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Financial development, liberalization and technological deepening

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ABSTRACT

This paper focuses on examining the effects of financial development and liberalization on knowledge accumulation. The results consistently show that while financial development facilitates the accumulation of new ideas, the implementation of financial reform policies is negatively associated with it. The undesirable effects of financial liberalization are found to operate through the triggering of crises and volatility in the financial system. There is also evidence supporting the hypothesis that financial liberalization reallocates talent from the innovative sector to the financial system, thus retarding technological deepening. Moreover, the findings also suggest that increased R&D activity and the presence of a stronger intellectual property rights protection framework tend to have beneficial effects on knowledge accumulation.

1. Introduction

Following the seminal contributions of Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992), the economics of ideas and technology have become the central focus in the literature of economic growth in recent years. The generation of ideas is strongly related to the process of technological change since new ideas improve the technology of production. Moreover, fluctuations in innovative activity closely follow productivity patterns. Thus, a better understanding of what determines the creation of knowledge is important, given that changes in the rates of innovation may explain productivity accelerations and slowdowns (Jones, 2002; Bottazzi and Peri, 2007).

Recent contributions in the theoretical growth literature have emphasized the importance of finance and R&D efforts in explaining productivity growth. In the models developed by Blackburn and Hung (1998), Aghion et al. (2005) and Aghion and Howitt (2009), the relationship between finance and growth is analyzed in the context of innovation-based growth models. These models predict that financial market imperfections increase the costs of monitoring and thus encourage the hiding of successful inventions so that firms can avoid loan repayments. The removal of these restrictions encourages more ideas to be produced and patented, thus deepening the technological sector. Hence, a positive relationship between finance and innovative production is predicted.

While the above studies assign an important theoretical role to finance in facilitating innovative production, so far there has been little empirical analysis conducted to examine the impact of financial development and financial liberalization under these innovation-driven growth frameworks. Moreover, although studies have demonstrated that financial development (and in some cases financial liberalization) tends to exert a beneficial impact on economic growth

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(see, e.g., Demetriades and Hussein, 1996; Arestis and Demetriades, 1997; Beck and Levine, 2004), little is known about how innovative production responds to changes in the development and policy environment in financial systems.

Against this backdrop, this paper seeks to provide an empirical assessment of the determinants of knowledge accumulation across countries by focusing on the roles of financial sector reforms and financial development. This issue deserves attention because if financial development and financial liberalization do have the potential to improve a country's growth performance, then it is vital to understand the mechanisms by which they can be enhanced and made more effective. Moreover, understanding the mechanisms through which finance affects growth performance allows policymakers to evaluate the costs and benefits associated with liberalising and deepening financial systems. The next section sets out the analytical framework underlying our empirical modeling strategy.

2. Analytical framework

The important role of innovative efforts as a driver of long-term growth has been highlighted by recent contributions in the theories of endogenous growth. To illustrate, let us consider a simple production function where total output (Y_t) produced at time t is given by

$$Y_t = A_t^{\sigma} K_t^{\alpha} L_t^{1-\alpha}, \quad \sigma > 0, \quad 0 < \alpha < 1, \tag{1}$$

where A_t is the total stock of knowledge or ideas available in the economy, K_t is physical capital and L_t is the labor force. There are constant returns to scale in K_t and L_t holding A_t unchanged, and increase in returns to A_t, K_t and L_t together. Expressing Eq. (1) in per worker terms yields the following:

$$y_t = A_t^{\sigma} k_t^{\alpha}, \quad \sigma > 0, \quad 0 < \alpha < 1, \tag{2}$$

where $y_t = Y_t/L_t$ and $k_t = K_t/L_t$. Taking logs and differentiation on both sides, the growth rate of output per worker in period t can be written as

$$\frac{\dot{y}_t}{y_t} = \sigma \frac{\dot{A}_t}{A_t} + \alpha \frac{\dot{k}_t}{k_t}, \tag{3}$$

Along a balanced growth path, the growth rate of output per worker is given by

$$g_y = \frac{\sigma}{1-\alpha} g_A. \tag{4}$$

From the above, it is clear that the accumulation of ideas is an important driver for long-term growth. According to the ideas production function of Romer (1990), the rate at which new ideas are discovered depends on the amount of resources devoted to the discovery of new ideas and the stock of existing ideas. Under this innovation-based growth framework, R&D activity is a key determinant of the generation of new ideas. Researchers interested in profiting from their inventions will continue to search for new ideas. However, the model does not consider the secrecy of inventions and property rights protection since it is assumed that researchers can take advantage of having free access to the entire stock of knowledge (Romer, 1990). To the extent this assumption is not valid, the consideration of these factors is important given that the ability to conceal successful innovations or enjoy some monopolistic power over new inventions can significantly affect the rate of discovery of new ideas.

Recent developments in the theories of endogenous growth emphasize that the undesirable effects of secrecy on innovative production can be mitigated through deepening the financial system. For example, using a product variety model, Blackburn and Hung (1998) propose that firms have incentives to hide successful R&D projects to avoid repaying their loans. Such a problem of moral hazard gives rise to the enforcement of incentive-compatible loan contracts through costly monitoring systems. In their model, financial development allows financial intermediaries to diversify among a large number of projects, thus significantly reducing delegation costs. The lower costs of monitoring spur ideas production and technological development.

In a similar vein, the Schumpeterian growth models with credit constraints developed by Aghion and Howitt (2009) show that financial development results in lower screening and monitoring costs, thus mitigating agency problems and increasing the frequency of innovations. In the innovation-based growth model developed by Aghion et al. (2005), it is also argued that firms can conceal the results of successful innovations and thereby avoid repaying their creditors. A low degree of creditor protection, which is often associated with financial market underdevelopment, makes fraud an inexpensive option, thus retarding the production of new ideas. In contrast, financial development and liberalization tend to increase the hiding costs by providing better laws and institutions, thus encouraging innovative entrepreneurs to produce and patent more new ideas.

Another key aspect is the legal system, which can be used as a mechanism to influence the degree of excludability of ideas so that the strengthening of a patent protection framework may stimulate the incentives to innovate (Gould and Gruben, 1996). Given that the production of ideas generally involves large one-time costs (initial layout) to create inventions, inventors are not willing to incur these costs unless the resulting profits can be captured. A higher degree of intellectual property rights protection provides legal mechanisms to influence the degree of excludability of ideas, thereby strengthening the incentive for inventors to create new ideas (Jones, 2002).

Using a quality-ladder model, O'Donoghue and Zweimüller (2005) show that protection against future imitators can stimulate innovative investment. In their model, patent policy is also useful in counteracting entrepreneurs' inclination to pursue suboptimal innovations. In the model of Grossman and Helpman (1991), the assumption of intellectual property rights protection is essential in ensuring that every industry has a unique quality ladder. These arguments underlie North's (1981) thesis that the development of systematic property rights in innovation is largely responsible for the increase in the private rate of return on developing new techniques, which subsequently results in sustained innovation and the formation of modern economic growth.

Based on the above considerations, the amount of new ideas generated ($\mathring{A}_t$) can be treated as the output of an ideas production process that uses R&D (R_t) and the ideas that have been discovered so far (A_t) as the key inputs, and that the incentive to produce new ideas is governed by the efficiency of the financial system (F_t) and the strength of the patents protection framework (P_t). Accordingly, the ideas production process can be characterized as follows[1]:

$$\mathring{A}_t = \lambda R_t^{\delta} A_t^{\phi} F_t^{\theta} P_t^{\pi}, \quad 0 < \delta \leq 1, \quad \phi < 1, \quad \theta > 0, \quad \pi > 0. \tag{5}$$

In a steady state, if the growth rate of ideas accumulation ($\mathring{A}_t/A_t$) is stationary, as confirmed by the empirical findings of Bottazzi and Peri (2007), Ha and Howitt (2007), Ang and Madsen (in press) and Madsen et al. (2010), the stock of ideas converges to a stochastic balanced growth path. We take logs and solve the model to obtain a specification suitable for empirical estimation. In the following steady-state relationship, we interpret $\ln R_t$, $\ln F_t$ and $\ln P_t$ as the long-run forcing variables explaining the behavior of $\ln A_t$:

$$\ln A_t = \beta_0 + \beta_R \ln R_t + \beta_F \ln F_t + \beta_P \ln P_t + \varepsilon \tag{6}$$

The above equation underscores the importance of finance in determining the development of new technology and scientific knowledge. However, despite the above discussions suggesting that financial development is likely to facilitate ideas production through reducing monitoring costs and moral hazard problems, how financial liberalization affects innovation is less clear. There is an active debate in the literature regarding the theoretical role of financial liberalization on aggregate growth. For instance, while the McKinnon–Shaw financial liberalization thesis predicts a positive effect of financial liberalization, alternative theories of Stiglitz and Weiss (1981) and Stiglitz (2000) do not suggest positive growth effects following financial reforms. The latter is broadly consistent with the empirical findings of Demetriades et al. (1998) and Arestis et al. (2003), who show that some forms of financial restraints have positive effects on productivity or economic efficiency . Furthermore, a growing empirical literature finds mixed results regarding the effects of financial liberalization on growth (see Eichengreen (2002) for a recent survey).

In fact, there are some arguments against the positive role of financial liberalization in the innovative sector. Using a dynamic stochastic oligopoly model, Stadler (1992) shows that the optimal innovative output is inversely related to interest rates. This proposition is feasible given that a reduction in interest rate restraints, which is often associated with financial liberalization, generally results in higher costs of capital, thereby impeding innovative production in the technological sector. Furthermore, directed credit programs may lead to increased investment in the targeted sectors (Schwarz, 1992). If more funds are allocated to the high-tech sector, an economy-wide increase in innovative output will be expected. Moreover, in principle, financial liberalization can also retard technological deepening indirectly through discouraging savings (Stiglitz, 1994; Bandiera et al., 2000), triggering financial instability (Demirguc-Kunt and Detragiache, 1998; Kaminsky and Reinhart, 1999; Stiglitz, 2000) and reallocating talent from the technology sector to the financial sector (Murphy et al., 1991; Acemoglu, 1995). Section 5 provides more detailed discussion. Given the above, it appears that the impact of financial liberalization on knowledge accumulation is theoretically ambiguous and is therefore an empirical matter.

The above also suggests that financial development and financial liberalization are two different variables capturing distinct aspects of finance that could impact on innovative production. Although the literature has focused on either the effect of financial liberalization or financial development on growth, so far there has been little attempt to consider both factors under an integrated framework. A more satisfactory approach to assessing the effects of finance on technological deepening should explicitly account for both the effects of deepening in financial systems and the policies pursued. This would provide a more complete analysis of the role of finance in facilitating technological deepening. A recent contribution by Ang (2010a) focusing on India shows that while financial development helps to reduce income inequality, financial liberalization has the opposite effect. Similarly, Ang (in press) finds that although financial development encourages private savings in Malaysia, financial liberalization tends to exert a dampening effect. These findings suggest that focusing on the effects of financial development on knowledge creation without taking into account the policies that are being pursued can produce misleading conclusions. Hence, we will consider the individual and the joint effects of these two financial variables.

[1] Following the findings of Jones (1995) that increases in R&D activity in the OECD are not matched by higher productivity growth rates, the assumption of constant returns to knowledge ($\phi = 1$) in Romer's (1990) model is no longer an acceptable empirical regularity. Therefore, following the suggestion of Jones (1995) we assume diminishing returns to knowledge ($\phi < 1$).

3. Data and construction of variables

The ideas accumulation function in Eq. (6) will be estimated using the data for 44 countries (including 22 OECD and 22 non-OECD countries) over the period 1973–2005. Patent data are widely used in the literature to capture the production of ideas (see, e.g., Kortum, 1993; Madsen, 2008). To the extent that the most valuable and commercially viable ideas are patented, patent counts may provide a reasonable measure of the number of ideas innovated. Of course, patent data also suffer from some shortcomings in that not all ideas are patented and patent counts do not provide the economic value of patents. The stock of inventive output or knowledge (A_t) is constructed based on the number of domestic patents applied for ($\mathring{A}_t$). Data from the first available year for each country are used to get as precise a measure as possible of the knowledge stock in 1973. The initial knowledge stock is estimated to be $A_0 = \mathring{A}_0/(\delta+g)$, where the depreciation rate δ is assumed to be 10% and g is the average growth in number of patents filed over the period considered. This gives the steady-state stock of ideas in the standard neoclassical growth models. Patent stock is then computed using the perpetual inventory method with a depreciation rate of 10%. The data are obtained from the World Intellectual Property Organization (WIPO).

For the measurement of patent rights protection (P_t), we use the patent rights index compiled by Ginarte and Park (1997). The index covers five dimensions: (1) patentability of various kinds of inventions, (2) membership in international patent arrangements, (3) provisions for loss protection, (4) enforcement mechanisms and (5) duration of the patent term. Each dimension is assigned a value ranging from zero to one. The unweighted sum of these five values provides an indication of the overall level of intellectual property rights protection, with higher values reflecting greater levels of protection. The updated dataset is reported for every five years to 2005. It is interpolated to obtain annual series.

We use R&D expenditures deflated by the GDP price deflator as the proxy for R&D input (R_t). A majority of the countries do not have continuous R&D data from 1973, especially the non-OECD ones. We have therefore followed the standard practice in the literature including only countries for which R&D data are sufficiently available and interpolated some of the missing years. The data are mainly obtained from various issues of the UNESCO Statistical Yearbook. Data for China are obtained from various issues of the "China Statistical Yearbook" and the "S&T Statistics Data Book", and for India from various issues of "R&D Statistics". Data for OECD countries are supplemented by the "Main Science and Technology Indicators" published by the OECD.

As discussed earlier, we consider both financial development and liberalization to capture the effects of finance (F_t) on knowledge accumulation. We use the ratio of private credit to GDP as the proxy for financial development (see, e.g., Ang and McKibbin, 2007; Baltagi et al., 2009). Private credit includes total lending extended by financial intermediaries (excluding the central banks and development banks) to the private sector. It does not consider credits issued to the public sector or state-owned enterprises. Beck et al. (2007) argue this is a more precise measure of financial development compared to alternative indicators such as M2 over GDP or the ratio of commercial bank assets to commercial bank plus central bank assets.

Financial liberalization is measured by an index capturing several types of policy changes in the financial environment. We consider a broad-based measure of financial liberalization compiled recently by Abiad et al. (2010). They consider seven policy dimensions as the inputs to construct the summary index: (1) credit controls and reserve requirements; (2) interest rate restraint; (3) entry barriers in the banking sector; (4) prudential regulations and supervision; (5) privatization in the financial sector; (6) restrictions on international capital flows; and (7) securities market policy. Along each dimension, a score of zero, one, two or three is assigned, indicating fully repressed, partially repressed, partially liberalized and fully liberalized, respectively. The aggregation of these seven components is used to obtain an overall measure that captures changes in the policy environment of the financial system.

Table 1 shows the changes of the key variables used in the empirical analysis. It is evident that all variables show a significantly larger increase in the non-OECD sample, except the indicator of financial development. Moreover, the strong increases in these variables suggest that they could be non-stationary cointegrated over time. To confirm this, we perform formal unit root and cointegration tests in the next section.

Table 1
Changes in key variables (1973–2005).

Last/initial year	All countries (N=44)	OECD (N=22)	Non-OECD (N=22)
Patent stock	18.99	3.61	34.36
Real R&D expenditure	48.36	16.43	85.92
Patent protection	2.47	1.77	3.18
Financial liberalization	6.54	3.69	9.40
Financial development	2.66	2.84	2.48

Notes: the OECD includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, South Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States; the non-OECD includes Argentina, Bolivia, Brazil, Chile, China, Colombia, Costa Rica, Ecuador, Egypt, India, Indonesia, Jordan, Malaysia, Mexico, Pakistan, Peru, the Philippines, Singapore, South Africa, Sri Lanka, Uruguay and Venezuela. Since financial liberalization indices are zero in 1973 for several countries, we divide the 2005 value with the first available non-zero value.

4. Results

4.1. Integration and cointegration analyses

The integration properties of the underlying variables are examined using several panel unit root tests, including that of Im et al. (2003) (IPS), and the Fisher-type tests using the ADF and PP tests of Maddala and Wu (1999) (MW) and Choi (2001), respectively. The results reported in Table 2 show that all variables appear to contain a unit root, or $I(1)$, at the 5% significance levels in all cases for the sample that includes all 44 countries. That is, the variables appear to follow a non-stationary process in levels but they achieve stationarity after taking a first difference. With only one exception, we obtain the same findings that all variables are integrated at order one in the sub-samples that consider only the OECD or non-OECD ones. The results (not reported) are largely invariant to the use of alternative decision rules of 1% or 10%. Therefore, we conclude that the levels' variables are non-stationary but their growth rates are stationary.

To confirm the presence of a steady-state relationship as stated in Eq. (6), we perform the panel cointegration tests of Pedroni (2004). The results are reported in Table 3. It contains six columns, where each column corresponds to the estimation results using different cointegration approaches detailed in Pedroni (2004). As is evident, the null hypothesis of no cointegration is strongly rejected at the 5% level of significance, regardless of whether the availability of finance is measured by financial development or financial liberalization (Models I and II). Strong evidence of cointegration is also found when both financial development and financial liberalization are considered in the same specification (Model III). On the whole, our results are not sensitive to the types of cointegration tests considered and the grouping of countries. Taken together, these results suggest the presence of a robust long-run relationship for the variables stated in Eq. (6).

Table 2
Unit root tests.

	Containing a unit root?								
	All countries (N=44)			OECD (N=22)			Non-OECD (N=22)		
	IPS	MW	Choi	IPS	MW	Choi	IPS	MW	Choi
Patent stock	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Real R&D expenditure	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Patent protection	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Financial liberalization	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Financial development	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: a trend term is included in the estimations that involve the levels of the variables but not the differenced variables. The unit root tests are based on a 5% decision rule. For the Im–Pesaran–Shin (IPS) and Maddala–Wu (MW) tests, SBC is used as the autocorrelation correction method. The Barlett–Kernel is used as the spectral estimation method and the bandwidth is selected using the Newey–West procedure for the Choi test. All variables are expressed in natural logarithms.

Table 3
The Pedroni panel cointegration tests.

	Evidence of cointegration at the 5% level of significance?					
	Panel rho-statistic	Panel PP-statistic	Panel ADF-statistic	Group rho-statistic	Group PP-statistic	Group ADF-statistic
Model I (excluding financial liberalization)						
All countries	Yes	Yes	Yes	Yes	Yes	Yes
OECD	Yes	Yes	Yes	Yes	Yes	Yes
Non-OECD	Yes	Yes	Yes	Yes	Yes	Yes
Model II (excluding financial development)						
All countries	Yes	Yes	Yes	Yes	Yes	Yes
OECD	Yes	Yes	Yes	Yes	Yes	Yes
Non-OECD	Yes	Yes	Yes	Yes	Yes	Yes
Model III (including all variables)						
All countries	Yes	Yes	Yes	Yes	Yes	Yes
OECD	Yes	Yes	Yes	Yes	Yes	Yes
Non-OECD	Yes	No	Yes	Yes	Yes	Yes

Notes: The full model (i.e., Model III) includes the stock of knowledge, real R&D expenditure, patent protection index, financial liberalization and financial development. An intercept but not a time trend was included in the estimation. The optimal lag length was chosen using SBC. Barlett–Kernel was used as the spectral estimation method and the bandwidth was selected using the Newey–West method. All variables are expressed in natural logarithms.

4.2. Long-run panel DOLS estimates

Having established evidence of cointegration, we proceed to deriving the long-run estimates using the within-dimension panel DOLS estimator of Kao and Chiang (2000). The *t*-statistics of this estimator have been found to have smaller size distortions compared to the panel FMOLS estimator of Pedroni (2000). Moreover, unlike the FMOLS estimator, the DOLS approach does not require any non-parametric correction and initial estimation. We impose homogeneity of the cointegrating vector across countries but include lead and lag terms to correct the nuisance parameter. All estimations include unreported, country-specific constants. The estimates are presented in Table 4.

Columns (1a)–(1c) report the estimates based on the entire sample of 44 countries. In all equations, the coefficients of R&D expenditure are found to be highly significant economically and statistically, consistent with the empirical results of Bottazzi and Peri (2007), and the predictions of the innovation-based growth model discussed in Section 2. Moreover, patent protection also enters all equations significantly at the 1% level of significance. Interestingly, while the effect of financial development on knowledge accumulation is found to be beneficial, the effect of financial liberalization is found to be deleterious, with long-run elasticity values of 0.378 and −0.088 (columns (1a) and (1b), respectively). The results are highly significant and remain robust when these two variables are considered in the same specification (column (1c)).

Results for the OECD and non-OECD are reported in columns (2a)–(2c) and columns (3a)–(3c), respectively. In all cases, we continue to find a positive and significant role of R&D and patent protection in stimulating ideas accumulation. While the long-run elasticity of patent stock with respect to R&D expenditure is found to be slightly higher in the non-OECD (average 0.367) compared to OECD countries (average 0.272), the positive elasticity of patent protection in the OECD (average 4.548) is found to be more than twice of that in the non-OECD (average 1.692). This suggests that domestic R&D activity has played a more significant role for technological deepening in developing countries whereas the protection of intellectual property has a more pronounced effect in countries for which the quality of institutions is already strong.

Interestingly, the negative effect of financial liberalization is only found to be statistically significant in the non-OECD group but not in OECD countries. A positive effect of financial development is found in both country groups, with a larger effect found in the OECD. The coefficients are highly significant at the 1% level. This is consistent with the observation that the process of financial development has occurred at a faster rate in the OECD compared to the non-OECD ones over the last three decades.

The findings suggest that technological deepening in advanced economies is driven by deepening in the financial system rather than changes in the financial policy environment in favor of a more liberalized regime. In the case of developing countries, only financial development is found to be effective in reducing financial constraints and thereby in facilitating innovative production. The relatively smaller coefficients of financial development perhaps suggest that finance feeds through to growth mainly through the channel of capital accumulation in these countries (see, e.g., Rioja and Valev, 2004). Financial sector reforms, however, appear to impede improvements in technology in developing countries. In Section 5, we will take a deeper look at the negative role of financial liberalization on knowledge accumulation and test several hypotheses that lead to this finding.

On the whole, the finding of a positive effect of financial development is highly consistent with the innovation-induced endogenous frameworks of Blackburn and Hung (1998), Aghion et al. (2005) and Aghion and Howitt (2009), which postulate that financial development reduces monitoring costs and moral hazard problems, thereby resulting in more inventive production. The results, however, do not support the McKinnon–Shaw thesis, which proposes that distortionary policies in the financial system should be removed in order to induce higher growth. Instead, for the developing countries, there is in fact some support for the repressionist ideology of Stiglitz and Weiss (1981), van Wijnbergen (1983), Devereux and Smith (1994) and Stiglitz (2000).

With regard to intellectual property protection, our results suggest that a stronger patent protection framework tends to increase the incentives to innovate. Therefore, stricter enforcement of intellectual property appears to be an effective strategy in stimulating the accumulation of knowledge. This result confirms the hypotheses of Gould and Gruben (1996) and O'Donoghue and Zweimüller (2005), which argue that the rate of technical innovation increases with greater patent protection in the long run. Our results are in line with the empirical findings of Park and Ginarte (1997) and Claessens and Laeven (2003), among others.

4.3. Robustness checks

Next, we perform several robustness checks using an alternative estimator, considering different measures and treatment of R&D, excluding major countries that have experienced volatile financial liberalization, excluding several OECD countries that conduct significant R&D activity and considering a different sample period. These sensitivity checks are only performed for the whole sample. First, we consider the use of an alternative estimator. Column (1) in Table 5 reports the estimates based on a feasible generalized least square (GLS) estimator. The seemingly unrelated regressions (SUR) approach is used to correct for both period heteroskedasticity and general correlation of observations within a given cross-section. We do not find significant variations in the results.

In the literature, it is also quite common to use R&D labor as the measure of R&D input in the process of ideas production (e.g., Ang, 2010b; Ang and Madsen, in press). Moreover, the international R&D spillovers literature often

Table 4
Within-dimension panel DOLS estimates of the cointegrated relationship.

Dep. var.=patent stock	All countries (N=44)			OECD (N=22)			Non-OECD (N=22)		
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Real R&D expenditure	0.100 (0.000)[a]	0.158 (0.000)[a]	0.127 (0.000)[a]	0.301 (0.000)[a]	0.262 (0.000)[a]	0.252 (0.000)[a]	0.347 (0.000)[a]	0.400 (0.000)[a]	0.353 (0.000)[a]
Patent protection	0.543 (0.000)[a]	0.849 (0.000)[a]	1.062 (0.000)[a]	4.954 (0.000)[a]	4.203 (0.000)[a]	4.488 (0.000)[a]	1.905 (0.000)[a]	1.449 (0.000)[a]	1.722 (0.000)[a]
Financial liberalization	−0.088 (0.005)[a]		−0.087 (0.038)[b]	−0.066 (0.706)		−0.249 (0.131)	−0.567 (0.000)[a]		−0.695 (0.000)[a]
Financial development		0.378 (0.000)[a]	0.111 (0.031)[b]		0.984 (0.000)[a]	0.993 (0.000)[a]		0.551 (0.000)[a]	0.640 (0.000)[a]

Notes: all regressions include unreported, country-specific constants. One lag and one lead of the regressors are used in the estimation. Numbers in parentheses indicate p-values.
All variables are expressed in natural logarithms.
[a] Indicates 1% level of significance.
[b] Indicates 5% level of significance.

Table 5
Sensitivity checks.

Dep. var.=patent stock	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Panel GLS with SUR weights	R&D input=R&D labor	R&D input=real R&D expenditure stock	Lagged R&D input	Exclude R&D input	Exclude countries with volatile financial liberalization	Exclude US	Exclude G7	1980–2005
Model I: full model									
R&D input	0.089 (0.000)[a]	0.669 (0.000)[a]	0.201 (0.000)[a]	0.152 (0.000)[a]		0.135 (0.000)[a]	0.121 (0.000)[a]	0.148 (0.000)[a]	0.137 (0.000)[a]
Patent protection	0.741 (0.000)[a]	0.586 (0.000)[a]	1.060 (0.000)[a]	1.162 (0.000)[a]	1.008 (0.000)[a]	1.105 (0.000)[a]	1.026 (0.000)[a]	1.052 (0.000)[a]	1.223 (0.000)[a]
Financial liberalization	−0.103 (0.000)[a]	−0.180 (0.000)[a]	−0.155 (0.002)[a]	−0.134 (0.003)[a]	−0.079 (0.038)[b]	−0.091 (0.012)[b]	−0.093 (0.027)[b]	−0.200 (0.000)[a]	−0.145 (0.004)[a]
Financial development	0.123 (0.000)[a]	0.189 (0.000)[a]	0.246 (0.000)[a]	0.182 (0.000)[a]	0.253 (0.000)[a]	0.298 (0.000)[a]	0.098 (0.049)[b]	0.222 (0.000)[a]	0.331 (0.000)[a]
Model II: excluding financial development									
R&D input	0.058 (0.000)[a]	0.599 (0.000)[a]	0.194 (0.000)[a]	0.122 (0.000)[a]		0.099 (0.000)[a]	0.101 (0.000)[a]	0.121 (0.000)[a]	0.147 (0.000)[a]
Patent protection	0.352 (0.001)[a]	0.601 (0.000)[a]	0.909 (0.000)[a]	1.352 (0.000)[a]	0.625 (0.000)[a]	0.458 (0.000)[a]	0.544 (0.000)[a]	0.728 (0.000)[a]	1.251 (0.000)[a]
Financial liberalization	−0.043 (0.018)[b]	−0.126 (0.000)[a]	−0.154 (0.000)[a]	−0.181 (0.000)[a]	−0.074 (0.017)[b]	−0.083 (0.003)[a]	−0.098 (0.002)[a]	−0.130 (0.000)[a]	−0.121 (0.002)[a]
Model III: excluding financial liberalization									
R&D input	0.164 (0.000)[a]	0.636 (0.000)[a]	0.220 (0.000)[a]	0.168 (0.000)[a]		0.261 (0.000)[a]	0.155 (0.000)[a]	0.228 (0.000)[a]	0.151 (0.000)[a]
Patent protection	0.769 (0.000)[a]	0.748 (0.000)[a]	0.726 (0.000)[a]	0.807 (0.000)[a]	0.927 (0.000)[a]	0.953 (0.000)[a]	0.834 (0.000)[a]	0.962 (0.000)[a]	0.759 (0.000)[a]
Financial development	0.360 (0.000)[a]	0.177 (0.000)[a]	0.367 (0.000)[a]	0.394 (0.000)[a]	0.341 (0.000)[a]	0.689 (0.000)[a]	0.361 (0.000)[a]	0.335 (0.000)[a]	0.327 (0.000)[a]

Notes: estimates are for all 44 countries. Unless otherwise specified, R&D input is measured as real R&D expenditure.
[a] Denotes 1% level of significance.
[b] Denotes 5% level of significance.

considers the *stock* of R&D expenditure as the determinant of patent stock rather than the *flow* of R&D expenditure as used in our present analysis (e.g., Madsen, 2007). As such, we also consider using these alternative R&D measures in our analyses. R&D expenditure stock is constructed using the same algorithm as patent stock. The results reported in columns (2) and (3) do not reveal any significant changes in the estimates, except that R&D personnel tends to produce larger coefficients. Importantly, our key qualitative findings remain largely unaltered.

Finance may have an indirect effect on ideas accumulation via influencing R&D activity. Thus, our estimates may be subject to specification bias given that R&D activity may be driven by the extent of credit constraints, which in turn depends on the level of development in the financial system and financial regulation. We address this concern considering a lagged measure of R&D activity since the decision to conduct research activity is unlikely to be driven by future financial development or liberalization, which is difficult to predict. To further tackle this issue, we remove R&D activity in the specification. The results reported in columns (4) and (5) show that our findings regarding how each variable affects knowledge accumulation is in line with those reported earlier in Table 4, suggesting that potential specification bias associated with R&D may not be an issue. Moreover, very limited evidence of cointegration is found when specifying research activity as the dependent variable. This suggests that financial development and liberalization cannot be interpreted as the long-run forcing variables explaining research activity and thus the issue of simultaneity bias may not be a concern here.

In column (6), we take several countries that have been subject to high volatility in financial sector reforms out of the sample to make sure that these countries do not upwardly bias the coefficients of the financial liberalization index. This leads to the removal of seven countries with a standard deviation of greater than 0.3 in the financial liberalization series. Moreover, with few exceptions, empirical literature on R&D and productivity growth has focused exclusively on OECD countries due largely to the availability and reliability of data, as well as the fact that most R&D is concentrated in several mature countries. Given this consideration, our results may be distorted by the inclusion of these countries in the analyses. Columns (7) and (8), respectively, report the estimates for which the US and the G7 (i.e., Canada, Japan, France, Germany, Italy, the UK and the US) are excluded. It is interesting to note that the exclusion of these countries does not significantly alter our previous findings.

Finally, the sample period of 1980–2005 is considered for which R&D activity is more prevalent, especially in developing countries. Restricting the estimation time frame to a more recent period is important given that R&D and patent data in those years are much more reliable than those recorded in the more distant past. However, no systematic changes in the estimates of finance are noted, as shown in column (9). This suggests that not only are our estimates insensitive to the consideration of the alternative sample period but also that the quality of data may not be an issue in the estimations. We have also considered alternative measures of financial development such as M2 over GDP and M3 over GDP (see, e.g., Ang and McKibbin, 2007; Ang, 2010a). They give by and large similar results and thus are not reported for space considerations.

5. A deeper look at the role of financial liberalization

Our results so far are supportive of a positive role for financial development in innovation but a negative role for financial liberalization. The finding of a negative impact of financial liberalization is intriguing, and this invites further analysis. Thus, to gain further insights into these findings, it would be necessary to explore the mechanisms that link the effects of financial liberalization to knowledge accumulation. In principle, financial liberalization may negatively influence innovative production through several channels. It may do so by reducing savings, triggering instability in financial systems or enabling the financial sector to offer higher returns than the technology sector in attracting the most talented people.

Stiglitz (1994) argues that some form of financial restrictions such as interest rate restraints may lead to higher financial saving when good governance is present in financial systems. When depositors perceive restrictions as policies aimed at enhancing the stability of the financial system, they may well be more willing to keep their savings in the form of bank deposits (see also van Wijnbergen (1982) and Taylor (1983)). Bayoumi (1993) and Jappelli and Pagano (1994) also argue that financial deregulation eases borrowing constraints and may therefore reduce the incentive to save. The empirical results of Bandiera et al. (2000) and Ang (in press) confirm this thesis. Given that domestic savings is an important source for facilitating the accumulation of knowledge, financial liberalization can potentially affect ideas accumulation indirectly via the channel of savings.

Several authors have also argued that the undesirable effects of financial liberalization can be due to the instability in financial systems triggered by the reform policies. For instance, Stiglitz (2000) proposes that financial market liberalization is systematically related to greater economic volatility and higher uncertainty since foreign capital is subject to substantial pro-cyclical movements, which tend to exacerbate economic fluctuations. Moreover, Demirguc-Kunt and Detragiache (1998) and Kaminsky and Reinhart (1999) show that a number of financial crises have occurred following financial liberalization programs. These crises are often associated with a loss of access to world credit markets and greater fluctuations in output and price levels, thus inducing higher macroeconomic uncertainty and negatively affecting innovative production.

Gylfason et al. (2010) argue that although the original financial policies may have enhanced the efficiency of financial systems, excessive constraints may retard financial innovation. Therefore, the relaxation of financial regulation has often been motivated by the desire to spur innovation in financial systems. Consequently, following the increase in the complexity of financial instruments, institutions and markets over the years, regulation and enforcement practices in financial systems became increasingly outdated and it was difficult to detect early crises or cope with any financial

turbulence. This development pattern observed in the US and other countries may have contributed to the severity of the recent global financial crisis.

The next hypothesis is built on models of Murphy et al. (1991) and Acemoglu (1995), who emphasize distortions in the structure of rewards as the key driver of the allocation of talent across sectors (see also Baumol, 1990). Their model predicts that the ablest people innovate and stimulate knowledge creation when they become entrepreneurs who improve technology, but they retard innovative growth when they become rent seekers who are predominantly involved in redistributing wealth. This choice of occupation mainly depends on rewards to ability and the scale in each sector. Murphy et al. (1991) further highlight that the flow of some of the most talented individuals into financial services in the US may be one of the reasons behind the low rates of innovative growth. In our context, liberalization of the financial system allows the sector to expand disproportionately through boosting its profitability. Higher profitability generates more rewards, thus inducing more capable individuals to enter the financial rather than the technology sector. As a result, the share of highly talented skilled workers in the financial sector increases, at the expense of technological development.

The above discussion highlights several ways in which financial reforms can negatively impact the accumulation of ideas. These hypotheses, which will be tested below, may shed some light on how ideas accumulation responds to changes in the policy environment of financial systems. To test the channel of transmission via savings, we enter the ratio of gross domestic savings to GDP into the specification. If this channel is operative, the coefficient of the savings variable should be statistically significant and negative, and the coefficient of the financial liberalization variable will turn insignificant. However, if the savings ratio is found to have no statistical effect or both the coefficients of savings and financial liberalization are statistically significant and negative, the effect of financial liberalization on knowledge accumulation is likely to work through other channels.

Instability in the financial system is captured using the financial crisis dummies of Caprio and Klingebiel (2003) and Reinhart and Rogoff (2009), as well as the volatility in the growth rates of real private credit and the ratio of private credit over GDP. Macroeconomic uncertainty is measured by the volatility in the rate of inflation and annual GDP growth rates. Following the approach of Bekaert et al. (2006), these volatility variables are measured by the rolling standard deviation of the variables of interest over a five-year period.

Empirically it is difficult to measure the allocation of talented people between the financial and the technology sectors. We use data on average earnings or salary rates in the banking and insurance sector as a proxy for the rewards to talent allocated to the financial sector and data on average earnings or salary rates in the innovative sector as a measure of the returns to ability for talented individuals allocated to the technology sector. Although this may not be the best proxy for the extent of rewards in each sector, we are unable to find a better measure.[2] The data are gathered from the online database of labor statistics maintained by the International Labor Organization. Some missing data points are interpolated and extrapolated. Both variables are measured in local currency and are expressed as an index using 2005 as the base year. Accordingly, the allocation of talent hypothesis is tested by entering the relative wage variable (average earnings in the financial sector over those in the technology sector).

Table 6 reports the results. In column (1), we do not find a robust impact of the savings ratio on ideas accumulation. Coupled with the fact that the coefficient of financial liberalization remains highly significant, we conclude that lower knowledge accumulation is not driven by a weakened incentive to save the following liberalization of financial systems. In columns (2) and (3), we find partial support for the view that financial liberalization triggers crises, thereby impeding technological deepening. The financial crisis dummy is negative and statistically significant only when it is measured using the dataset of Caprio and Klingebiel (2003) but not that of Reinhart and Rogoff (2009).

Financial liberalization may also lead to higher volatility in the financial system or produce greater macroeconomic uncertainty without triggering financial crises. The results in columns (4) and (5) show that the coefficients of the volatility measures of the growth rates in real private credit and private credit over GDP are negative and significant whereas the coefficients of financial liberalization are not. These results imply that the negative effect of financial liberalization operates through inducing greater instability in financial systems. We do not find the channel of macroeconomic uncertainty to be operative when the volatility measures of inflation and the economic growth rate are considered in columns (6) and (7), respectively. Finally, the coefficient of the relative wage measure is found to be highly significant and have the right sign (column (8)). Thus, our results support the view that financial liberalization spurs the expansion of the financial sector, thereby reallocating talent from the technology sector and hurting innovative production.

It should be highlighted that while we focus our analysis on financial liberalization, the inclusion of financial development in the specification produces largely invariant results. We have also considered removing R&D activity, entering financial liberalization as a lagged variable or excluding it when its coefficients are not significant. However, our results remain largely insensitive to these considerations. Moreover, our results may be driven by the high correlation between the financial liberalization and the variables capturing each channel of transmission. Table A1 in the Appendix shows that their correlation coefficients are all below 0.4 (column (1)), suggesting that the results are unlikely to be subject to problems associated with multicollinearity.

[2] The ILO database provides a total of 159 occupations. We restrict the occupations to accountants for the banking sector and agents and computer programmers in the insurance sector as talent in the financial industry as these are the highest paid occupations in the sector. For the innovative sector, we consider engineers, tertiary mathematics teachers and highly skilled technicians as talented individuals in this sector. Unfortunately, data for R&D scientists are not available.

Table 6
Financial liberalization and the knowledge stock—identifying the channels of transmission.

Dep. var.=patent stock	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Real R&D expenditure	0.146 (0.000)[a]	0.105 (0.000)[a]	0.151 (0.000)[a]	0.153 (0.000)[a]	0.177 (0.000)[a]	0.139 (0.000)[a]	0.128 (0.000)[a]	0.118 (0.000)[a]
Patent protection	1.030 (0.000)[a]	0.598 (0.000)[a]	0.793 (0.000)[a]	1.019 (0.000)[a]	1.159 (0.000)[a]	1.172 (0.000)[a]	1.053 (0.000)[a]	1.067 (0.000)[a]
Financial liberalization	−0.105 (0.010)[b]	−0.046 (0.151)	−0.062 (0.057)[c]	−0.028 (0.577)	−0.068 (0.169)	−0.102 (0.008)[a]	−0.098 (0.004)[a]	−0.010 (0.817)
Savings ratio	−0.232 (0.362)							
Financial crisis (Caprio–Klingebiel)		−0.035 (0.011)[b]						
Financial crisis (Reinhart–Rogoff)			0.051 (0.137)					
Volatility of growth in real private credit				−0.044 (0.027)[b]				
Volatility of growth in private credit over GDP					−0.049 (0.009)[a]			
Volatility of inflation						0.010 (0.528)		
Volatility of annual GDP growth							−0.015 (0.239)	
Relative wages (financial sector/technology sector)								−0.154 (0.000)[a]

Notes: all regressions include unreported, country-specific constants. Numbers in parentheses indicate *p*-values.
[a] Indicates 1% level of significance.
[b] Indicates 5% level of significance.
[c] Indicates 10% level of significance.

6. Concluding remarks

Motivated by recent developments in the theories of endogenous growth that highlight the important role of finance in the process of technological deepening and the lack of any empirical evidence on this issue, this paper takes a first step in this direction by examining the effects of financial development and liberalization on the accumulation of ideas. Using data for 44 countries over the period 1973–2005, panel cointegration results show that there is a statistically robust relationship between knowledge accumulation, R&D input, patent law and finance. The results further indicate that while the accumulation of ideas is positively associated with R&D activity and protection of intellectual property, the effects of finance are mixed. Specifically, while financial development is found to have a beneficial effect on innovation in all countries, the effect of financial liberalization is found to be negative in developing countries.

One of the main findings in this paper is that financial liberalization is associated with lower knowledge accumulation, contrary to the notions of higher incentives to invent through improved monitoring and reduced moral hazards. We therefore also tested several possible channels through which financial liberalization inversely affects innovative production. The literature suggests that financial reforms may negatively influence innovations in several different theoretical settings. It may do so by weakening the incentives to save and thus reducing the domestic resources available for facilitating invention, producing more instability and triggering financial crises that exacerbate economic fluctuations and dampen knowledge creation, or by enabling the financial sector to expand disproportionately and become more profitable and thus leading to more talent being attracted from the technology sector. Our results provide strong support for the hypothesis that financial liberalization relocates talent to the financial system, thus hurting the technology sector. There is also clear evidence supporting the view that financial liberalization retards technological development through inducing financial instability.

The findings in this paper provide mixed blessings for developing countries aiming to deepen their financial systems through further financial reforms. This is because, on the one hand, financial development facilitates innovative production, but, on the other hand, financial liberalization seems to impede technological improvements. However, whilst financial liberalization appears to have a harmful impact on ideas accumulation, this negative effect can potentially be mitigated through improving the quality of institutions with more effective regulation and supervision. The examination of this issue will be left for future research.

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Appendix

See Table A1.

Table A1
Correlation matrix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Financial liberalization	Financial crisis (Caprio–Klingebiel)	Financial crisis (Reinhart–Rogoff)	Savings ratio	Volatility of inflation	Volatility of annual GDP growth	Volatility of growth in private credit over GDP	Volatility of growth in real private credit	Relative wages (financial sector/ technology sector)
Financial liberalization	1.000								
Financial crisis (Caprio–Klingebiel)	0.024 (0.376)	1.000							
Financial crisis (Reinhart–Rogoff)	−0.025 (0.344)	0.582 (0.000)[a]	1.000						
Savings ratio	0.001 (0.996)	0.050 (0.058)[b]	−0.025 (0.349)	1.000					
Volatility of inflation	−0.399 (0.000)[a]	0.164 (0.000)[a]	0.167 (0.000)[a]	−0.171 (0.000)[a]	1.000				
Volatility of annual GDP growth	−0.238 (0.000)[a]	0.180 (0.000)[a]	0.118 (0.000)[a]	−0.050 (0.056)[b]	0.459 (0.000)[a]	1.000			
Volatility of growth in private credit over GDP	−0.094 (0.001)[a]	0.177 (0.000)[a]	0.134 (0.000)[a]	−0.132 (0.000)[a]	0.456 (0.000)[a]	0.283 (0.000)[a]	1.000		

Table A1 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Financial liberalization	Financial crisis (Caprio–Klingebiel)	Financial crisis (Reinhart–Rogoff)	Savings ratio	Volatility of inflation	Volatility of annual GDP growth	Volatility of growth in private credit over GDP	Volatility of growth in real private credit	Relative wages (financial sector/ technology sector)
Volatility of growth in real private credit	−0.099 (0.000)[a]	0.180 (0.000)[a]	0.130 (0.000)[a]	−0.134 (0.000)[a]	0.459 (0.000)[a]	0.326 (0.000)[a]	0.948 (0.000)[a]	1.000	
Relative wages (financial sector/ technology sector)	0.310 (0.000)[a]	0.036 (0.166)	−0.101 (0.000)[a]	0.060 (0.022)[c]	−0.295 (0.000)[a]	−0.116 (0.000)[a]	−0.136 (0.000)[a]	−0.119 (0.000)[a]	1.000

Notes: *p*-values are reported in parentheses.
[a] Indicates 1% levels of significance.
[b] Indicates 10% levels of significance.
[c] Indicates 5% levels of significance.

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