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## Financial deepening and innovation efficiency: The role of political institutions

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**ADB Working Paper Series**

**FINANCIAL DEEPENING AND  
INNOVATION EFFICIENCY: THE  
ROLE OF POLITICAL INSTITUTIONS\***

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**Abstract**

This study investigates the effects of financial deepening on innovation efficiency for various democratic levels of political institutions using panel data from 69 countries spanning 1970–2010. Banking market deepening is associated with increased innovation efficiency only when political institutions are sufficiently democratic. In contrast, the enhancing effect of stock market deepening on innovation efficiency requires a lower level of political democracy. Furthermore, the results are stronger for countries with lower incomes than for countries with higher incomes. Our results are robust for the use of the instrumental variable approach and alternative measures for financial deepening, democracy, and innovation inputs.

**JEL Classification:** E02, G20, O30

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## 1. INTRODUCTION

It is well known that innovation is a catalyst for sustainable economic growth, which is on the development agenda of numerous developed and developing countries (Romer 1990; Grossman and Helpman 1991; Aghion and Howitt 1992). What can governments do to promote innovation? Consistent with the insight of Schumpeter (1911), recent empirical studies have determined that financial development promotes innovation (Ang 2011; Ayyagari et al. 2011; Brown et al. 2013; Hsu et al. 2014). Because countries that have deeper financial systems are better at mobilizing resources, allocating funding, and diversifying risks, they can channel more funding to profitable but risky innovation projects. Consequently, financial deepening increases the resources devoted to the research and development (R&D) sector to foster innovation (King and Levine 1993b). Furthermore, recent studies have indicated that political institutions affect cross-country differences in financial development by instituting rules and regulations (Haber et al. 2008). Motivated by these two strands of literature, we examine how financial deepening and political institutions affect innovation efficiency.

Political institutions define the rules and policies that shape the interactions (e.g., the contractual relationships) between market participants, which in turn affect the incentives and expectations of investors and innovators. Democratic political institutions limit the power of the state by constraining executive authority and fostering political competition, which better protects investor and innovator gains (Jensen 2008; Li 2009). We expect that innovators would be more motivated to transform innovation inputs to innovation outputs under the influence of more democratic political institutions, indicating a positive relationship between political democracy and innovation efficiency, i.e., the transformation rate from innovation inputs to innovation output.

More importantly, we not only analyze whether financial deepening and political democratization directly affect innovation efficiency but also examine how their interaction affects innovation efficiency. We expected that political democratization would promote the innovation-enhancing effect of banking and stock market deepening through alternative channels. First, more democratic countries possess less power to restrict the entry of new financial intermediaries into the marketplace and affect the allocation of credit (La Porta et al. 2002). By promoting political participation and competition, democratic political institutions limit the power of the state to control and repress the financial system, reduce the chance of both predatory and opportunistic behavior, and thereby generate a more competitive and more efficient banking system (Haber et al. 2007). More competitive financial intermediaries, in turn, are more strongly committed to terminating poor investment projects than monopolistic financial intermediaries. This commitment increases the ability of competitive financial intermediaries to finance risky investments and promote innovation (Huang and Xu 1999).

Second, from the stock market perspective, investors are able to extract the relevant but noisy information from equilibrium prices under rational expectation (Grossman 1976). This information allows investors to make investment decisions regarding innovation projects. The information contained in equity prices also provides timely information to entrepreneurs about the prospect of their innovations, which in turn improves their investment decisions (Allen and Gale 1999). We expect that the more democratic political institutions that impose greater constraints on governments would be more likely to implement policies that improve information disclosure to investors. For example, Bushman et al. (2004) demonstrated that greater corporate transparency

is observed in countries where the state is less likely to expropriate the firms' wealth. As a result, there is a positive interactive effect between stock market deepening and political democratization on innovation related to the role of political democracy that improves the quality of information produced by the stock market.

To test the above hypotheses regarding the direct and indirect effects through financial deepening of political democracy on innovation, we employ panel data that encompassed 69 countries over the period 1970–2010; countries vary greatly in terms of the degree of financial depth and political democracy. Our empirical model was derived from a knowledge production function that linked a country's innovation outputs to innovation efficiency, innovation inputs, and other factors. We measure each country's innovation outputs as follows: the stock of patents includes those that were granted by the United States (US) Patent and Trademark Office (USPTO); the depth of the banking market was measured by the ratio of private credit by banks to gross domestic product (GDP); the depth of the formal financial intermediaries was measured by the ratio of their liquid liabilities to GDP; the depth of the stock market was measured by the ratio of stock market capitalization to GDP; and R&D inputs were measured by the number of R&D researchers per capita in addition to R&D expenditures per capita. We operationalize the concept of political democratization at the country level using quantitative measures of institutionalized democracy, i.e., the polity score provided by the Polity IV Project (Marshall and Jaggers 2011) and the Political Rights (PR) index that was published by the Freedom House (2011). We estimate our model using lagged explanatory variables as instrumental variables in alignment with the system Gaussian mixture model (GMM) approach (Arellano and Bond 1991; Blundell and Bond 1998) to address the potential issue of endogeneity. Furthermore, we incorporate a full set of country and year fixed effects and a set of time-varying control variables to address the potential issue of omitted variables.

Our empirical analyses result in several conclusions. First, we note a positive effect of political democratization on innovation efficiency. Second, and more importantly, we demonstrate that deepening of both the banking market and the formal financial intermediaries have a positive and significant effect on innovation efficiency only when a threshold level of polity score has been attained. To clarify, deepening of the banking market and the formal financial intermediaries causes innovation inputs to be allocated more efficiently among innovative projects only when a country has a sufficiently high level of political democracy. Conversely, there is a much lower requirement for the polity score to allow stock market deepening and improve innovation efficiency. These results are consistent with our hypothesis that political democratization has an indirect effect on innovation through financial deepening.

Third, among the various components of the polity score, increasing the state's openness and competitiveness in executive recruitment for leaders and tightening constraints on leaders' powers are more effective in promoting the positive effect of banking market and financial intermediary sector deepening on innovation efficiency. Fourth, we conduct a subsample analysis according to income levels. We note that our primary results remained stable for countries that had lower incomes, suggesting that countries with lower incomes may sustain growth by increasing political democratization. This result occurred because when countries have better democratic political institutions, financial deepening can better promote innovation. Finally, our results are robust for the use of alternative measures of political democracy and innovation inputs.

Our study extends two strands of literature. First, we contribute to a growing strand of literature that demonstrates the positive effects of financial development on innovation. Recent empirical studies that analyzed cross-countries data have demonstrated that access to bank loans and banking market development foster innovation (Ayyagari et al. 2011; Ang 2011). Brown et al. (2013) and Hsu et al. (2014) demonstrate that stock market development is more important than banking market development for promoting R&D expenditures and patents filed in the US. Our study extends this strand of literature by demonstrating that political democratization may promote the positive effects of financial development on innovation efficiency. Furthermore, bank-based and market-based financial systems have different requirements for political democracy that can promote innovation efficiency.

Second, our study is related to literature regarding political institutions and growth. Earlier studies have provided mixed results regarding the effect of democracy on growth (Barro 1996; Acemoglu et al. 2014). In close alignment with our work, certain earlier studies have demonstrated that political democratization indirectly promotes growth through enhancing human capital accumulation (Tavares and Wacziarg 2001; Acemoglu et al. 2014). Our study adds to this literature by demonstrating that political institutions have positive direct and indirect effects on promoting innovation, which studies have indicated to be an engine of growth.

The remainder of the paper is organized as follows. Section 2 presents the empirical model, and section 3 describes the data. Section 4 reports the empirical results with various robustness checks, and section 5 presents further analyses. The final section provides concluding remarks.

## 2. MODEL AND ESTIMATION METHODOLOGY

### 2.1 Model

The approach we use to examine innovation in different countries is based on the knowledge production function that is used for the endogenous growth theory. In alignment with Ha and Howitt (2007) and Madsen (2008), we specify a production function for technological innovations as follows:

$$\Delta A_{it} = \delta(F_{it}, P_{it})A_{it}^{\varphi}(R_{it}/Q_{it})^{\sigma}, Q_{it} \propto L_{it}^{\beta} \text{ in steady state,} \quad (1)$$

where country and year are denoted by  $i$  and  $t$ , respectively.  $\Delta A_{it}$  represents the flow of new knowledge,  $A_{it}$  represents the stock of existing knowledge available to produce new knowledge,  $R_{it}$  represents the R&D inputs devoted to knowledge production,  $Q_{it}$  is the product variety that counterbalances the innovation-enhancing effect of R&D inputs, and  $L_{it}$  is employment or population. The focus of our study is the function of innovation efficiency  $\delta(F_{it}, P_{it})$ , which is the transformation rate of innovation inputs to new knowledge relating to the levels of financial deepening ( $F_{it}$ ) and political democracy ( $P_{it}$ ).

The parameter  $\sigma$  is the duplication parameter and ranges from 0 if all innovations are duplicates, to 1 if no innovation is duplicated. The parameter  $\varphi$  characterizes the return to scale effect of the existing knowledge stock on producing new knowledge.  $\beta$  is the parameter of product proliferation and captures whether the effectiveness of R&D is diluted due to the proliferation/complexity of products as technology deepens. Although there is an ongoing debate in the literature regarding the values of parameters  $\varphi$  and  $\beta$ , we aligned with Jones (2005b) to assume  $\varphi < 1$  and  $\beta < 1$ , which is consistent with the



semi-endogenous model with product proliferation. This model is more appropriate for empirical analysis because it allows for a continuum of possible values for those two parameters.<sup>1</sup> In a steady state of this model, because the growth rate of knowledge accumulation ( $\Delta A_{it}/A_{it}$ ) is stationary, the stock of knowledge converges to a stochastic balanced growth path:

$$A_{it} = \delta(F_{it}, P_{it})^{1/(1-\varphi)} R_{it}^{\sigma/(1-\varphi)} L_{it}^{-\beta\sigma/(1-\varphi)}, \quad (2)$$

where  $F_{it}$ ,  $P_{it}$ ,  $R_{it}$ , and  $L_{it}$  are the long-run forcing variables that explain the behavior of  $A_{it}$ .

## 2.2 Estimation Methodology

We log-linearize Equation (2) to obtain our empirical specification:

$$\ln(A_{it}/L_{it}) = \beta_0 + \beta_1 F_{it} + \beta_2 P_{it} + \beta_3 F_{it} * P_{it} + \beta_4 \ln(R_{it}/L_{it}) + \beta_5 \ln L_{it} + \alpha_i + \alpha_t + u_{it}, \quad (3)$$

The dependent variable  $A_{it}$  represents the stock of patents granted by the USPTO to each country (normalized by  $L_{it}$ , which is measured by the total population). For a long period of time, patents have been widely used, not without controversy, as a measure of innovation output (Griliches 1990). Although not all inventions are patented, those that are patented must meet minimal standards of novelty, originality, and potential use. Therefore, patents are an appropriate proxy for economically significant innovation. We use the patents granted by the USPTO as a proxy for the stock of knowledge to avoid concerns that the measurement is incomparable across countries because domestic patent offices across countries do not exhibit uniform quality in granting patents. Specifically, we align with Hall et al. (2005) and Ang and Madsen (2011) to use the perpetual inventory model with a depreciation rate of 15% to account for the effect of depreciation on constructing the stock of patents.

The primary explanatory variables of our interest are  $F_{it}$ ,  $P_{it}$ , and the interactions between them. In alignment with the seminal study conducted by King and Levine (1993a), we use three measures of financial deepening. First, we use the ratio of private credit to GDP to measure the banking market deepening of a country. Second, we use the ratio of liquid liabilities owed by financial intermediaries to GDP to measure the depth of financial intermediaries.<sup>2</sup> Third, we use the ratio of stock market capitalization to GDP to measure the stock market deepening of a country. The ratio of private credit to GDP and the ratio of liquid liabilities to GDP are used as two alternative measures of banking market deepening. Higher ratios of private credit, liquid liabilities, and stock market capitalization to GDP indicate a higher level of financial deepening.

<sup>1</sup> There exist other endogenous growth models that have alternative restrictions on these two parameters. The first-generation endogenous growth models assume  $\varphi = 1$  and  $\beta = 0$ , implying that the growth rate of knowledge is proportional to the level of R&D inputs. However, these models were rejected by Jones (1995b) with empirical evidence. The semi-endogenous growth models (e.g., Jones 1995a; Kortum 1997; Segerstrom 1998) assume  $\varphi < 1$  and  $\beta = 0$ . As such, R&D must continuously increase to sustain a positive growth rate of knowledge. The Schumpeterian growth models (e.g., Aghion and Howitt 1992; Dinopoulos and Thompson 1998; Howitt 1999) maintain the assumption that  $\varphi = 1$  and  $\beta = 1$ . As such, to sustain a positive growth rate of knowledge, R&D must increase over time to counteract the increasing range and complexity of products that decrease the productivity of R&D inputs.

<sup>2</sup> Liquid liabilities include currency held outside the banking system plus demand and interest-bearing liabilities of banks and nonbank financial intermediaries.

We employ the polity score as our primary measure of country-level institutionalized political democracy. This score is based on a weighted score of the state's openness and competitiveness in executive recruitment for the leaders of a country, the constraints on its executive authority, and the competitiveness of its political participation. A higher score indicates a more democratic institution, which creates greater constraints on the government by introducing more open and competitive executive recruitment for the leaders of a country, imposing tighter constraints on executive authority and promoting more competitive political participation (Marshall and Jaggers 2011). The interaction term between financial deepening and political democratization investigates how the effects of financial deepening on knowledge accumulation vary in countries with different level of political democracy. A positive coefficient of the interaction term indicates that financial deepening contributes more to knowledge accumulation when it operates under more democratic institutions. To ensure that the interaction term does not proxy for the level of financial deepening or political democracy, both of the latter variables ( $F_{it}$  and  $P_{it}$ ) are included in the regression independently.

We employ the total number of R&D researchers per capita as our primary measure for  $R_{it}$  and the total R&D expenditures per capita as an alternative measure. These variables have often been used in empirical studies to proxy the direct effort for innovation (Ang and Madsen 2011). We use R&D expenditures per capita as a measure of  $R_{it}$  for a robustness check because that specification does not allow political democratization to enhance the effect of financial deepening on knowledge accumulation through altering R&D expenditures. This exclusion may omit an important channel through which financial deepening affects knowledge accumulation.

Furthermore, we include two time-varying control variables. First, we include intellectual property rights (IPR) protection at the country-level,  $IPR_{it}$ , to control for the institutions that directly interfere with innovation. As a result, the variable  $P_{it}$  only captures the effects of political democratization on knowledge accumulation through channels other than developing and enforcing IPR. Second, a disadvantage of using patents granted by the USPTO to measure patent output is selection bias because domestic innovators may not apply for patents in the US if they only need patent protection in their home country. To address selection bias, we include the log of exporting volume per capita of each country to the US in our empirical model. To clarify, in Equation (3), we assume that

$$u_{it} = v_{it} + \beta_6 IPR_{it} + \beta_7 \ln TRADE_{it} \quad (4)$$

where  $IPR_{it}$  denotes the IPR of country  $i$  in year  $t$ , and  $TRADE_{it}$  denotes the exporting volume of country  $i$  to the US at year  $t$ .

Equation (3) also includes a full set of country dummy variables,  $\alpha_i$ , which capture time-invariant country characteristics that affect the equilibrium levels of knowledge accumulation. For example, these dummy variables eliminate the effect of constant, potentially historical factors. Additionally, a full set of time dummy variables,  $\alpha_t$ , are included to capture common shocks to knowledge accumulation of all countries. For example, these dummy variables eliminate the spillover effect from patent stocks across the globe. The error term  $u_{it}$ , captures all of the other omitted idiosyncratic factors, where  $E[v_{it}] = 0$  for all  $i$  and  $t$ .

To control for the potential endogeneity of explanatory variables, including  $F_{it}$ ,  $F_{it} * P_{it}$ ,  $\ln R_{it}$ ,  $IPR_{it}$  and  $\ln TRADE_{it}$ , we use the lagged explanatory variables as instrumental variables, in alignment with the system GMM approach (Arellano and Bond 1991; Blundell and Bond 1998), to estimate our empirical model.

### 3. DATA AND DESCRIPTIVE STATISTICS

We compile a large international panel of data for empirical analysis from various sources, including the World Intellectual Property Organization (WIPO) Statistics Database and USPTO Patent Statistics for patent data; the World Bank for private credit, liquid liabilities, and stock market capitalization data; Marshall and Jaggers (2011) for polity scores; Freedom House (2011) for political rights indexes; Lederman and Saenz (2005) for R&D researchers and R&D expenditures as a percentage of GDP for the time period 1965–2000; UNESCO for R&D researchers and R&D expenditures as a percentage of GDP for the time period 2001–2005; Park (2008) for a measure of IPR protection; and the Penn World Table 7.1 for real GDP per capita and total population. The sample includes 69 countries (see Appendix A for the entire list of sample countries) covering the time period 1970–2010; the time periods correspond to 5-year intervals.

**Table 1: Variable Definitions and Summary Statistics**

Variables	Mean	SD	Min	P25	Median	P75	Max
A	0.12	0.24	0	0.00	0.01	0.18	1.53
<b>Alternative measures for financial development</b>							
PC	0.54	0.39	0.02	0.23	0.44	0.75	1.90
LL	0.59	0.37	0.05	0.32	0.53	0.75	2.39
STOCK	0.22	0.38	0	0.00	0.05	0.22	2.09
<b>Alternative measures for democracy</b>							
POLITY	6.10	5.86	−10	6	9	10	10
EXREC	8.87	2.33	1	2.29	10	10	10
EXCONST	8.13	2.75	1	1	10	10	10
POLCOMP	7.91	2.96	1	1	9	10	10
PR	2.39	1.81	1	1	1	4	7
<b>Control variables</b>							
R = RDPER	2.44	4.21	0.00	0.05	0.51	2.81	21.51
R= RDEXP	21,672	26,874	8	1,484	7,771	36,101	120,863
L	68,686	188,657	627	6,872	15,695	55,572	1,297,765
IPR	3.08	1.13	0	2.33	3.25	4.01	4.67
TRADE	0.32	0.67	0.00	0.03	0.10	0.28	4.70

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0–5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Number of observations = 257 (243 for PR and 247 for RDEXP). Each observation represents one country over the period of a year. Variable definitions are provided in Appendix B.

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE = Database of US Census Bureau and the database of the Center for International Data of UC Davis.

Summary statistics are reported in Table 1 (see Appendix B for variable definition). Table 2 reports the correlation matrix of the key variables, which indicates that positive and statistically significant pairwise correlations exist between knowledge accumulation and financial deepening and between knowledge accumulation and polity scores.

**Table 2: Correlation Matrix for Key Variables**

	<b>A</b>	<b>PC</b>	<b>LL</b>	<b>STOCK</b>	<b>POLITY</b>
PC	0.5483***	1			
LL	0.5459***	0.8719***	1		
STOCK	0.4841***	0.5009***	0.4001***	1	
POLITY	0.3147***	0.2965***	0.2271***	0.1501**	1
RDPER	0.4056***	0.2568***	0.1972***	0.2762***	0.0388
RDEXP	0.483***	0.3578***	0.2167***	0.3558***	0.1865***
L	-0.0925	-0.0028	0.0973	0.0671	-0.1575**
IPR	0.4474***	0.4989***	0.3968***	0.4436***	0.5389***
TRADE	0.3289***	0.3238***	0.2888***	0.2705***	0.0912
	<b>RDPER</b>	<b>RDEXP</b>	<b>L</b>	<b>IPR</b>	<b>TRADE</b>
PC					
LL					
STOCK					
POLITY					
RDPER	1				
RDEXP	0.5063***	1			
L	-0.1089*	-0.1886***	1		
IPR	0.3532***	0.3924***	-0.1285**	1	
TRADE	0.2149***	0.3412***	-0.1015	0.2765***	1

\* Significant at the 10% level; \*\* Significant at the 5% level; \*\*\* Significant at the 1% level.

<<list all abbreviations here and their definitions>>

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0—5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Number of observations = 257 (247 for RDEXP). Each observation represents one country over the period of a year.

Data sources: Same as Table 1.

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE=Database of US Census Bureau and the database of the Center for International Data of UC Davis.

## 4. EMPIRICAL RESULTS

### 4.1 Benchmark Results

Table 3 reports the empirical results of Equation (3) with  $R_{it}$  measured by R&D researchers per capita. Columns 1–3 report the direct effects of financial deepening and political democratization on knowledge accumulation without including the interaction terms between financial deepening and political democracy. Columns 4–6 report the results from the full model that includes the interaction term. The bottom of Table 3 provides the results of the Sargan test and the serial correlation test. The null hypothesis of the Sargan test is that the instruments used are not correlated with the residuals. The null hypothesis of the serial correlation test is that the errors in the first-difference regression exhibit no second-order serial correlation. Both tests failed to reject the null hypothesis and supported the validity of our results obtained using the system GMM estimation.

Columns 1–3 of Table 3 indicate that the coefficients of  $F_{it}$  are positive and significant regardless of which measure of financial deepening is used. Political democracy has a positive and significant effect on knowledge accumulation, suggesting that a higher level of political democracy promotes innovation efficiency. The coefficients of the other variables in all the regressions are of the expected signs. The coefficient of  $\ln R_{it}$  is positive and significant, suggesting that there is a decreasing return to scale for knowledge production and not all new knowledge duplicates existing knowledge. The coefficient of  $\ln L_{it}$  is negative and insignificant, suggesting that there is no significant effect of product proliferation/complexity decelerating the growth of knowledge as technology deepens. The coefficients of  $\text{IPR}_{it}$  and  $\text{InTRADE}_{it}$  are positive and significant, suggesting that countries that have a stronger domestic IPR protection and export to the US file more patent applications with the USPTO.

The primary results are reported in Columns 4–6. There is no qualitative change in the coefficients of the other variables even after the interaction term between  $P_{it}$  and  $F_{it}$  is included. The coefficients of the interaction term between  $P_{it}$  and  $F_{it}$  are positive and significant, but the coefficients of  $P_{it}$  become negative (Column 4–5) or less positive (Column 6). Our results support the hypothesis that political democracy has indirect effects on innovation through financial deepening. However, the direct effect of political democracy on innovation is weak. To clarify, political democratization promotes innovation primarily by improving the financing role that allows for the innovation of banking and stock markets.

Nonetheless, we must be careful regarding the interpretation of the overall effect of financial deepening on innovation efficiency because it depends on the level of political democracy as follows:

$$\text{Total effect of financial deepening} = \beta_1 F_{it} + \beta_3 F_{it} * P_{it}.$$

**Table 3: Baseline Results**

	(1)	(2)	(3)	(4)	(5)	(6)
	F=PC	F=LL	F=STOCK	F=PC	F=LL	F=STOCK
F	1.042** [0.455]	1.103** [0.464]	1.314*** [0.279]	-3.198** [1.270]	-2.062* [1.233]	0.220 [0.334]
F*P				0.374*** [0.133]	0.299*** [0.098]	0.091*** [0.027]
P	0.064* [0.032]	0.077** [0.033]	0.080** [0.034]	-0.087* [0.052]	-0.081 [0.051]	0.059* [0.030]
LnR	0.925*** [0.192]	0.986*** [0.180]	0.980*** [0.203]	0.960*** [0.158]	0.949*** [0.132]	0.959*** [0.130]
LnL	-0.060 [0.140]	-0.084 [0.148]	-0.096 [0.123]	0.160 [0.169]	0.146 [0.212]	-0.046 [0.119]
IPR	0.954*** [0.194]	0.838*** [0.252]	0.894*** [0.160]	0.550** [0.263]	0.552*** [0.161]	0.776*** [0.265]
LnTRADE	0.420** [0.174]	0.421* [0.214]	0.383** [0.190]	0.986*** [0.203]	0.702*** [0.212]	0.550*** [0.128]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	257	255	257	257	255	257
Number of countries	69	68	69	69	68	69
Sargan test	0.141	0.114	0.386	0.481	0.817	0.465
Arellano-Bond test for AR(2)	0.995	0.669	0.711	0.674	0.601	0.680
Threshold				8.541*** [1.052]	6.899*** [2.743]	-2.426** [4.185]

\* Significant at the 10% level; \*\* Significant at the 5% level; \*\*\* Significant at the 1% level.

<<please list in alphabetical order all abbreviations used in the table and their definitions here>>

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0–5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Figures in parentheses are standard errors corrected for heteroskedasticity. The political democracy P is the polity score. For Threshold, we conduct a two-sided hypothesis test with  $H_0$ : Threshold  $\leq -10$  versus  $H_1$ : Threshold  $> -10$ .

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE = Database of US Census Bureau and the database of the Center for International Data of UC Davis.

For example, when we examine the regression specification for  $F_{it}$  measured with the ratio of private credit to GDP in Column 4 of Table 3, the total effect of a one-unit increase in  $F_{it}$  on knowledge accumulation (in log form) ranges from  $-3.198+0.374^*$  ( $-10$ ) for countries with polity scores of  $-10$  to  $-3.198+0.374^*(10)$  for countries with polity scores of 10. Therefore, the total effect of financial deepening on innovation efficiency changes from negative to positive when the polity score  $P_{it}$  is greater than 8.541. In addition, the last row of Table 3 reports that the threshold 8.541 is significantly larger than the lower bound on the polity score, i.e.,  $-10$ . These results

suggest that there could exist thresholds of polity scores above which banking market deepening enhances innovation efficiency. Similar results were identified when the ratio of liquid liabilities to GDP was used as a measure for the depth of the formal financial intermediaries (see Columns 5 of Table 3). Interestingly, compared with the deepening of banking market and formal financial intermediaries, stock market deepening requires a much lower threshold of polity scores to enhance innovation efficiency (see Column 6 of Table 3). To clarify, the positive effect of stock market deepening on innovation efficiency applies to a wider set of countries. This result is consistent with Hsu et al. (2014), who demonstrated that on average, stock market deepening exhibits a more positive impact on promoting innovation.

Finally, it was unexpected that financial deepening deteriorates innovation efficiency when polity scores are low. Nonetheless, bank and stock markets only represent the formal finance sector of a country. In many developing countries, the informal finance sector commonly coexists with and complements the formal sector by serving private and small enterprises. The informal finance sector is perceived as having a comparative advantage in enforcement capacity and monitoring private and small enterprises (Stiglitz 1990). Expansion of a formal finance sector may worsen the terms of credit that are offered by informal lenders and, hence, the availability of loans in the informal finance sector. From this perspective and in light of the cross-country evidence that private enterprises rely more on informal financing and are more innovative than state-owned enterprises (Ayyagari et al. 2011), the impact of a deepening formal finance sector on innovation efficiency may be negative for developing countries that have a larger informal finance sector and a low level of political democracy.

## 4.2 Alternative Measure of Political Institutions

The previous subsection demonstrates that financial deepening requires a threshold polity score to foster innovation efficiency. As a robustness check, this subsection estimates our model with another commonly used measure of political democracy, the PR index published by Freedom House (2011). For instance, Acemoglu et al. (2008) use this variable with polity scores to measure political democracy.

The PR index measures the degree of freedom in the electoral process, political pluralism and participation, and government functioning. This index ranges from 1 to 7; a rating of 7 represents the least amount of political freedom, and a rating of 1 represents the most political freedom. A rating of 1 indicates free and fair elections, political competition, and autonomy for all citizens, including minority groups. A rating of 2 indicates that a country is less free, and corruption, violence, political discrimination against minorities, and military influence on politics may all exist. These same factors play a progressively larger role in countries with ratings of 3, 4, or 5: citizens of these countries typically experience certain political rights (e.g., freedom to organize somewhat controversial groups, reasonably free referenda) along with more damaging influences (e.g., civil war, heavy military involvement, one-party dominance). Countries and territories with political rights rated 6 are ruled by military juntas, one-party dictatorships, religious hierarchies, or autocrats; there may be a few local elections or limited minority representation. The political rights of countries with a rating of 7 are basically nonexistent due to extremely oppressive regimes, civil war, extreme violence, or warlord rule.

**Table 4: Alternative Measure of Political Institutions – Political Rights Index**

	(1)	(2)	(3)	(4)	(5)	(6)
	F=PC	F=LL	F=STOCK	F=PC	F=LL	F=STOCK
F	1.081** [0.519]	1.034* [0.573]	0.880*** [0.319]	1.660*** [0.584]	1.431** [0.595]	1.388** [0.633]
F*P				-0.631** [0.310]	-0.440** [0.195]	-0.187 [0.196]
P	-0.260** [0.106]	-0.193* [0.108]	-0.264** [0.129]	0.011 [0.182]	-0.020 [0.189]	-0.182 [0.157]
LnR	0.795*** [0.251]	0.816*** [0.202]	0.863*** [0.203]	0.732*** [0.213]	0.769*** [0.229]	1.069*** [0.220]
LnL	0.052 [0.159]	-0.057 [0.188]	-0.025 [0.157]	0.092 [0.163]	0.047 [0.185]	0.020 [0.199]
IPR	0.849*** [0.201]	0.725*** [0.206]	0.802*** [0.207]	0.654*** [0.196]	0.467** [0.192]	0.692** [0.284]
LnTRADE	0.567** [0.230]	0.663*** [0.245]	0.565*** [0.157]	0.815*** [0.180]	0.846*** [0.193]	0.581*** [0.197]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	243	241	243	243	241	243
Number of countries	66	65	66	66	65	66
Sargan test	0.211	0.0708	0.389	0.376	0.354	0.286
Arellano-Bond test for AR(2)	0.376	0.975	0.891	0.680	0.516	0.658
Threshold				2.631*** [1.086]	3.251** [1.875]	7.422 [5.993]

\* Significant at the 10% level; \*\* Significant at the 5% level; \*\*\* Significant at the 1% level.

<<please list all abbreviations used in the table (and their definitions) in alphabetical order here>>

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0–5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Figures in parentheses are standard errors corrected for heteroskedasticity. The political democracy P is PR index. For Threshold, we conduct a two-sided hypothesis test with  $H_0$ : Threshold  $\geq 7$  versus  $H_1$ : Threshold  $< 7$ .

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE = Database of US Census Bureau and the database of the Center for International Data of UC Davis.

We estimate Equation (3) by replacing the polity score with the PR index. The empirical results are provided in Table 4. The use of the PR index slightly reduces our sample size because the PR index has only been available since 1975. Encouragingly, the empirical results estimated with the PR index are consistent with those estimated using the polity score. Columns 1–3 of Table 4 report the results for the specifications without the interaction term of  $P_{it}$  and  $F_{it}$ . The positive and significant coefficient of  $F_{it}$  and the negative and significant coefficient of  $P_{it}$  suggest that financial deepening and political democratization foster innovation efficiency. Columns 4–6 of Table 4 include the



interaction term between  $P_{it}$  and  $F_{it}$ . The coefficients of that interaction term are negative and significant when  $F_{it}$  measures the depth of the banking market and the formal financial intermediary sector (see Columns 4–5); however, that coefficient is negative and insignificant when  $F_{it}$  measures the depth of the stock market (see Column 6). These results again suggest that banking market and formal financial intermediary sector deepening is associated with a higher innovation efficiency only when a country has enough political freedom; stock market deepening may improve innovation efficiency even for countries that have limited political freedom. These results are consistent with those reported in Table 3.

### 4.3 Alternative Measure of Research and Development Inputs

For the second robustness check, this subsection estimates Equation (3) using R&D expenditures per capita to measure  $R_{it}$ . These results are reported in Tables 5 and 6, where  $P_{it}$  indicates the polity score and PR index, respectively. Most of the coefficients reported in Table 5 are similar to those reported in Table 3, and most of the coefficients reported in Table 6 are similar to those reported in Table 4. Specifically, the results in Tables 5 and 6 again suggest that bank market and formal financial intermediary sector deepening requires sufficiently democratic institutions to foster innovation efficiency; however, stock market deepening requires a much lower or nonexistent democratic level of political institutions to foster innovation efficiency.

## 5. FURTHER ANALYSES

The earlier section demonstrates that our baseline specification used in subsection 4.1 was robust to the use of alternative measures of democracy and R&D inputs. Therefore, in this section, we conduct further analyses of the baseline specification and use the polity score to measure political democracy and the number of R&D personnel per capita to measure R&D inputs.

### 5.1 Component Analysis

Because we demonstrate the positive indirect effects of political democratization on knowledge accumulation through financial deepening and the polity score measures a country's political democratization based on three components, it would be helpful to understand which component of the polity score has the largest positive impact on the innovation-enhancing effect of financial deepening. Addressing this issue is important to help policy makers be more effective when reforming political institutions and to facilitate innovation.

We provide an empirical analysis of the components of the polity score, specifically the country's openness and competitiveness in executive recruitment of leaders, the constraint on executive authority and the competitiveness of political participation. Specifically, we estimate Equation (3) with each component of the polity score, including executive recruitment (EXREC), executive constraint (EXCONST), and political competition (POLCOMP), sequentially. The empirical results are reported in Table 7.

**Table 5: Alternative Measure of Research and Development Inputs – Research and Development Expenditure per Capita (P = polity score)**

	(1)	(2)	(3)	(4)	(5)	(6)
	F=PC	F=LL	F=STOCK	F=PC	F=LL	F=STOCK
F	0.904** [0.388]	0.875* [0.517]	0.623* [0.358]	-4.307** [1.978]	-3.107*** [1.133]	-1.251 [0.826]
F*P				0.470** [0.199]	0.396*** [0.139]	0.204** [0.096]
P	0.070* [0.036]	0.076** [0.033]	0.079** [0.032]	-0.113 [0.074]	-0.126 [0.068]	0.023 [0.043]
LnR	1.071*** [0.153]	1.111*** [0.203]	1.101*** [0.152]	0.897*** [0.273]	0.962*** [0.236]	1.022*** [0.259]
LnL	-0.077 [0.118]	-0.095 [0.108]	-0.090 [0.107]	0.019 [0.248]	0.063 [0.157]	-0.003 [0.139]
IPR	0.382* [0.205]	0.343 [0.228]	0.440** [0.214]	0.309** [0.132]	0.362 [0.223]	0.389 [0.276]
LnTRADE	0.245 [0.220]	0.204 [0.232]	0.211 [0.170]	0.728** [0.296]	0.590** [0.287]	1.022*** [0.259]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	247	245	247	247	245	247
Number of countries	67	66	67	67	66	67
Sargan test	0.179	0.169	0.155	0.110	0.154	0.277
Arellano-Bond test for AR(2)	0.316	0.378	0.369	0.143	0.313	0.397
Threshold				9.171*** [1.028]	7.839*** [1.246]	6.141*** [2.332]

\* Significant at the 10% level; \*\* Significant at the 5% level; \*\*\* Significant at the 1% level.

<<please list all abbreviations used in the table (and their definitions) in alphabetical order here>>

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0—5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Figures in parentheses are standard errors corrected for heteroskedasticity. The political democracy P is polity score. For Threshold, we conduct a two-sided hypothesis test with  $H_0$ : Threshold  $\leq -10$  versus  $H_1$ : Threshold  $> -10$ .

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE = Database of US Census Bureau and the database of the Center for International Data of UC Davis.

**Table 6: Alternative Measure of Research and Development Inputs – Research and Development Expenditure per Capita (P = PR index)**

	(1)	(2)	(3)	(4)	(5)	(6)
	F=PC	F=LL	F=STOCK	F=PC	F=LL	F=STOCK
F	0.809*	1.026*	0.641**	0.992***	2.425***	0.844**
	[0.517]	[0.568]	[0.319]	[0.321]	[0.627]	[0.381]
F*P				-0.472*	-0.585**	-0.079
				[0.230]	[0.247]	[0.108]
P	-0.191**	-0.205**	-0.211**	-0.009	0.068	-0.196*
	[0.082]	[0.088]	[0.098]	[0.170]	[0.187]	[0.102]
LnR	1.063***	1.088***	1.037***	1.045***	0.930***	0.977***
	[0.159]	[0.189]	[0.237]	[0.180]	[0.179]	[0.229]
LnL	-0.042	-0.051	-0.021	0.098	0.004	0.003
	[0.121]	[0.133]	[0.124]	[0.187]	[0.151]	[0.147]
IPR	0.444*	0.418*	0.478**	0.236	0.376*	0.566***
	[0.234]	[0.217]	[0.209]	[0.282]	[0.221]	[0.194]
LnTRADE	0.276	0.215	0.325	0.517*	0.392	0.394
	[0.193]	[0.193]	[0.292]	[0.283]	[0.284]	[0.325]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	234	232	234	234	232	234
Number of countries	64	63	64	64	63	64
Sargan test	0.528	0.466	0.508	0.123	0.130	0.256
Arellano–Bond test for AR(2)	0.315	0.381	0.279	0.483	0.768	0.210
Threshold				2.103***	4.143**	10.657
				[0.940]	[1.638]	[11.898]

\* Significant at the 10% level; \*\* Significant at the 5% level; \*\*\* Significant at the 1% level.

<<please list all abbreviations used in the table (and their definitions) in alphabetical order here>>

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0–5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Figures in parentheses are standard errors corrected for heteroskedasticity. The political democracy P is PR index. For Threshold, we conduct a two-sided hypothesis test with,  $H_0$ : Threshold  $\geq 7$  versus  $H_1$ : Threshold  $< 7$ .

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE = Database of US Census Bureau and the database of the Center for International Data of UC Davis.

**Table 7: Component Analysis (P = Polity score)**

	(1) F=PC P=EXREC	(2) F=PC P=EXCONST	(3) F=PC P=POLCOMP	(4) F=LL P=EXREC	(5) F=LL P=EXCONST
F	-12.537** [6.245]	-4.418* [2.493]	-1.061 [0.980]	-11.912** [5.232]	-2.468*** [0.752]
F*P	1.405** [0.577]	0.552** [0.244]	0.199** [0.078]	1.331** [0.528]	0.370*** [0.086]
P	-0.289 [0.234]	-0.086 [0.112]	0.060 [0.090]	-0.428** [0.148]	-0.038 [0.084]
LnR	0.965*** [0.223]	0.894*** [0.238]	1.030*** [0.242]	0.927*** [0.218]	0.826*** [0.210]
LnL	0.120 [0.190]	-0.039 [0.180]	-0.042 [0.137]	0.154 [0.208]	-0.076 [0.153]
IPR	0.553** [0.251]	0.848*** [0.223]	0.819*** [0.267]	0.533 [0.322]	0.787*** [0.200]
LnTRADE	0.651** [0.295]	0.657*** [0.242]	0.470** [0.228]	0.530** [0.202]	0.676*** [0.213]
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	257	257	257	255	255
Number of countries	69	69	69	68	68
Sargan test	0.458	0.448	0.101	0.269	0.148
Arellano-Bond test for AR(2)	0.872	0.335	0.745	0.978	0.799
Threshold	8.926*** [0.901]	8.005*** [1.249]	5.321* [3.277]	8.952*** [0.608]	6.669*** [1.223]
	(6) F=LL P=POLCOMP	(7) F=STOCK P=EXREC	(8) F=STOCK P=EXCONST	(9) F=STOCK P=POLCOMP	
F	-1.852 [1.113]	-4.779 [2.918]	-0.979* [0.562]	1.046*** [0.299]	
F*P	0.291** [0.123]	0.575* [0.295]	0.202*** [0.062]	0.047 [0.032]	
P	0.006 [0.115]	0.113 [0.088]	0.105 [0.069]	0.171*** [0.057]	
LnR	0.898*** [0.233]	1.002*** [0.170]	0.935*** [0.127]	0.874*** [0.184]	
LnL	-0.002 [0.158]	-0.032 [0.132]	-0.065 [0.127]	-0.111 [0.101]	
IPR	0.724*** [0.246]	0.976*** [0.174]	0.860*** [0.209]	0.793*** [0.214]	
LnTRADE	0.648*** [0.206]	0.417** [0.159]	0.568*** [0.132]	0.449*** [0.120]	
Country FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Observations	255	257	257	257	
Number of countries	68	69	69	69	
Sargan test	0.215	0.294	0.262	0.732	
Arellano-Bond test for AR(2)	0.961	0.937	0.916	0.950	
Threshold	6.368*** [1.726]	8.309*** [0.897]	4.846*** [1.554]	-22.211 [19.336]	

\* Significant at the 10% level; \*\* Significant at the 5% level; \*\*\* Significant at the 1% level.

<<please list all abbreviations used in the table (and their definitions) in alphabetical order here>>

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0–5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Figures in parentheses are standard errors corrected for heteroskedasticity. For Threshold, we conduct a two-sided hypothesis test with  $H_0$ : Threshold  $\leq 1$  versus  $H_1$ : Threshold  $> 1$ .

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE = Database of US Census Bureau and the database of the Center for International Data of UC Davis.

Columns 1–3 of Table 7 indicate that all components of the polity score have positive indirect effects on innovation efficiency when  $F_{it}$  is measured by the ratio of private credit by banks to GDP. Among the three components of the polity score, EXREC has the largest indirect effect on innovation efficiency through banking system deepening, and POLCOMP has the smallest indirect effect on innovation efficiency through banking system deepening. Our results suggest that increasing a government's openness and competitiveness in executive recruitment for the leaders is more effective in fostering the positive effect of banking system deepening on innovation efficiency.

In analyzing the thresholds mentioned above that the three components of polity score will promote innovative efficiency, we demonstrate that the thresholds for those three components are similar to each other. Because the range of EXREC in the dataset is [1,10], the total effect of a one-unit increase of  $F_{it}$  on knowledge accumulation (in log form) ranges from  $-12.537+1.405$  to  $-12.537+1.405*10$ . Therefore, banking market deepening is associated with greater innovation efficiency only when a country's EXREC score is greater than 8.926. Similarly, banking market deepening is associated with greater innovation efficiency only when a country's EXCONST and POLCOMP scores are greater than 8.005 and 5.321, respectively.

Furthermore, when we use the ratio of liquid liabilities to GDP as an alternative measure of banking market deepening, we obtain similar results. The coefficients of the interaction term of  $F_{it}$  and  $P_{it}$  remain positive and significant (see columns 4–6 of Table 7).  $EXREC_{it}$  still has the largest complementary impact on the innovation-enhancing effect of banking market deepening and continues to have the highest threshold among the three components of the polity score. When we use the ratio of stock market capitalization to GDP to measure  $F_{it}$ , the coefficients of the interaction term of  $F_{it}$  and  $P_{it}$  (see columns 7–9 of Table 7) are smaller and less significant than those in columns 1–6 of Table 7, which again suggest that the innovation-enhancing effect of stock market deepening is less dependent on political democracy.

Overall, among the components of the polity score, we demonstrate that executive recruitment induces a larger positive effect of financial deepening on innovation than executive constraint and political competition. Our results provide new information regarding how countries sustain economic growth by reshaping their political institutions to enhance their innovation efficiency. A higher score on executive recruitment is associated with more openness and competitiveness in recruiting executives, such as transparency in executive recruitment and candidates competing for positions in all important aspects, which could hinder political leaders from developing large networks of power and restrict entry of financial intermediation into the marketplace because of self-interest. As a result, our results suggest that improving the openness and competitiveness of executive recruitment is a more effective method for countries to reform their political institutions to sustain economic growth by enhancing their innovation efficiency.

## 5.2 Heterogeneity across Income Level

This subsection reviews the subsample analyses that were conducted according to the income level of our sample countries. We first divide all observations according to their GDP per capita into two groups: low income and high income. These two groups differ in several important dimensions. Countries with lower incomes possess less knowledge stock and a lower polity score than countries with higher incomes.

**Table 8: Subsample Analysis by Income Level (P = Polity score)**

	(1)	(2)	(3)	(4)	(5)	(6)
	F=PC	F=PC	F=LL	F=LL	F=STOCK	F=STOCK
	Low Income	High Income	Low Income	High Income	Low Income	High Income
F	-2.873*	10.450*	0.622	4.336	-3.051	3.985**
	[1.637]	[5.561]	[0.696]	[7.624]	[2.273]	[1.794]
F*P	0.671**	-1.035*	0.125**	-0.295	0.592**	-0.346*
	[0.255]	[0.553]	[0.060]	[0.767]	[0.254]	[0.174]
P	-0.165	1.119***	0.017	0.561	0.010	0.515***
	[0.155]	[0.395]	[0.052]	[0.691]	[0.065]	[0.103]
LnR	0.730*	0.597	0.571*	0.896**	1.030**	0.753**
	[0.415]	[0.569]	[0.286]	[0.436]	[0.482]	[0.365]
LnL	0.232	0.115	0.036	0.004	0.071	0.073
	[0.326]	[0.283]	[0.180]	[0.266]	[0.264]	[0.243]
IPR	0.184	0.147	0.903***	0.015	0.396	-0.277
	[0.631]	[0.337]	[0.312]	[0.398]	[0.751]	[0.339]
LnTRADE	0.940*	1.413**	0.400	1.036***	0.878**	1.294**
	[0.544]	[0.626]	[0.365]	[0.325]	[0.340]	[0.473]
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	128	129	128	127	128	129
Number of countries	47	29	47	28	47	29
Sargan test	0.969	0.952	0.0590	0.681	0.995	0.866
Arellano–Bond test for AR(2)	0.660	0.260	0.804	0.944	0.485	0.350

\* Significant at the 10% level; \*\* Significant at the 5% level; \*\*\* Significant at the 1% level.

<<please list all abbreviations used in the table (and their definitions) in alphabetical order here>>

A = the number of the stock of patents granted by USPTO from year 1883 to each country in the current year (normalized by population), EXCONST = a component of POLITY: the constraint on executive authority, EXREC = a component of POLITY: the state's openness and competitiveness in executive recruitment, IPR = Intellectual property rights protection index (range 0–5), L = Total population (in 1,000), LL = the ratio of liquid liabilities to GDP, PC = the ratio of private credit by deposit money banks to GDP, PR = the Political Rights (FHPR) Index, POLCOMP = a component of POLITY: the competitiveness in political, POLITY = the Polity score, RDEXP = R&D expenditures per capita (in \$), RDPER = Number of R&D researchers per 1,000 people, STOCK = the ratio of stock market capitalization to GDP, TRADE = Exporting volume to the United States (US) (normalized by total population; in \$1,000).

Note: Figures in parentheses are standard errors corrected for heteroskedasticity. The political democracy P is the polity score. Low Income includes observations with GDP per capita that belong to the lower half of our sample, whereas High Income includes observations with GDP per capita that belong to the upper half of our sample.

Data Source: A = The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers, 2011); IPR = Park (2008); L = Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank (November 2013 version); PR = Freedom House (2011); RDPER and RDEXP = Lederman and Saenz (2005) and UNESCO; TRADE = Database of US Census Bureau and the database of the Center for International Data of UC Davis.

We estimate Equation (3) for these two subsamples, and the results are provided in Table 8. The results for countries with lower incomes are consistent with those for our full sample. Our results suggest that countries with lower incomes can improve the innovation-enhancing effect of financial deepening by increasing their political democracy. As these countries become wealthier, they will increase their knowledge stock and develop more democratic political intuitions; the innovation-enhancing effect of stock market deepening is stronger than for banking market deepening. Furthermore, there is no variation in political democracy among most of our sample countries with higher incomes. We suggest that the innovation-enhancing effect of

financial deepening does not depend on political institutions because countries with higher incomes possess similar political institutions. This situation is similar to that evaluated in Hsu et al. (2014) for 32 developed and emerging economies.

Our results provide new information regarding how developing countries can sustain their economic growth. For example, Asian economies such as Japan, the Republic of Korea, Singapore, and Taipei, China developed into high-income economies with high innovative capacities after World War II. However, other Asian economies appear to suffer from the symptoms of the middle-income trap. Agenor (2017) argues that Malaysia (with a real GDP per capita of approximately \$11,000 in 2005 in constant 2005 international dollars) employs a growth strategy that does not encourage innovation, which hinders its ability to overcome the middle-income trap.

Private credit to GDP ratio of Malaysia increased from 1.018 in 2005 to 1.051 in 2010. Our results support this conclusion because the polity score remained unchanged between 2005 and 2010 at the value of 3, and the steady-state knowledge stock decreased by 2.84%. Banking market deepening slightly decreases innovation efficiency because the polity score is lower than the threshold. If the polity score had increased from 3 to 10 during 2005–2010, the steady-state knowledge stock could have increased by 375.31%. Consequently, the economic performance of Malaysia could have been greatly enhanced due to a larger knowledge stock.

## 6. CONCLUSIONS

This study analyzes a large international panel of data to examine the effects of financial deepening and political democratization on innovation. We demonstrate that financial deepening promotes innovation only when a country's political institutions are sufficiently democratic. This result is stronger for countries with lower incomes than for countries with higher incomes. We also determine that, among the components of the polity score, executive recruitment induces a larger positive indirect effect of financial deepening on innovation than executive constraint and political competition.

Our empirical results provide implications for innovation policy, which should be of interest to policy makers, particularly in developing countries that seek to sustain economic growth by fostering innovation. When policy makers evaluate the benefits of reforming political institutions, such as liberalizing the executive recruitment process, they should consider the complementary effects of this reform on innovation. Specifically, if a country that has a bank-based financial system seeks to promote innovation, it is important for this country to enhance its political democracy and deepen its financial system.

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## APPENDIX A: SAMPLE COUNTRIES

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Argentina	Denmark	Ireland	Nicaragua	Spain
Australia	Ecuador	Israel	Nigeria	Sri Lanka
Austria	Egypt	Italy	Norway	Sudan
Bangladesh	El Salvador	Jamaica	Pakistan	Swaziland
Belgium	Ethiopia	Japan	Panama	Sweden
Bolivia	Finland	Jordan	Paraguay	Switzerland
Brazil	France	Korea, Republic of	Peru	Thailand
Bulgaria	Ghana	Lithuania	Philippines	Tunisia
Canada	Greece	Madagascar	Poland	Turkey
People's Republic of China	Guatemala	Malaysia	Portugal	Uganda
Colombia	Hungary	Mauritius	Russian Federation	Uruguay
Costa Rica	India	Mexico	Senegal	Viet Nam
Cyprus	Indonesia	Netherlands	Singapore	Zambia
Czech Republic	Iran	New Zealand	South Africa	

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## APPENDIX B: VARIABLE DEFINITIONS

Variable	Definition	Source
A	The number of stock of patents granted by the USPTO from 1883 to each country in the current year (normalized by total population)	WIPO Statistics Database and USPTO Patent Statistics
<b>Alternative measures for financial development</b>		
PC	The ratio of private credit by deposit money banks to GDP	Database of Financial Development and Structure provided by the World Bank (November 2013 version)
LL	The ratio of liquid liabilities to GDP	Same as above
STOCK	The ratio of stock market capitalization to GDP	Same as above
<b>Alternative measures for democracy</b>		
POLITY	The Polity score	Polity IV: Political Regime Characteristics and Transitions, 1800–2010 (Marshall and Jaggers 2011)
EXREC	A component of POLITY: The state's openness and competitiveness in executive recruitment	Same as above
EXCONST	A component of POLITY: The constraint on executive authority	Same as above
POLCOMP	A component of POLITY: The competitiveness in political participation	Same as above
PR	The Political Rights (FHPR) Index	Freedom House (2011)
<b>Control variables</b>		
R = RDPER	Number of R&D researchers per 1,000 people	Lederman and Saenz (2005) and UNESCO
R= RDEXP	R&D expenditures per capita (in \$)	Same as above
L	Total population (in 1,000)	Penn World Table 7.1
IPR	Intellectual property rights protection index (range 0–5)	Park (2008)
TRADE	Exporting volume to the United States (US) (normalized by total population; in \$1,000)	Database of US Census Bureau and the database of the Center for International Data of UC Davis

GDP = gross domestic product, R&D = research and development, USPTO = United States Patent and Trademark Office, WIPO = World Intellectual Property Organization.

Data Source: A=The WIPO Statistics Database and USPTO Patent Statistics; POLITY, EXREC, EXCONST and POLCOMP = Polity IV: Political Regime Characteristics and Transitions, 1800-2010 (Marshall and Jaggers, 2011); IPR= Park (2008); L= Penn World Table 7.1; LL, PC, and STOCK = The database of Financial Development and Structure provided by the World Bank(November 2013 version); PR=Freedom House (2011); RDPER and RDEXP=Lederman and Saenz (2005) and UNESCO; TRADE=Database of US Census Bureau and the database of the Center for International Data of UC Davis.