-0.322** (0.078)	-0.470** (0.113)	-0.429** (0.114)	-0.403** (0.122)
Loans	0.812** (0.125)	0.872** (0.175)	0.818** (0.174)	0.759** (0.190)
J stat. for valid instruments	10.396 [0.001]	3.433 [0.064]	3.718 [0.054]	3.663 [0.056]
C stat. for endogeneity	16.125 [0.000]	20.131 [0.000]	21.550 [0.000]	11.568 [0.000]

Table 3: Firms' market value, knowledge capital, and provincial IP protection

In this table, we regress the logarithmic number of the sample firm's market value (MV) on its patent capital scaled by assets (Pat/A), the provincial IP protection index, and other control variables including the logarithmic number of assets, the provincial credit market index, the firm's leverage (debt-to-equity ratio), changes in logarithmic sales (d ln (S)), SOE dummy (1=SOE), year dummies, and 22 industry dummies. Pat/A and IP protection have been standardized for interpretive purposes. In the 2SLS regressions, we consider three instrumental variables including the private R&D-to-patent ratio, the R&D-to-scientists and engineers ratio (R&D/Tech), and the density of patent law firms. Heteroscedasticity-consistent standard errors are shown in parentheses. For illustrative purposes, we use * and ** to denote the significance of the coefficients associated with explanatory variables at 10% and 5%, respectively. We also report the J-statistics for the validity of instrumental variables and the C-statistics for the endogeneity of Pat/A and IP protection. Sample period is 1991-2007.

Panel A: OLS regression

	(1)	(2)	(3)	(4)
Sample firms	Positive Pat/A	Positive Pat/A	All firms	All firms
Dependent variable	ln (MV)	ln (MV)	ln (MV)	ln (MV)
Pat/A	0.019** (0.007)	0.019** (0.008)	0.012** (0.006)	0.012* (0.007)
IP protection	0.062** (0.008)	0.063** (0.008)	0.061** (0.005)	0.060** (0.005)
ln (A)	0.689** (0.010)	0.693** (0.010)	0.627** (0.007)	0.629** (0.008)
Credit		0.004 (0.004)		0.012** (0.002)
D/E		-0.009** (0.003)		-0.001 (0.000)
d ln (S)		0.200** (0.026)		0.066** (0.011)
SOE dummy		-0.059** (0.017)		-0.016* (0.010)
Constant	0.351 (0.203)	-0.414 (0.270)	-0.638** (0.175)	-0.786** (0.187)
Year dummy	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes
R-square (%)	78.1	78.4	75.1	74.9
Observations	4698	4425	15367	13661

Panel B: 2SLS regression

Second stage	(5)	(6)	(7)	(8)
Sample firms	Positive Pat/A	Positive Pat/A	All firms	All firms
Dependent variable	ln (MV)	ln (MV)	ln (MV)	ln (MV)
Pat/A	0.166** (0.060)	0.205** (0.093)	0.480** (0.106)	0.460** (0.145)
IP protection	0.064** (0.010)	0.067** (0.010)	0.067** (0.007)	0.066** (0.007)
ln (A)	0.714** (0.017)	0.727** (0.025)	0.645** (0.010)	0.648** (0.011)
Credit		-0.018* (0.011)		-0.004 (0.006)
D/E		-0.007** (0.003)		-0.000 (0.000)
d ln (S)		0.179** (0.026)		0.062** (0.013)
SOE dummy		-0.038* (0.023)		-0.005 (0.015)
Constant	0.479 (0.403)	-0.249 (0.482)	-0.087 (0.230)	-0.107 (0.238)
Year dummy	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes
R-square (%)	73.5	70.7	56.8	58.0
Observations	3779	3550	12479	11258
First stage (Pat/A)				
R&D/Pat	-0.135** (0.018)	-0.077* (0.043)	-0.029** (0.002)	-0.022** (0.002)
R&D/Tech	-0.016 (0.037)	0.077* (0.044)	-0.009 (0.010)	0.019* (0.012)
Patent law firms	0.084 (0.133)	-0.084 (0.126)	0.024 (0.050)	-0.073 (0.050)
First stage (IP protection)				
R&D/Pat	-0.003 (0.005)	-0.042 (0.046)	-0.016** (0.002)	-0.036** (0.002)
R&D/Tech	0.134** (0.010)	0.059** (0.008)	0.127** (0.005)	0.057** (0.005)
Patent law firms	4.322** (0.042)	4.509** (0.030)	4.257** (0.026)	4.477** (0.020)
J stat. for valid instruments	0.021 [0.886]	2.060 [0.151]	0.899 [0.343]	2.492 [0.114]
C stat. for endogeneity	8.083 [0.018]	9.406 [0.009]	43.756 [0.000]	16.620 [0.000]

Table 4: The effect of infringement on high-tech firms' market value

In this table, we regress the logarithmic number of the firm's market value (MV) on the provincial infringement ratio, the patent capital scaled by assets (Pat/A), the provincial IP protection index, and other control variables including the logarithmic number of assets, the provincial credit market index, the firm's leverage (debt-to-equity ratio), changes in logarithmic sales (d ln (S)), SOE dummy (1=SOE), year dummies, and 22 industry dummies. The sample firms are the firms with positive patent capital in the six high-tech industries. The provincial infringement ratio, Pat/A, and IP protection have been standardized for interpretive purposes. In the 2SLS regressions, we consider two instrumental variables: the provincial incorruption index and the R&D-to-scientists and engineers ratio (R&D/Tech). Heteroscedasticity-consistent standard errors are shown in parentheses. For illustrative purposes, we use * and ** to denote the significance of the coefficients associated with explanatory variables at 10% and 5%, respectively. We also report the J-statistics for the validity of instrumental variables and the C-statistics for the endogeneity of the provincial infringement ratio protection. Sample period is 1991-2007.

Panel A: OLS regression			**Panel B: 2SLS regression**		
			Second stage		
	(1)	**(2)**		**(3)**	**(4)**
Sample firms	Positive Pat/A	Positive Pat/A	**Sample firms**	Positive Pat/A	Positive Pat/A
Dependent variable	ln (MV)	ln (MV)	**Dependent variable**	ln (MV)	ln (MV)
Infringement ratio	-0.012* (0.007)	-0.019* (0.011)	**Infringement ratio**	-0.115** (0.044)	-0.136* (0.084)
Pat/A	0.018** (0.008)	0.016** (0.008)	**Pat/A**	0.019** (0.008)	0.019** (0.008)
IP protection	0.064** (0.011)	0.064** (0.010)	**IP protection**	0.051** (0.013)	0.049** (0.017)
ln (A)	0.667** (0.012)	0.659** (0.012)	**ln (A)**	0.671** (0.013)	0.670** (0.013)
Credit		-0.007 (0.004)	**Credit**		-0.007 (0.008)
D/E		-0.008** (0.003)	**D/E**		-0.010** (0.003)
d ln (S)		0.203** (0.030)	**d ln (S)**		0.227** (0.035)
SOE dummy		-0.043** (0.021)	**SOE dummy**		-0.051** (0.022)
Constant	0.212 (0.267)	0.501* (0.258)	**Constant**	0.068 (0.276)	0.163 (0.277)
Year dummy	Yes	Yes	**Year dummy**	Yes	Yes
Industry dummy	Yes	Yes	**Industry dummy**	Yes	Yes
R-square (%)	73.1	73.0	**R-square (%)**	72.5	73.2
Observations	3205	3188	**Observations**	2708	2705
			First stage **(Infringement ratio)**		
			Incorruption	-0.129** (0.007)	-0.077** (0.009)
			R&D/Tech	0.021** (0.003)	0.040** (0.016)
			J stat. for valid instruments	0.033 [0.856]	0.118 [0.731]
			C stat. for endogeneity	6.789 [0.009]	24.633 [0.031]

Table 5: The patent flow and subsequent stock returns

In this table, we regress the monthly excess returns of each sample firm on the patent flow (scaled by sales) in the prior year and control variables including market beta, size, book-to-market ratio, momentum, investment intensity, SOE dummy (1=SOE), year dummies, and 22 industry dummies. The sample firms are the firms with positive patent flow in the six high-tech industries. The sample includes the firms with positive patent in six high-tech industries (Models (1) and (2)) and in all industries (Models (3) and (4)). Patent flow has been standardized for interpretive purposes. To estimate market beta, we regress the monthly excess returns on market premium. ln (MV) denotes the logarithmic value of the firm's market value, and ln (B/M) denotes the logarithmic value of the book assets over market value. Momentum denotes the accumulative returns in the past 12 months. Investment intensity denotes the capital expenditures over the book assets. In the 2SLS regressions, we consider three instrumental variables: the private R&D-to-patent ratio, the R&D-to-scientists and engineers ratio (R&D/Tech), and the density of patent law firms. Heteroscedasticity-consistent, year-clustered standard errors are reported in parentheses. For illustrative purposes, we use * and ** to denote the significance of the coefficients associated with explanatory variables at 10% and 5%, respectively. We also report the J-statistics for the validity of instrumental variables and the C-statistics for the endogeneity of patent flow. Sample period is 1991-2007.

Panel A: OLS regression

	(1)	(2)	(3)	(4)
Industries	All	All	High-tech	High-tech
Sample firms	Positive patent flow	Positive patent flow	Positive patent flow	Positive patent flow
Dependent variable	Monthly excess returns	Monthly excess returns	Monthly excess returns	Monthly excess returns
Patent flow/S (%)	0.096** (0.020)	0.082** (0.015)	0.096** (0.020)	0.054** (0.015)
Market beta	0.008 (0.012)	0.005 (0.011)	0.007 (0.012)	0.003 (0.013)
ln (MV)	-0.005 (0.004)	-0.004 (0.004)	-0.005 (0.004)	-0.005 (0.004)
ln (B/M)	0.013** (0.006)	0.012* (0.006)	0.013* (0.006)	0.015** (0.007)
Momentum		-0.015 (0.015)		-0.042** (0.020)
Investment		-0.013 (0.020)		0.002 (0.014)
SOE dummy		0.001 (0.002)		-0.000 (0.002)
Constant	0.087* (0.048)	0.130* (0.071)	0.115* (0.058)	0.091 (0.062)
Year dummy	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes
R-square (%)	10.4	9.9	10.3	11.6
Observations	17108	16745	13284	13028

Panel B: 2SLS regression

Second stage

	(5)	(6)	(7)	(8)
Industries	All	All	High-tech	High-tech
Sample firms	Positive patent flow	Positive patent flow	Positive patent flow	Positive patent flow
Dependent variable	Monthly excess returns	Monthly excess returns	Monthly excess returns	Monthly excess returns
Patent flow/S (%)	3.129** (0.711)	4.667** (1.285)	3.206** (1.037)	3.526** (1.432)
Market beta	0.009 (0.013)	0.013 (0.020)	0.008 (0.012)	0.014 (0.030)
ln (MV)	0.006** (0.003)	0.012 (0.008)	0.007 (0.005)	0.010 (0.013)
ln (B/M)	0.022** (0.007)	0.027** (0.009)	0.023** (0.009)	0.025* (0.014)
Momentum		-0.027** (0.012)		-0.023** (0.010)
Investment		0.037** (0.015)		0.044 (0.036)
SOE dummy		0.010 (0.008)		0.005 (0.012)
Constant	-0.006** (0.107)	-0.071 (0.118)	-0.058 (0.099)	-0.096 (0.219)
Year dummy	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes
R-square (%)	8.6	8.8	7.8	6.3
Observations	15360	15107	12049	7246

First stage (Pat flow/S)

	(5)	(6)	(7)	(8)
R&D/Pat	-0.008** (0.001)	-0.085** (0.016)	-0.095** (0.013)	-0.133** (0.040)
R&D/Tech	0.020 (0.177)	0.062 (0.184)	0.130 (0.216)	0.363 (0.357)
Patent law firms	-0.129 (0.223)	-0.122 (0.230)	-0.135 (0.269)	-0.163 (0.215)
J stat. for valid instruments	0.897 [0.639]	1.722 [0.423]	1.003 [0.606]	1.487 [0.475]
C stat. for endogeneity	5.276 [0.022]	8.279 [0.004]	4.601 [0.032]	6.369 [0.012]

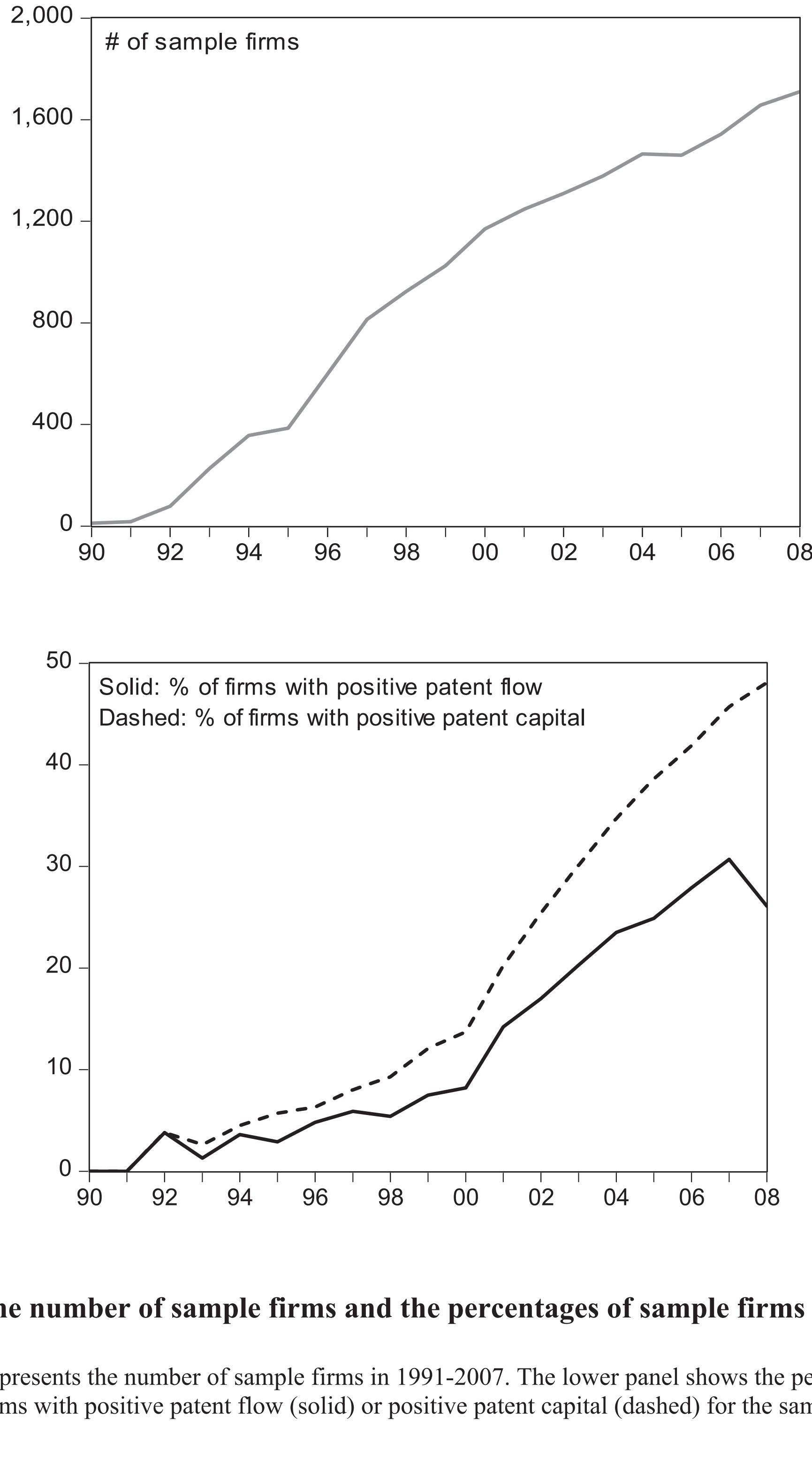

Figure 1. The number of sample firms and the percentages of sample firms with patents

The upper panel presents the number of sample firms in 1991-2007. The lower panel shows the percentage of every year's sample firms with positive patent flow (solid) or positive patent capital (dashed) for the sample period 1991-2007.