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FINANCIAL DEVELOPMENT AND INNOVATION ACTIVITY: EVIDENCE FROM SELECTED EAST ASIAN COUNTRIES

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Abstract:

This paper examines the role of financial development in promoting innovation-related activity using panel data for seven East Asian countries for the period from 1998-2009. On overall financial development, we find that, financial sector size and the overall activity of banks and stock market exert positive influences on patent applications. In particular, our results show that all measures of banking development are positively and significantly related to the number of patent applications after controlling for variables known to affect innovative activities. Interestingly, we find no evidence that variation in patent applications is affected by a country's stock market development. The findings suggest that banking sector plays important roles in supporting innovation activity in East Asian countries.

Keywords: financial development, patents, banking development, stock market development, innovative activities.

JEL Classification: G10; G15; G20

1. Introduction

Innovation has long been known as a key driver in promoting economic growth and innovative potential is now an important source of competitive advantage for many countries, including those of East Asia. Theoretical underpinnings for the link between innovation and economic growth can be traced back to century-old work of Schumpeter (1912). He emphasizes the role of finance in stimulating economic growth and technological innovation. Schumpeter views entrepreneur as innovator who is capable of making drastic changes to the economy in a process that Schumpeter termed as "*creative destruction*". King and Levine (1993), Morales (2003), Acemoglu *et al.* (2006), among others, provide support for Schumpeter's (1912) argument that banks encourage innovative activities. These authors find that banks promote technological innovation by allocating resources to entrepreneurs with the most promising new opportunities, such as new products, production methods, and new markets that have the highest success rate. This suggests that by altering the resource allocation process,

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financial sector of a country exerts positive influences on innovation-related activity. The objective of this paper is to examine the extent to which financial development explains the variations in the number of patent applications for a sample of seven East Asian countries.

As argued by Cabral and Mata (2003), the unavailability of financing sources averts firms from achieving their optimal size and hence reduces their involvement in innovation activities. In other words, the greater the financial constraints faced by innovative firms, the higher the occurrences of innovation failures. Thus, the presence of well-developed banking sectors and capital markets is crucial in providing different forms of external financing to spur growth and to sustain the survival of innovative firms. Rajan and Zingales (1998) argue that well-developed financial sector liberates firms from the need of sourcing funds internally. Their findings show that industries that are more dependent on external finance grow relatively faster in countries that are more financially developed.

Theoretical and empirical research on financial development indicates that financial systems perform various functions. Proponents of bank-based view highlight the importance of banks in facilitating capital allocation and enforcing corporate governance (Diamond, 1984; Ramakrisnan and Thakor, 1984); improving risk management (Allen and Gale, 1999); lessening monitoring costs and moral hazard distortions (Boot and Thakor, 1997). Supporters of market-based view argue that well-developed financial markets are capable of reducing risk intertemporally (Levine, 1991); enhancing corporate governance quality (Jensen and Murphy, 1990); decreasing information acquisition costs and hence generating higher profits to innovative firms (Holmstrom and Tirole, 1993). Allen and Gale (2000) contend that bank-based and market-based financial systems have different effects on innovative activities as both systems perform diverse functions in facilitating resource allocation. Market-based financial structure is more conducive to new inventions and industries than bank-based structure. On the other hand, banking institutions are the preferred channel of financing when firms need additional capital for funding business expansion and for extending innovative activities. Such arguments suggest that the co-presence of bank and capital market financing creates a well-functioning financial system that allows innovation to thrive and deliver benefits.

Innovation-based growth model of Aghion *et al.* (2005) and Aghion and Howitt (2009) shows that financial development plays vital role in creating and sustaining innovation-based economies. Financial development reduces the cost of screening and monitoring activities, which subsequently diminishes agency problems and hence inspires firms to engage in innovation-related activities. The model suggests that capital market imperfections increase monitoring costs and to evade repayment of borrowed funds, firms deceive their creditors by concealing successful innovation outcomes. Since poor legal protection of creditors is commonly associated with under-developed financial markets, it makes fraud an affordable option. This in turn hampers innovative efforts

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due to difficulty in obtaining financing. Thus, better developed financial markets have stronger creditor rights and higher governance quality that contribute to mitigating fraud risk of financial institutions. For this reason, creditors are more confident in identifying and providing credits to firms that have greater prospects of successfully innovating new technologies.

Building on the above discussion, the objective of this paper is to examine the role of financial development in promoting a country's innovation-related activity for a sample of seven East Asian countries from 1998 to 2009. Specifically, we investigate the importance of the overall financial development as captured by overall size, activity, and financial structure in explaining differences in the number of patent applications. We also shed light on the relative importance of banking sector development and stock market development in influencing patenting activity. Empirical analyses are performed using panel data analysis after controlling for factors known to influence innovation-related activity. The findings of this study provide insights to the governments of selected East Asian countries in designing and implementing policy measures needed to foster innovative sectors. This study is organized as follows. Section 2 presents the literature review. Section 3 describes the data and methodology. The findings are discussed in Section 4 and Section 5 concludes the study.

2. Literature Review

In a highly cited literature on innovation systems, Furman *et al.* (2002) introduce the concept of "national innovative capacity" that provide a novel framework for analyzing the fundamental determinants of innovation process. Empirical investigations based on the model highlight that country-level differences in innovation intensity are importantly determined by a country's total stock of knowledge, which is needed to drive the production of innovative ideas, public policy choices such as investment in education and training, and intellectual property protection that are needed to spur innovative productivity. Their findings suggest that well-designed public policies promote human capital development in the area of science and engineering, improve innovation incentives, support cluster-specific research and development production, and strengthen the interactions between innovative sectors.

Varsakelis (2006) examines the determinants of national innovation activities emphasising on the roles of quality of education and political institutions after controlling for research and development intensity. The results show that strong protection of civil and political rights, low corruptions, and high accountability are important factors that influence both the quantity and quality of a country's effort in making innovation and technological advance. Orientation towards science education is found to be positively and significantly correlated with innovation productivity. Similarly, Spielman *et al*. (2008) find that education and training positively affect the efficiency level of innovation production. These results parallel those of Youtie and Shapira (2008) that emphasize on the importance of improving education quality in fostering inventive activities. That is,

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nurturing highly skilled and educated workforce is critical to inspire innovative ideas that would ignite and encourage innovation activities. Wang (2010) finds that tertiary education and the quantity of scientific researchers have significant positive impacts on research and development investment. The finding also reveals that patent rights protection and income growth rate marginally affect research and development investment. On the contrary, Buesa *et al.* (2010) present evidence that education is generally not statistically significant in determining the patentability of the inventions.

Teitel (1994) shows that *per capita* income, and research and development expenditures are positively associated with patenting activities. Romer (1994) contends that higher income encourages greater incentives for conducting research and development. When consumers get richer, they demand more highly differentiated products and this encourages firms to develop competitive and innovative products in providing customers with added values. The findings of Varsakelis (2001) indicate that the presence of strong patent laws increases research and development intensity and countries with stronger patent protection laws invest more in research and development activity. This is because higher degree of patent rights protection encourages firms to allocate a larger proportion of their resources in undertaking innovative activities. Additionally, Fu (2008) finds that well-enforced legislation and intellectual property rights protect the interest of innovator better by providing sufficient legal remedies for rights infringement and thus attract more foreign direct investment inflows into the technology-intensive sectors. Similarly, as contended by Ginarte and Park (1997), countries that are actively involved in innovative activities tend to have strong desire to safeguard their intellectual property rights in order to sustain the pace of innovation.

The findings of Hyytinen and Toivanen (2005) highlight that financial market imperfections constrain growth and hold back innovative activities of firms in Finland and indicate that public policy plays important role in alleviating financial market imperfections. Dosi (1990) examines the relationship between financial structures and industrial innovation and finds that market-oriented and bank-oriented financial systems have different impacts on the paces and types of innovative activities. The design of financial systems across different countries can either speed up or hinder the process of innovation. The financial services view advanced by Merton and Bodie (1995) and Levine (1997) emphasizes the importance of having well-developed banks and financial markets in the creation of sound financial services. The authors contend that financial arrangements occur to mitigate market frictions, promote liquidity, identify and analyse investment prospects, enforce corporate controls, and minimize risk exposures. The financial services view is consistent with bank-based and market-based systems where banks and financial markets are seen as complement rather than as substitute to each other. The presence of a healthy economic environment is crucial for banks and capital markets to offer high-quality financial services.

Ang (2010, 2011) provides evidence that financial development is important in alleviating market frictions, and hence in promoting knowledge-based activities. The findings suggest

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that the lack of intellectual property rights protection hinders knowledge accumulation and therefore strains innovation process. The creation of good institutions that foster financial development is necessary in increasing the availability of external financing for innovative firms. The findings also indicate that countries with stricter enforcement of intellectual property rights are better able to promote technological deepening. The impact of intellectual property rights protection on the rate of technological innovation is stronger when a country's institutional framework exhibits higher governance quality. Barbosa and Faria (2011) find that credit market regulation is an important determinant of innovation production and contend that financial development promotes innovative activities by improving information sharing and thereby facilitating access to credit for firms, especially technology-based start-up firms. Evidence is also presented that higher *per capita* income leads to higher innovation capacity. This is because firms have greater incentives to generate innovation since the demand for differentiated products are usually high particularly when customers grow richer. In a recent study, Maskus *et al*. (2012) examine whether financial development, both domestic and international are associated with investment in research and development. Domestic financial development as measured by private credit by deposit money banks, stock market capitalization, and private bond market capitalization, is found to have significant positive impact on research and development intensity. Interestingly, the results show that bond market is the main funding source for research and development. This result is supported by the facts that bond market is able to tolerate the presence of opinions diversity among funds providers and that bondholders have priorities over stockholders in obtaining their money back in the event of insolvency. Foreign direct investment is the only indicator of international financial development that is positively related to research activities.

3. Data and Methodology

The sample for this study consists of a group of seven selected East Asian economies with unbalanced data for the study period from 1998 to 2009. The countries are Indonesia, Japan, South Korea, Malaysia, Philippines, Singapore, and Thailand. Due to the lack of more robust indicators, patent is the most common indicator employed to proxy for inventive outputs (Griliches, 1990). Acs *et al.* (2002) present empirical evidence that patent data is a fairly reliable proxy for measuring regional innovative activities. Patents are fair reflection on the flow of new knowledge, which is imperative for fostering and sustaining the knowledge-based economy transformation. Patent data are retrieved from the World Intellectual Property Organization (WIPO) Database and high levels of data reliability, availability, and accessibility motivate the usage of patent statistics. We employ natural logarithm of patent applications (LPATENT) as the dependent variable where it represents the number of patent applications submitted to national patent offices. These applications are to obtain exclusive rights established in patent legislation for an invention, a product or a process that provides new means of undertaking something or presents a new-fangled technological solution to a predicament. The number of patent applications is also used as a measure for the level of innovative activities in recent

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studies for examples, Kortum (1993), Varsakelis (2006), Ang (2010), Ang (2011), among others.

We employ panel data analysis to examine whether financial development plays an imperative role in influencing innovative activities in East Asian countries. We use Hausman specification test to compare the fixed effect versus the random effect models under the null hypothesis of no correlation between unobserved individual effects and other regressors, $\text{Cov}(X_{it},\alpha_i) = 0$, $t = 1,2,\ldots,T$. Failing to reject null hypothesis suggests that the preferred model is random effect. The Breusch-Pagan Lagrange Multiplier (LM) test is applied to test the random effects under the null hypothesis that cross-sectional variances are zero. Non rejection of the null hypothesis means pool regression model is an appropriate model. We also estimate the heteroskedastic robust standard error to eliminate potential biases in the estimated standard errors.

The analyses are divided into two parts and are conducted using a log-log specification, with the exception of indicators that are expressed as a percentage. In the first part as shown in Equation (1), we examine the importance of the overall financial development in explaining cross-country differences in innovative activities. In the second part of the analysis as shown by Equation (2), we shed light on the relative importance of banking development and stock market development in influencing a country's innovative activity. The empirical models are shown below.

$$\text{LPATENT}_{it} = \beta_0 + \beta_1\text{LOFD}_{it-1} + \beta_2\text{LRDLABOR}_{it} + \beta_3\text{LGDPCAP}_{it} + \beta_4\text{EDUCATION}_{it} + \beta_5\text{GOVERNANCE}_{it} + \alpha_i + u_{it} \quad (1)$$

$$\text{LPATENT}_{it} = \beta_0 + \beta_1\text{LFD}_{it-1} + \beta_2\text{LRDLABOR}_{it} + \beta_3\text{LGDPCAP}_{it} + \beta_4\text{EDUCATION}_{it} + \beta_5\text{GOVERNANCE}_{it} + \alpha_i + u_{it} \quad (2)$$

$i = 1, \ldots, N$, $t = 1, \ldots, T$

where i represents countries and t represents the years; β are the vectors of estimated coefficient; α is the unobserved country heterogeneity and u denotes idiosyncratic disturbances. LPATENT is patent applications. Since the effect of financial development on patent applications is only observed with delay, we impose a 1-year lag on all measures of financial development. In the Equation (1), LOFD is the overall financial development and is measured by the natural logarithm of the overall size, activity, and financial structure as denoted by LSIZE, LACTIVITY, and LSTRUCTURE, respectively. The overall size of the financial development (LSIZE) is measured by an indicator that comprises private credit by deposit money banks to GDP and stock market capitalization as a percentage of GDP. The measure for overall financial development activity (LACTIVITY) is obtained through the multiplication of the following two indicators, private credit by deposit money banks to GDP and stock market total value traded to GDP. The indicator for the overall financial structure (LSTRUCTURE) is defined as the private credit by deposit

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money banks to GDP divided by stock market capitalization as a proportion of GDP. Higher values indicate a more bank-based financial system and these measures follow those of Levine (2002) and Beck *et al*. (2010).

In Equation (2), LFD captures financial development in the banking sector and the stock market. Following Levine and Zervos (1998), Levine (2002), Beck and Levine (2004), and Beck *et al.* (2010), banking sector development is measured by the natural logarithm of the following four indicators: private credit by deposit money banks to GDP (LBANK); deposit money bank assets to GDP (LASSET); bank credit to bank deposits (LDEPOSIT); and private credit by deposit money banks and other financial institutions to GDP (LCREDIT). Similarly, stock market development is proxied by four indicators expressed in natural logarithm. LSTOCK is stock market capitalization to GDP and it is equivalent to the value of listed shares as a proportion of GDP (Levine and Zervos, 1998; Levine, 2002; Beck and Levine, 2004; Beck *et al*., 2010). This is considered to be the best available indicator since it is more circumspect than any other measures of stock market development after taking into consideration the economic impact of the stock market. Stock market value traded (LTRADE) is the total value of shares traded to GDP and it gauges the value of stock transactions in relation to the size of the economy. Stock market turnover (LTURNOVER) is the total value of shares traded to market capitalization and it measures the value of equity transactions in relation to the size of the stock markets (Levine, 2002; Beck and Levine, 2004; Beck *et al*., 2010). While the turnover ratio measures the trading volume of the stock markets, it ignores the effects of trading volume on stock prices. Higher trading volume leads to higher price volatility. Since it is imperative to minimize the price swings that occur on high trading volume, stock market depth is considered a better indicator of stock market liquidity than the conventional turnover ratio (Amihud, 2002; Daouk *et al*., 2006). For this reason, we compute the stock market depth (LDEPTH) by dividing the trading volume with the standard deviation of stock market returns. In fact, this variable is a volatility-adjusted indicator of stock market turnover ratio. All financial development data are sourced from World Bank's Financial Development and Financial Structure Dataset.

In addition to financial development indicators, we also include a range of control variables that are associated with innovation activities, such as research and development labours (LRDLABOR); real GDP *per capita* (LGDPCAP); secondary school enrolment (EDUCATION); and the quality of country-level governance (GOVERNANCE). The natural logarithm of research and development labours (LRDLABOR) is a proxy for expenditures of research and development activities. Research and development labours consist of researchers and technicians whose main task is to propel the creation of new knowledge that spurs innovative activities and technological development. Real GDP *per capita* (LGDPCAP) captures the ability of a country's wealth in increasing its inventive activities. This variable is also log-transformed. The data are gathered from the World Development Indicators (WDI) Database. Secondary school enrolment (EDUCATION) serves as a proxy for education and it is measured by the proportion of relevant age group that receives full-time secondary education. The education data is derived from

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IMD World Competitiveness Database. To capture a country's quality of governance (GOVERNANCE), we employ country-level governance data of Kaufmann *et al*. (2010), gathered from the World Bank's Worldwide Governance Indicators (WGI) Database. The governance score is the overall governance index representing the average value of the following six governance dimensions: political stability and absence of violence/ terrorism; voice and accountability; government effectiveness; regulatory quality; rule of law; and control of corruption. The indicator ranges from -2.5 to +2.5 with higher values indicating better governance quality. Countries with well-functioning governance mechanisms have better incentives to undertake more innovative activities.

4. Empirical Findings and Discussion

Table 1 reports the descriptive statistics for patent applications, financial development measures, and other potential determinants of innovative activity in East Asian countries over the period from 1998 through 2009. The average number of patent applications (PATENT) is 87477 and the highest number of patent applications made by a particular country is 440248 which is considerably high compared to the mean value. On the overall financial development indicators, financial structure (STRUCTURE) has an average value of 1.3184. Given that higher value is associated with more bank-oriented structure, this suggests that on average, East Asian countries have bank-based financial systems.

Tables 2 through 4 present results of the random effect panel regression analyses for the link between financial development and innovation-related activity. The dependent variable is the number of patent applications. The random effect model is shown to be the preferred model since the result of the Hausman specification test does not reject the null hypothesis that unobserved heterogeneity is uncorrelated with the explanatory variables. The Breusch-Pagan Lagrange multiplier (LM) test statistic indicates that the random effect model is the preferred model.

In Table 2, we present results for the link between patent applications and the overall financial development as measured by the overall size, activity and financial structure. The baseline regression as represented by Model 0 shows that governance quality (GOVERNANCE) is the only control variable with significant coefficient. This is possibly because the effects of other control variables in the model are captured in the governance variable. As reported in Appendix C, governance quality is highly correlated with other control variables such as research and development labours, real GDP *per capita*, and secondary school enrolment with correlation coefficients of 0.84, 0.93, and 0.87, respectively. The result suggests that higher governance quality is positively associated with higher number of patent applications. Models 1, 2, and 3 present findings for the effects of the overall financial development on the number of patent applications. The overall financial development is measured by the overall size (LSIZE), activity (LACTIVITY), and financial structure (LSTRUCTURE) as shown in Models 1, 2, and 3, respectively. In Models 1 and 2, the significant positive coefficients of LSIZE and LACTIVITY suggest that overall financial sector size and the activity of banks and stock

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market correlates positively and significantly with patent applications in East Asian countries. That is, larger financial sector and higher banking and stock market activity are important for fostering innovative activities which subsequently increases the number of patent applications. However, as shown in Model 3, a country's financial structure *i.e*., the distinction between market-and bank-based financial system is not significantly related to the number of patent applications. Such finding is broadly consistent with the arguments of Merton and Bodie (1995), Levine (1997), Allen and Gale (2000) that financial system with the combination of bank-based and market-based elements are important for providing different funding channels to innovative firms based on their specific needs. A more developed financial sector allows firms to have better access to external finance through either banks or stock markets in funding their innovation activities.

Table 3 reports the results of the relation between banking sector development and the number of patent applications. As reported in Models 4 through 7, we employed four commonly used indicators for banking development, *i.e*., private credit by deposit money banks to GDP (LBANK); deposit money bank assets to GDP (LASSET); bank credit to bank deposits (LDEPOSIT); and private credit by deposit money banks and other financial institutions to GDP (LCREDIT). The four banking indicators in Models 4 through 7 have positive and significant coefficients after controlling for other factors known to influence innovative activities. Such findings suggest that banking sector development plays important role in promoting patent applications in East Asian countries. Countries with higher level of banking development on average have higher level of innovative outputs production, which subsequently increases the number of patent applications. Our findings are also consistent with the notions that banks are competent in providing capital to fund risky innovative activities due their expertise in mitigating risk (Aghion *et al*., 2005; Aghion and Howitt, 2009; Ang, 2011; and Maskus *et al*., 2012). The coefficients of real GDP *per capita* and governance quality are positive and significant suggesting that high *per capita* income and well-functioning governance framework are also important in promoting patenting activity. Countries with strong governance framework have better investment climates that would incentivise more firms to invest in innovative sectors (Ginarte and Park, 1997; Varsakelis, 2001; Furman *et al*., 2002; Aghion *et al*., 2005; Varsakelis, 2006; Fu, 2008; Ang, 2010; Ang, 2011; and Barbosa and Faria, 2011). The results also indicate that real GDP *per capita* plays a vital role in increasing the number of patent applications. This is because when customers are richer, the demand for innovative products gets higher and this inspires firms to innovate more in order to gain competitive advantage. Such finding reinforces the results of Teitel (1994), Romer (1994), *and* Barbosa and Faria (2011) that confirm a positive relationship between real GDP *per capita* and patenting activities.

Table 4 presents findings for the link between stock market development and patent applications. As shown in Models 8 through 11, the results indicate that none of the stock market measures is significant in explaining the variations in the number of patent applications. This implies that stock markets have yet to play an important

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role in influencing patenting activities in East Asian countries. The coefficient of governance is positive and significant in all models suggesting that higher governance quality encourages more innovation outputs which eventually lead to higher number of patent applications.

5. Conclusion

This study employs random effects models to examine the link between financial development and innovative-related activity in seven East Asian countries over the period 1998 through 2009. The sample comprises Indonesia, Japan, South Korea, Malaysia, Philippines, Singapore, and Thailand. We examine the extent to which financial development influences the cross-sectional variations in patent applications after controlling for factors known to affect innovative activities. The dependent variable employed is the number of patent applications, a proxy for innovation-related activity.

The results for overall financial development show that financial sector size and the activity of banks and stock market are positively related to patent applications. Such findings underline the importance that financial development has for patenting activity in East Asian countries. However, we find that the structure of financial system is not important in explaining the cross-country differences in patent applications. For banking sector development, we observe consistent results that all banking measures correlate positively with the number of patent applications. Interestingly, we find no evidence that variation in patent applications in East Asian countries is affected by stock market development. Our results suggest that banking sector seems more important than stock market in channelling funds to stimulate innovative-related activity. The findings of the study also highlight the importance of governance quality and real GDP *per capita* in influencing patenting activity in East Asian countries.

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Appendix A

Sample Countries

Indonesia	Japan	Malaysia	Philippines	Singapore	South Korea	Thailand

Appendix B

Definitions and Sources of Variables

Variable	Definition	Source
Patent applications	The number of innovation patent applications (in logarithmic form)	World Intellectual Property Organization (WIPO) Database
Research and development labours	The number of researchers and technicians (in logarithmic form)	World Development Indicators (WDI) Database
Real GDP per capita	GDP per capita, PPP (constant 2005 international $) (in logarithmic form)	World Development Indicators (WDI) Database
Education	The relevant age group receiving full-time secondary education (in percentage)	IMD World Competitiveness Database
Governance	The average value of overall six governance dimensions (in value ranges from -2.5 to +2.5)	World Bank's Worldwide Governance Indicators (WGI) Database
Financial development - Size	Private credit by deposit money banks to GDP and stock market capitalization to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Financial development- Activity	Private credit by deposit money banks to GDP times stock market total value traded to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Financial structure	Private credit by deposit money banks to GDP divided by stock market capitalization to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Private credit by deposit money banks to GDP	Private credit by deposit money banks to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Deposit money bank assets to GDP	Deposit money bank assets to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Bank credit to bank deposits	Bank credit to bank deposits (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Private credit by deposit money banks and other financial institutions to GDP	Private credit by deposit money banks and other financial institutions to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Stock market capitalization	Stock market capitalization to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset

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Stock market value traded	Total value of shares traded to GDP (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Stock market turnover	Total value of shares traded to market capitalization (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset
Stock market depth	Trading volume to standard deviation of stock market returns (in logarithmic form)	World Bank's Financial Development and Financial Structure Dataset and Datastream

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Correlation Coefficients

	PAT	LAB	GDP	EDU	GOV	SIZ	ACT	STR	PRV	AST	DEP	CRE	STO	TRA	TUR	DEPT
PAT	1															
LAB	0.62**	1														
GDP	0.43**	0.90**	1													
EDU	0.64**	0.90**	0.87**	1												
GOV	0.46**	0.84**	0.93**	0.87**	1											
SIZ	0.19	0.39**	0.68**	0.53**	0.77**	1										
ACT	0.38**	0.43**	0.64**	0.75**	0.65**	0.58**	1									
STR	0.22	-0.10	-0.12	0.08	0.03	-0.05	-0.13	1								
PRV	0.46**	0.33*	0.46**	0.51**	0.65**	0.79**	0.43**	0.47**	1							
AST	0.63**	0.47**	0.54**	0.57**	0.70**	0.76**	0.42**	0.42**	0.96**	1						
DEP	-0.16	-0.15	0.13	0.29**	0.27**	0.35**	0.45**	0.35**	0.44**	0.24*	1					
CRE	0.43**	0.40**	0.53**	0.66**	0.72**	0.72**	0.47**	0.49**	0.93**	0.86**	0.56**	1				
STO	-0.08	0.28	0.66**	0.40**	0.65**	0.88**	0.54**	-0.45**	0.40**	0.38**	0.18	0.36**	1			
TRA	0.28**	0.36*	0.61**	0.69**	0.58**	0.42**	0.95**	-0.20	0.23*	0.22*	0.42**	0.34**	0.45**	1		
TUR	0.21	0.04	0.21	0.43**	0.22*	-0.06	0.49**	0.18	0.04	-0.01	0.42**	0.27**	-0.12	0.61**	1	
DEPT	0.44**	0.40**	0.47**	0.63**	0.45**	0.14	0.63	-0.01	0.14	0.17	0.20	0.28**	0.10	0.74**	0.74**	1

PAT is the number of patent applications. The overall financial development measures are SIZ, ACT, and STR. SIZ and ACT are financial sector size and activity, respectively, while STR is the financial structure. Banking sector development measures are PRV, private credit by deposit money banks to GDP; AST, deposit money bank assets to GDP; DEP, bank credit to bank deposits; and CRE, private credit by deposit money banks and other financial institutions to GDP. Stock market development measures are STO, stock market capitalization; TRA, stock market valued traded; TUR, stock market turnover; and DEPT, stock market depth. The control variables are: LAB, research and development labours; GDP, real GDP *per capita*; EDU, secondary school enrolment; and GOV, the quality of governance.

* and ** indicate significance at the 5% and 1% levels, respectively.

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Table 1
Descriptive Statistics from 1998 through 2009

Variable	Mean	Standard deviation	Median	Minimum	Maximum
PATENT	87477	146612	6340	854	440248
RDLABOR	3504	2360	3884	83	6616
GDPCAP	16472.18	13873.94	11101.15	2459.27	49738.89
EDUCATION	77.71	16.96	71.08	49.70	99.76
GOVERNANCE	0.3680	0.7247	0.3391	-0.9199	1.5111
SIZE	1.7243	0.8657	1.6502	0.3150	3.4387
ACTIVITY	0.6331	0.5960	0.5038	0.0101	2.9729
STRUCTURE	1.3184	1.0077	0.9297	0.2899	6.3469
BANK	0.8680	0.4538	0.9402	0.1724	2.0061
ASSET	1.0436	0.5078	1.0783	0.3025	2.3643
DEPOSIT	0.9210	0.3321	0.9222	0.3864	1.9029
CREDIT	0.9550	0.4719	1.0079	0.1724	2.0061
STOCK	0.8563	0.5781	0.6590	0.1361	2.4983
TRADE	0.6464	0.6030	0.4344	0.0331	2.7603
TURNOVER	0.8770	0.9165	0.5583	0.0758	6.2242
DEPTH	0.2197	0.1892	0.1517	0.0194	1.0184

PATENT is the number of patent applications. SIZE and ACTIVITY are the overall financial sector size and activity, respectively, while STRUCTURE is the financial structure. Banking sector development measures are BANK, private credit by deposit money banks to GDP; ASSET, deposit money bank assets to GDP; DEPOSIT, bank credit to bank deposits; and CREDIT, private credit by deposit money banks and other financial institutions to GDP. Stock market development measures are STOCK, stock market capitalization; TRADE, stock market valued traded; TURNOVER, stock market turnover; and DEPTH, stock market depth. The control variables are: RDLABOR, research and development labors; GDPCAP, real GDP *per capita*; EDUCATION, secondary school enrolment; and GOVERNANCE, the quality of governance.

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Table 2

Random Effect Panel Regression Results of the Link between Overall Financial Development and Patent Applications from 1998-2009

	Model 0	Model 1	Model 2	Model 3
Constant	3.0984 (1.27)	5.0204* (2.32)	4.1637 (1.83)	1.6030 (0.61)
LRDLABOR	0.1883 (0.91)	0.1328 (0.76)	0.0527 (0.28)	0.1457 (0.74)
LGDPCAP	0.5351 (1.46)	0.2937 (0.93)	0.4185 (1.27)	0.7257* (1.95)
EDUCATION	-0.0001 (-0.01)	0.0073 (0.90)	0.0146 (1.44)	-0.0002 (-0.03)
GOVERNANCE	0.6192* (2.44)	0.6176** (2.92)	0.5710** (2.55)	0.6592** (2.72)
LSIZE		0.3201** (3.47)		
LACTIVITY			0.1252** (2.52)	
LSTRUCTURE				0.0792 (1.18)
R-squared	0.6526	0.7648	0.7139	0.6694
Hausman Test	6.52 [0.16]	6.68 [0.25]	0.77 [0.98]	1.60 [0.90]
Breusch-Pagan LM Test	84.79 [0.00]	42.00 [0.00]	99.98 [0.00]	71.85 [0.00]

Dependent variable is LPATENT, the natural logarithm of the number of patent applications. The overall financial development measures are: LSIZE is the financial sector size; LACTIVITY is the activity of banks and stock market; and LSTRUCTURE is the financial structure. All financial development measures are expressed in logarithmic form. The control variables comprise the followings: LRDLABOR is the natural logarithm of research and development labours; LGDPCAP is the natural logarithm of real GDP *per capita*; EDUCATION is the secondary school enrolment; and GOVERNANCE is the overall quality of governance.

t-statistics shown in the parentheses are adjusted for heteroskedasticity in the error terms.*p*-values are in square brackets. * and ** indicate significance at the 5% and 1% levels, respectively.

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Table 3

Random Effect Panel Regression Results of the Link between Banking Sector Development and Patent Applications from 1998-2009

	Model 4	Model 5	Model 6	Model 7
Constant	2.0402 (1.00)	2.8946 (1.49)	1.8976 (0.84)	1.3865 (0.62)
LRDLABOR	0.0516 (0.30)	0.1037 (0.63)	0.2085 (1.12)	0.0883 (0.49)
LGDPCAP	0.6915* (2.33)	0.5627* (1.95)	0.7014* (2.13)	0.7515* (2.33)
EDUCATION	0.0080 (1.02)	0.0076 (1.01)	-0.0053 (-0.62)	0.0048 (0.58)
GOVERNANCE	0.6134** (3.00)	0.4801* (2.37)	0.5884** (2.60)	0.7604** (3.40)
LBANK	0.2771** (3.78)			
LASSET		0.4477** (4.42)		
LDEPOSIT			0.3039** (2.52)	
LCREDIT				0.2438** (2.74)
R-squared	0.7745	0.8080	0.7215	0.7305
Hausman Test	5.69 [0.34]	1.20 [0.94]	6.55 [0.26]	4.55 [0.47]
Breusch-Pagan LM Test	42.70 [0.00]	8.60 [0.00]	30.62 [0.00]	85.77 [0.00]

Dependent variable is LPATENT, the natural logarithm of the number of patent applications. Banking sector development measures are as follows: LBANK is private credit by deposit money banks to GDP; LASSET is deposit money bank assets to GDP; LDEPOSIT is bank credit to bank deposits; LCREDIT is private credit by deposit money banks and other financial institutions to GDP. All financial development measures are expressed in logarithmic form. The control variables comprise the followings: LRDLABOR is the natural logarithm of research and development labours; LGDPCAP is the natural logarithm of real GDP *per capita*; EDUCATION is the secondary school enrolment; and GOVERNANCE is the overall quality of governance.

t-statistics shown in the parentheses are adjusted for heteroskedasticity in the error terms. *p*-values are in square brackets. * and ** indicate significance at the 5% and 1% levels, respectively.

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Table 4

Random Effect Panel Regression Results of the Link between Stock Market Development and Patent Applications from 1998-2009

	Model 8	Model 9	Model 10	Model 11
Constant	4.9027 (1.89)	3.1486 (1.25)	3.2010 (1.34)	1.3785 (0.52)
LRDLABOR	0.1245 (0.65)	0.1486 (0.74)	0.1744 (0.88)	0.2050 (1.03)
LGDPCAP	0.3641 (1.01)	0.5492 (1.50)	0.5506 (1.57)	0.7188* (1.99)
EDUCATION	0.0037 (0.41)	0.0012 (0.12)	-0.0026 (-0.29)	-0.0029 (-0.32)
GOVERNANCE	0.5740* (2.43)	0.6265** (2.55)	0.6261** (2.60)	0.6246** (2.62)
LSTOCK	0.1447 (1.73)			
LTRADE		0.0177 (0.33)		
LTURNOVER			-0.0514 (-1.03)	
LDEPTH				-0.0591 (-1.27)
R-squared	0.6904	0.6549	0.6686	0.6738
Hausman Test	1.44 [0.92]	1.01 [0.96]	1.28 [0.94]	0.98 [0.96]
Breusch-Pagan LM Test	76.98 [0.00]	85.29 [0.00]	71.28 [0.00]	89.60 [0.00]

Dependent variable is LPATENT, the natural logarithm of the number of patent applications. Stock market development measures are as follows: LSTOCK is stock market capitalization to GDP; LTRADE is the stock market valued traded to GDP; LTURNOVER is total value of shares traded to market capitalization; LDEPTH is stock market depth representing the volatility adjusted of stock market turnover ratio. All financial development measures are expressed in logarithmic form. The control variables comprise the followings: LRDLABOR is the natural logarithm of research and development labours; LGDPCAP is the natural logarithm of real GDP *per capita*; EDUCATION is the secondary school enrolment; and GOVERNANCE is the overall quality of governance.

t-statistics shown in the parentheses are adjusted for heteroskedasticity in the error terms. *p*-values are in square brackets. * and ** indicate significance at the 5% and 1% levels, respectively.