The Effects of Financial Sector Development on Innovation as an Engine of Sustained Growth

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The finance-led growth hypothesis states that financial development promotes economic growth by enhancing either efficiency of capital accumulation or technological innovation or both. A typical strategy to test the validity of the hypothesis is to regress measures of financial development on aggregate growth measures such as GDP per capital growth. This type of approach is problematic because of simultaneity. Furthermore, the channel of influence from the financial sector to the real sector is not specified. This paper focuses on the innovation channel of influence and tests whether financial development positively affects the rate of technological innovation. By focusing on a specific channel of influence, simultaneity is ameliorated. Using a panel of patent application data of developing countries as a proxy for technological innovation, this paper provides evidence that financial development seems to be an important determinant of the rate of technological innovation across countries and over time.

Keywords: The finance-led growth, Patent, Innovation, Simultaneity, Panel

JEL Classification: E10, E44, G20, O16, O30, O43

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I. Introduction

Recently, much research has been done to examine the link between financial development and economic growth. A large number of empirical papers were written to either support or refute the hypothesis that financial development promotes economic growth, the idea that was originally proposed by Bagehot (1873) almost two centuries ago. Regardless of these efforts, no clear-cut answer exists yet as to whether or not a better financial sector is an important determinant of economic growth due to, in no small part, well-known econometric difficulties.

The goal of this study is to shed a new light on the finance-growth nexus by focusing on a particular channel of influence from the financial sector to economic growth. In order to achieve this goal, I start with two fundamental propositions. First, a purposeful research activity aimed at promoting technological innovation is a fundamental source of economic growth, and that this activity necessitates the use of funds. Second, it is posited that a flow of funds needed to sustain economic activities is partially affected by agency costs, that proxy for the level of development of the financial sector that provides the funds. The idea is that the agency costs will be lower with a better developed financial sector, and this will enable a larger flow of funds into the research sector, thus allowing a more rapid rate of technological innovation. If the finance-led growth hypothesis is correct, then one should be able to see evidence of financial development having positive effects on the rate of technological innovation, which is the main engine of economic growth.

To examine this hypothesis, I extend a simple model of standard endogenous growth where the degree of financial development is proxied by the costs of borrowing. The purpose of this practice is to illustrate how the innovative process could be hampered by high borrowing costs in a simple endogenous growth setting. With this model as a theoretical motivation, I examine empirically whether financial development has positive effects on the rate of technological innovation. Using patents as a proxy for technological innovation and a panel of patent growth rates of 27 developing countries from 1970 to 2000, this study finds support for the finance-led growth hypothesis. The evidence suggests that a better developed financial sector is a significant determinant of patent growth rates in these countries.

II. Literature Review

The literature on the finance-led growth hypothesis is vast. To get a better grasp of where empirical studies stand relative to theoretical models of this hypothesis, I first briefly review the models of the finance-led growth.

As noted in the previous section, the idea that a well-developed financial sector exerts positive influences on the rate of economic growth was originally proposed by Bagehot (1873). Goldsmith (1969), McKinnon (1973), and Shaw (1973) were a first group of researchers who conducted a systematic empirical investigation of this idea, and they found that there exist a positive relationship between financial development and economic growth. However, the lack of a formal theoretical foundation prevented the finance-led growth hypothesis from gaining currency among researchers. Then, the arrival of endogenous growth with its rich implications provided a fertile ground on which to build economic models where the financial sector positively affects those factors that are considered to be driving forces of economic growth. Among those factors, the ones that received most attention by researchers of the finance-led growth are productivity and capital accumulation.

Diamond and Dybvig (1983) and Bencievenga and Smith (1991) studied how the provision of liquidity by the banking sector affects economic growth. In their model, the banking sector enables more investment in illiquid/productive assets by minimizing adverse effects of random liquidity shocks, and thereby enhances the efficiency of capital accumulation and economic growth. Roubini and Sala-i-Martin (1995) shows how a reduction of agency costs due to financial development can lead to faster economic growth. Their idea is similar to Bencievenga and Smith (1991) in that a lower agency cost allows a larger share of savings to be channeled into investment (illiquid/productive assets in Bencievenga and Smith' model). All in all, a common thread in this type of models is the assumption that capital accumulation has growth-enhancing effects.

Recent empirical studies forcefully suggest that capital accumulation may not be an important determinant of economic growth. The evidence suggests that what explains most of income and growth differences across countries is not capital accumulation but "residuals" (Easterly and Levine 2001). A line of research that focuses on the relationship between financial development and innovation/productivity includes King and Levine (1993) and Galetovic (1996). In their models, the role of the financial sector is to monitor and/or screen innovative activities. The existence of the financial sector promotes more (efficient) investment in innovation and thus faster economic growth. Saint-Paul (1992) takes a slightly different approach. While his main theme is similar to the others in spirit, he focuses on how the financial sector, in his case a stock market, allows firms to specialize and achieve higher productivity by reducing idiosyncratic risks associated with productive but risky technologies.

Overall, the channels of influence that the theoretical models of the finance-led growth suggest is that financial development enhances economic growth by allowing either more efficient accumulation of capital or more efficient investment in innovative activities.

A flood of empirical studies began to appear in the 1990s to test the validity of the finance-led growth hypothesis. Unfortunately, theoretical models of finance-led growth do not provide empirical researchers with structural guidelines on which they can base their estimation. As a result, one is forced to use reduced-form estimation and test the general conclusion of these models. A typical test strategy involves regressing some indicator of financial development on aggregate growth measures such as investment growth, GDP growth or total factor productivity growth.[1]

A first attempt in this direction was made by employing cross-sectional estimation (King and Levine 1993; De Gregorio and Guidotti 1995). Using a cross-sectional framework, they find a positive relationship between financial development and economic growth. However, a potentially endogenous relationship between financial development and economic growth made interpretation of these results difficult. Demetriades and Hussein (1996) and Odedokun (1996) take a Granger causality approach to avoid these problems and present mixed results. They find that the effects of financial development on growth are country-specific. Based on their findings, they argue that a robust test of the finance-led growth hypothesis should incorporate the time dimension of the data under consideration. Benhabib and Spiegel (2000) employ a panel GMM

[1] In this section, I discuss not the whole empirical literature but a select few that are representative of distinct research directions for brevity.

method to reach a similar conclusion and argue that weakened effects of finance with inclusion of fixed effects may indicate that financial development indicators are proxying for underlying country characteristics.

By and large, the current empirical literature lacks one crucial element in that they do not consider the channels of influence suggested by theoretical models and fail to show *how* financial development affects economic growth. Furthermore, time-series approach, while potentially resolving endogeneity issue, does not tell us exactly what the relationship between financial development and economic growth is. In addition, their results are as difficult to interpret as cross-sectional estimation because Granger causality does not really provide an answer for the causal relationship between financial development and economic growth. Researchers who conduct causality tests in this area argue that, for some countries, economic growth causes financial development, when what they really should say is that economic growth Granger-causes financial development. This does not really address the question of what causes what, especially when one considers that, statistically, Christmas card sales Granger-cause Christmas.

In sum, the current empirical literature suffers from two problems. First, as long as one regresses GDP growth on a measure of financial development, the issue of endogeneity is not satisfactorily resolved. Second, the channel of influence has not been specified so far, thus, limiting our understanding of how the financial sector affects growth.

In examining the validity of the finance-led growth hypothesis, I depart from the conventional literature. Instead of estimating a relationship between aggregate growth measures and financial development indicators as is commonly done in the current literature, I test whether financial development enhances innovation. By narrowing the focus of investigation this way, I argue that the problem of endogeneity is ameliorated and that a channel of influence can be specified, leading to more meaningful policy implications.

In Section II, I provide a theoretical motivation for the empirical analysis by extending a simple model of endogenous growth to include agency costs and draw a testable implication. In Section III, I discuss the estimation strategy employed and the issues that need to be addressed. In Section IV, I conclude.

III. Theoretical Background

Given the plentiful supply of theoretical models where the financial sector interacts with innovators to make an economy grow faster, my aim in this section is not to propose yet another new model but to illustrate briefly how the financial sector can promote innovation under a basic endogenous growth structure.

One of the common assumptions made in finance-led growth theories is that the financial sector (mainly the banking sector) actively monitors borrowers of funds. Allen and Gale (2001) show that evidence is to the contrary. They show that in most cases, the banking sector does not serve as an active monitor. The rationale for this is that often times the banking sector makes a debt contract with the borrowers in which profits of a lending bank are not dependent upon the borrower's degree of success. Rather, they simply depend on whether the borrower succeeds or not.[2] Therefore, the welfare of the lending bank will depend more on how well it screens out the bad borrowers and less on its effectiveness as a monitor. Based on this observation, I extend a simple model of endogenous growth (Jones 2002) to illustrate how the agency cost affects the rate of technological innovation.

A. Final Goods Sector

A perfectly competitive final goods sector produces a single homogenous consumption good by combining labor and intermediate goods. The production function for the final goods sector is given by

$$Y=\int_0^A x_j^{\alpha}\,dj, \tag{1}$$

where A is the number of intermediate goods used and x is the amount of intermediate good j used and is between 0 and 1. Given this production function, and normalizing the price of final goods to one, a firm in the final goods sector maximizes its profit; $\int x_j^{\alpha}dj - \int_0^A p_j x_j dj$, where p_j is the price of an intermediate good j. Profit maximization gives the price of an intermediate good j as

[2] Of course, this is not the case for equity contracts. However, in most cases, equity markets are relatively small in terms of intermediating funds and are ignored in this paper.

$$p_j=\alpha x_j^{\alpha-1}. \tag{2}$$

B. Intermediate Goods Sector

The intermediate goods sector consists of monopolistic firms that buy designs from the research sector to be used in production of intermediate goods. These firms are monopolistic since the designs they buy are protected by patents that exclude others from using the same designs. Therefore, each monopolist produces only one type of intermediate good. With the design in hand, the monopolist produces intermediate goods using a one-to-one production function. In other words, the monopolist requires one unit of capital to produce one unit of intermediate good.

Formally, the monopolist maximizes the profit function given by

$$p_j(x_j)x_j-rx_j, \tag{3}$$

where r is the interest rate for borrowing capital. The firm's supply of x_j derived from the profit maximization, together with the demand schedule in Eq. (2), determines the price of x_j to be equal to r/α, which implies that $x_j=x$ and, consequently, that $Y=Ax^{\alpha}$.

Using Eq. (2). and $p_j=r/\alpha$, we get $x=\alpha^2 Y/Ar$. Then, the profit for each monopolist can be specified as

$$\begin{aligned}\pi_1&=(p-r)x\\&=\alpha(1-\alpha)\frac{Y}{A}.\end{aligned} \tag{4}$$

Further, since the total amount of the intermediate goods used in the final goods sector, $\int_0^A x_i di=Ax$, should be equal to the total amount of capital spent in the intermediate goods sector, $(1-a_K)K$, x is equal to $(1-a_K)K/A$. Note that $(1-a_K)$ is the portion of capital stock used in the intermediate goods sector, and K is the total stock of capital in the economy.

Finally, the production function turns out to be

$$Y=A^{1-\alpha}[(1-a_K)K]^{\alpha}. \tag{5}$$

C. The Research Sector

Recall that my primary goal in this section is to provide a theoretical sketch of how financial development affects innovation. I aim to show here that the share of capital spent in research sector is increasing in the degree of financial development as proxied by lower agency costs.

At this juncture, it would be useful to describe how the financial sector behaves in this model. First of all, the financial sector and its level of financial development are assumed to be exogenous in this setup. The reason for this simplification is that the main interest of this paper is to see whether or not the level of financial development has any effect on the real sector activity, not how the financial sector evolves over time or interacts with other players in the model.[3] Then, in line with the current literature, the assumption that agency cost in provision of funds is negatively correlated with the level of financial development is made (Diamond and Dybvig 1983; Bencievenga and Smith 1991; Roubini and Sala-i-Martin 1995). Moreover, in this model, the financial sector incurs agency costs when it transacts with the researchers of which the results of their innovative activities are unknown at a time the funds are supplied. Therefore, the agency cost in this model can be regarded as extra costs that the financial sector incurs in its attempt to gauge the likelihood of successful innovative activities. Since the demand for funds by the researchers is inelastic, the financial transfers all the burden of agency costs to the researchers.[4]

In this model, each researcher faces a similar problem as the monopolist in the intermediate goods sector. In other words, each researcher borrows capital from the financial sector to finance her innovation. What is different from the monopolist's case is that the researcher's cost of borrowing capital is not r but $r+c$ where c is the exogenous agency costs. The researcher pays an additional cost of c because the financial sector has to screen the researchers when they borrow funds as described above. With this environment, the

[3] By this simplification, I am de facto accepting the notion that there is a feedback from the real sector to the financial sector. However, the key research question in this paper is whether or not financial development affects growth.

[4] The question of exactly who bears how much of the burden does not affect the model's implication as long as demand for funds is perfectly elastic.

researcher tries to maximize her profit based on her production function. I make a standard assumption that when the researcher innovates, she takes the actions of other researchers and the knowledge stock as given so that she faces the arrival rate of δ defined as

$$\delta = A^{1-\beta}[a_K K]^{\beta-1}, \tag{6}$$

where δ stands for the arrival rate of new technology per unit of capital spent on innovation at the individual researcher's level.

When a new technology is developed, assuming that the design lasts forever, the researcher receives a price, p_A which is equal to the monopolist's profit discounted by r, $(1-\alpha)x/\alpha$. Since $x=\alpha^2 Y/Ar$,

$$p_A = \frac{\alpha(1-\alpha)Y}{rA}. \tag{7}$$

Given the price p_A and the arrival rate δ, the marginal product of capital spent in the research sector equals simply $p_A\delta$. Equating this to the marginal cost of capital, $r+c$, and noting that $r=\alpha^2 Y/(1-a_K)K$, I get the share of capital used in the research sector as

$$\left(\frac{1-\alpha}{\alpha}\right)(1-a_K)\left(\frac{K}{A}\right)^{\beta} = a_K^{1-\beta}\left[\alpha^2\left(\frac{A}{K}\right)^{1-\alpha}\left(\frac{1}{1-a_K}\right)^{1-\alpha}+c\right]. \tag{8}$$

Although the Eq. (8) cannot be solved explicitly for a_K, it can be seen that there exists a unique value of a_K by noting that the LHS of the equation is decreasing in a_K and that the RHS of the equation is increasing in a_K for the entire range of a_K.

D. The Growth of the Economy

Given the production function (5), I need to specify how the economy evolves over time. First, technological innovation occurs by the following law of motion:

$$\dot{A}_t = A_t^{1-\beta}[a_K K_t]^{\beta}, \tag{9}$$

where β is between 0 and 1. This specification assumes that technological innovation is a function of capital devoted in the research sector. However, the production of new technologies faces diminishing returns in K. Furthermore, it assumes that the stock of knowledge in the economy also contributes to production of new technologies.

Following Solow (1956), I assume that the capital stock evolves by

$$K_t = sY_t, \tag{10}$$

where s is a constant investment ratio. Also, assume, for simplicity, that there is no population growth so that $n=0$. Substituting Eq. (5) into Eq. (10), and dividing both sides by K_t, the growth rate of capital is given by

$$\frac{\dot{K}}{K} = s(1-a_K)^{\alpha}\left(\frac{A_t}{K_t}\right)^{1-\alpha} \equiv g_K. \tag{11}$$

Similarly, the growth rate of technology is given by

$$\frac{\dot{A}}{A} = a_K^{\beta}\left(\frac{K_t}{A_t}\right)^{\beta} \equiv g_A. \tag{12}$$

Along the balanced growth path, the usual steady state condition applies so that $g_K = g_A = g \equiv$ the growth rate of the economy. Combining Eq. (11) and Eq. (12), the steady state growth rate of the economy, dropping time index, is given by

$$g = [s(1-a_K)^{\alpha} a_K^{1-\alpha}]^{\beta/(1-\alpha+\beta)}, \tag{13}$$

and $g' \geq 0$ if $a_K \leq 1-\alpha$.

Note that the steady state growth rate of the economy is increasing in a_K as long as the share of the capital spent in the research sector is less than or equal to $1-\alpha$. Further, it can be seen from Eq. (8) that the equilibrium amount of capital spent in the research sector is decreasing in the agency cost, c.

It is shown in this model that the steady state growth rate of the economy is increasing in a_K, which is itself a decreasing function of the agency cost. Therefore, a better developed financial sector in this model raises the rate of technological innovation by channeling more funds to the research sector. Having teased out the testable implication of the model, I proceed to an empirical examination of this hypothesis in the next section.

IV. Empirics

In the previous section, a basic model of endogenous growth with the financial sector was introduced. The testable implication drawn from that model was that financial development is associated with a faster rate of technological innovation. In this section, I empirically examine whether financial development does have any significant effect on the rate of technological innovation proxied by patent data.

A. Patents as a Proxy for Technological Innovation

Quantifying underlying technological changes in a given country is a difficult task. In the literature, variables such as R&D expenditure, the number of scientists and engineers, the number of articles published in scientific journals, and patent count data have been proposed as measures of technological innovations. The main difficulty with the first three variables is that they are not widely available for a long time span except for a few developed countries. Therefore, using these variables limits the number of countries a researcher can include in her sample to a selective few rich countries.

An alternative and less direct measure of technological innovation that has been popular among researchers is Total Factor Productivity. By assuming a certain type aggregate production function, one can easily estimate this for a number of countries over a long period of time. However, this residual measure is only distantly related to technological innovation (Griliches 1990). In other words, it simply is something that economists do not have full understanding of how changes in total factor productivity are brought about. This ambiguous nature of total factor productivity (TFP) as a measure of technological innovation maybe harmless in some context, but can prove to be not so harmless in other cases. When the relationship under consideration is the one between development of the private financial sector and total factor productivity, we first need to have a well-defined idea about how the former affects the latter. The theoretical literature is not clear on this as total factor productivity can be influenced by many factors, almost by definition, which may have nothing to do with what goes on in the financial sector. What the literature suggests is that financial development encourages more efficient allocation of investment among *purposeful* innovation projects. However, it does not tell us how financial development affects productivity as measured by total factor productivity.

In this study, I use patent data as a proxy for technological innovation. According to the USPTO, a patent is generally defined as a document issued by an authorized governmental agency, granting the right to exclude anyone else from the production or the use of a specific new device, apparatus, or process for a stated number of years. Using patent as a proxy for technological innovation to examine the effects of financial development on innovative activities has a number of advantages. Firstly, patent data is the most direct measure of innovative output. Contrary to other proxies of technological innovation mentioned above, "a patent does represent a minimal quantum of invention that has passed both the scrutiny of the patent office as to its novelty and the test of the investment of effort and resources by the inventor and his organization into the development of this product or idea, indicating thereby the presence of non-negligible expectation as its ultimate utility and marketability." (Griliches 1990) Also, "patents are a direct outcome of the inventive process, and more specifically of those inventions, which are expected to have a commercial impact … a particularly appropriate indicator for capturing the propriety and competitive dimension of technological change." (Archibugi and Pianta 1996) An inventor will apply for a patent right only if the perceived benefits are greater than the expected costs of obtaining patent protection. By its nature, patent data alludes us to qualities of innovations that are produced. Stern *et al.* (2000) argue that patents, by its very nature, reflect an important portion of the innovative output by a country and are the most concrete and comparable measure of innovative output across countries and time. Secondly, as mentioned above, patent data bears the closest resemblance to innovative output as described in the theoretical literature in this area. Furthermore, the relationship between financial development and innovative output is well-defined by existing theoretical models. It is also intuitively appealing to argue that patent production requires investments that are intermediated by the financial sector. Thirdly, and related to the second argument above, using patents allows a more concentrated focus on the effects the private financial sector has on technological innovation. Research shows that industries heavily involved in government contract work tend to patent fewer inventions of a given quality than those which pay for their own research (Comanor and Scherer 1969). This indicates that, compared to other measures of technological innovation, patent data reflects to a lesser degree the influence of government activities that are not associated with financial development.

Having argued that patent data is the best measure of technological innovation that serves the conceptual purpose of this study, there still remains a doubt if I may be barking at the wrong tree. An example is so-called Fox paradox. It states that in a given country, patent production may come from a small industry that does not affect the country's economic growth while a large industry that is actually responsible for the country's economic growth remains dormant in terms of patent production.[5] Therefore, despite its advantages mentioned above, using patent data will not serve the empirical purpose of this study if it is not related to economic activities. Research shows that indeed this is not the case. Comanor and Scherer (1969) argue that a simple count of the number of patents reflects not statistical noise but a meaningful message in the results of studies using patents by showing that the correlation between patents and the value of new product sales is significant. On an aggregate level, using patent data as a measure of technological change, it is shown that a higher intensity of technological activities has a generally positive impact on national growth (Archibugi and Pianta 1996). Porter and Stern (2000) reach a similar conclusion in their study that there is a positive link between ideas production and realized productivity growth. Further, micro-based studies indicate that patents are actively utilized in production processes. They show that the share of patents actually used by firms range from 40% to 60% (Napolitano and Sirilli 1990). EPO survey found that the majority of European firms utilized their patents most of the time. Also, it found that 84% of patenting firms cited patents in the case of products and 71% in the case of

[5] Heterogeneity across countries such as this can be taken care of by using country dummies.

processes as their usual means of protecting new products and processes (Archibugi and Pianta 1996). These studies further strengthen the validity of using patent data as a proxy for technological innovation.

B. Specification

There are well-known concerns with respect to using patent data for economic analysis. First, there is an issue of heterogeneous quality of patents. Naturally, patents differ greatly in their technical and economic significance over time. Scherer (1965) suggests that the way to get around this issue is to invoke the law of large numbers. The idea is that by the law of large numbers, the economic significance of any sampled patent can be interpreted as a random variable with some probability distribution. Furthermore, the problem of differing qualities does not apply only to patent data. Other measures of technological innovation such as a simple count of scientists and engineers, or R&D expenditures are also prone to this problem. (Comanor and Scherer 1969). Given this fact, using patent data as a proxy for technological innovation may have more merits than other measures for it allows one to examine a wide range of countries.

Secondly, each country has a different propensity to patent arising from differences among countries in terms of their industrial composition. Thirdly, and related to the second, using USPTO patent data may exclude those innovations that are novel to a country but have been already discovered elsewhere, or those innovations that are not worthwhile patenting internationally. In order to take care of these two problems, I follow Eaton and Kortum (1996) and Porter and Stern (2000) and make an assumption similar to the one above. Specifically, it states that the value of innovations is distributed according to a fixed distribution across economies and a constant fraction of innovative output turns out to be valuable enough to justify an international patent. To the extent that this fractional value varies across countries, it is overcome through the use of fixed country specific effects in the regression.

Aside from the issues involved with using patent data as a proxy for technological innovation, as a matter of general principle in this literature, one needs to incorporate time-series dimension into estimation along with country specific effects (Demetriades and

Hussein 1996; Odedokun 1996; Benhabib and Spiegel 2000) to produce more reliable empirical results. Hence, the regression equation I estimate has the following form:

$$(\text{Patent Growth Rate})_{it} = \alpha_i + \beta_i(\text{Fianacial Development Indicators})_{it} + \gamma(\text{Control Variables})_{it} + \varepsilon_{it}, \quad (14)$$

where α is a country specific effect, i and t are country and time indexes, respectively.

C. Data

The patent data I use is based on the Technology Assessment and Forecast Report, compiled by the United States Patent and Trademark Office (USPTO) and reported to the World Intellectual Property Office on an annual basis. The motivation for using the U.S. patent data is based on the evidence that the U.S. has the lowest granting rate in the world (Griliches 1990). It indicates that the U.S. has the highest standard for granting patent rights and gives us a hint about qualities of inventions for which patent protection is asked. Porter and Stern (2000) argue that because USPTO approval requires that patents constitute novel, non-obvious inventions, patenting captures a sense of the degree to which a national economy is developing and commercializing new-to-the-world technologies and that by only including inventions that are granted patent protection in the U.S., we can be confident both that a relatively common standard has been applied and that the counted inventors are, in fact, near the global technological frontier. More importantly, using patent data from one source allows me to avoid the issue of heterogeneity across databases collected by various agencies. When one tries to combine the databases of several agencies, she needs to deal with different classification systems each agency has as well as quality differences in patents granted by different patent agencies. Many attempts have been made to handle these problems with only limited success. When a conceivable advantage of this kind of comprehensive data is basically a larger dataset, the benefit hardly outweighs the costs of having to deal with aforementioned problems. It is especially so if the number of countries covered in the U.S. dataset is reasonably large.

USPTO has six categories for patent grants; Utility, Design, Plant, Reissue, DEF, and Statutory invention registration. Among them, what is relevant for this study is utility patents. According to the USPTO definition, these are patents that are issued for the invention of a new and useful process; machine, manufacture, or composition of matter, or a new and useful improvement thereof. Therefore, utility patents have a direct bearing on industrial production processes. Once granted, they provide twenty years of protection. This data contains both developed and developing countries, and the country of origin is based on the residence of the first named inventor.

Finding a single quantitative measure that captures every aspect of financial development is nearly impossible due to complexities involved with functions the financial serves in the economy. Therefore, I use three different indicators proposed in the literature to capture various aspects of financial development. They are

- The ratio of private credit by deposit money banks to GDP (henceforth, PC)
- The ratio of liquid liabilities to GDP (henceforth, liquidity)
- The ratio of deposit money bank assets to GDP (henceforth, DMBA)[6]

PC measures the activity in channeling savings to investors and is equal to the ratio of claims on the domestic private sector by deposit money banks to GDP. The assumption is that as the financial sector develops, it will be able to channel more funds from savers to investors. De Gregorio and Guidotti (1995) also suggest that PC represents more accurately the role of financial intermediaries in channeling funds to private market participants. Since the main role of the financial sector I emphasize in this section is to serve as an effective intermediary of funds, PC is the variable that I will be primarily interested in.

Liquidity is the most commonly used indicator of financial development and usually referred to as “financial depth.” It measures the overall size of the financial sector without distinguishing between the financial sectors or between the uses of liabilities (Beck *et al.* 1999). It is equal to the ratio of currency plus demand and interest bearing liabilities of banks and other financial intermediaries to GDP.

[6] Data for these variables are from Beck *et al.* (1999).

However, the use of liquidity as a financial development indicator has come under attack recently. De Gregorio and Guidotti (1995) argue that it is conceivable that a high level of monetization (implied by a high level of liquidity) is a result of the lack of alternative assets that would serve as stores of value. Eastern Europe and the former Soviet Union provide evidence for this scenario. To overcome this problem, one can use a broader measure of monetary aggregates such as M3. However, to the extent that M1 is included in M3, it does not resolve the problem. Moreover, the fact that M3/GDP is also the inverse of the velocity of circulation of the broad money stock suggests that a positive association between the level of financial development, proxied by liquidity, and real GDP is tantamount to a downward trend in the velocity of circulation and may simply reflect an income elasticity of the demand for money with respect to GDP which is greater than unity (Demetriades and Hussein 1996). So, I use liquidity for the sake of completeness and with reservations.

Finally, I also use DMBA as another measure of financial development. DMBA is a so-called absolute size measure and reflects the importance of the financial services performed by the banking sector.[7]

Patrick (1966) argues that as the process of real growth occurs, the supply-leading impetus generally becomes less important and the demand-following financial response becomes dominant. Similarly, Fritz (1984), Jung (1986), and Dee (1986) suggest in their studies that developing countries have rather a supply-leading causality pattern of development than a demand-following pattern. What these studies say is that the developing countries should provide a fertile testing ground for finance-led growth hypothesis. If the hypothesis is not valid, a measure of financial development would not enter significantly in estimation. Furthermore, there is no reason to believe that choosing developing countries as a sample would present an upward bias in my estimation. In sum, if finance-led growth

[7] All the measures used here are the ratios of a stock variable to a flow variable, which creates problems with correct timing and in terms of deflating correctly. Beck *et al.* (1999) address these problems and calculate each measure by $(1/2)(FD_t/CPI_{e,t}+FD_{t-1}/CPI_{e,t-1})/(GDP_t/CPI_{a,t})$, where e: end of period, a: average for the period. The end year of year *CPI* is either the value for December or, if not available, the value for the last quarter. For additional information, see their paper.

TABLE 1
SAMPLE COUNTRIES USED IN THE REGRESSION

Argentina	India	Pakistan
Brazil	Indonesia	Peru
Chile	Iran	Philippines
Colombia	Iceland	Singapore
Costa Rica	Israel	Thailand
Dominican Republic	Jamaica	Trinidad & Tobago
Ecuador	Korea	Uruguay
Egypt	Mexico	Venezuela
Guatemala	Malaysia	South Africa

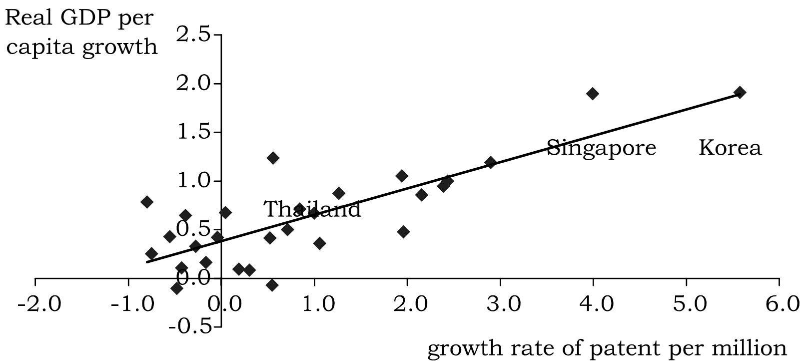


FIGURE 1
LONG RUN GDP GROWTH *VS.* LONG RUN PATENT GROWTH

hypothesis is valid, the effects of financial development will be strong and significant for developing countries, and if it is invalid, they will be insignificant regardless of the countries chosen. Therefore, I select 27 developing countries from USPTO database to be included in the sample.[8] Table 1 shows a list of countries that are included in the analysis.

Figure 1 shows the relationship between averages of real GDP growth rates and patent growth rates over 1970-2000. It shows that the latter is closely related to the former, in line with the previous

[8] A criterion for selecting developing countries is from IMF.

discussion on the effects of patents produced on economic growth.[9]

In order to construct a panel data, I compute average growth rates of patent applications per million persons for six periods, 1970-74, 75-79, 80-84, 85-89, 90-94, 95-2000, as a proxy for the rate of technological innovation. To measure the degree of financial development, I use the initial levels of financial development indicators for each corresponding period to ameliorate endogeneity.[10]

There are a couple of hand-waiving arguments against this as a solution for endogeneity. Firstly, if economic agents were forward-looking, the use of the initial levels of financial development indicators would not eliminate endogeneity (Rajan and Zingales 1998). The idea is that, if the economy were expected to grow in the future, forward-looking economic agents would step up lending now hoping to take advantage of a economic boom in the future. Then, the level of financial intermediation today is going to be affected by future states of the economy. Hence, endogeneity still exists even if one uses the initial values of financial development indicators. This argument needs two assumptions satisfied to be valid. One is that, empirically, the dependent variable used in the regression is such that economic agents could observe its behavior, for example, its growth rate, easily enough so that the economy-wide change in lending activity could occur in response to the changes in its behavior. The other is that this change in lending activity is sufficiently big so that it affects the total volume of credit in a non-negligible manner. Aggregate growth measures typically used in this literature such as GDP *per capita* growth satisfy these assumptions. Thus, the argument by Rajan and Zingales (1998) is true if what the analysis focuses on is the relationship between the financial sector development and aggregate growth measures. However, the focus in this paper is on the relationship between the rate of technological change and the degree of financial development, and their argument does not apply well for two reasons. As for the first assumption mentioned above, the inherent nature of uncertainty associated with R&D activity makes it difficult for economic agents to observe the changes in the rate of technological innovation. In

[9] Although it would be an interesting exercise to statistically examine how well patent growth explains variations in output growth, it is not the main point of this paper.

[10] For a discussion of simultaneity, see Tsuru (2000).

addition, there is no theoretical background to support that future economic conditions cause changes in the current rate of technological innovation. As a matter of fact, the consensus is that it is technological innovation that determines future economic conditions. Further, even if the first assumption is met, the resulting lending activity is not sufficiently big enough to affect the total volume of credit in a non-negligible manner since research is only a small part of what bank lending finances. Secondly, if financial development indicators are correlated across time, then using the initial values of financial development indicators would not remove endogeneity since they would simply be proxies for their contemporaneous levels (Demetriades and Hussein 1996). Figure 2 shows movements of financial development indicators for sample countries across time. Significant variations in these indicators suggest that the use of initial values of financial development indicators is justified.

In order to select variables to control for other features of economic conditions that may influence patent growth, I adhere strictly to the recommendations of the R&D literature. R&D literature indicates that R&D effort is a significant determinant of technological innovation. The most commonly used measure of R&D effort for the developed countries is the number of researchers in the research sector. However, the data is not available for a long time span for developing countries. Therefore, I instead use the human capital measure compiled by Barro and Lee (2000). Among various measures they compiled, I use the percentage of the population 25 years of age or older who have attained “higher” education as a proxy for the number of researchers in the research sector assuming that the number of researchers in the research sector is positively correlated with the extent of college education in the population. Although this is a somewhat indirect measure of R&D effort, I believe it to be reasonable to think that much of the innovation stems from college-educated innovators. For my analysis, I use the initial levels of this measure for each corresponding period (**Higher Education**). This variable, according to the literature, is expected to have a positive effect on the patent growth rate. Therefore, the estimated coefficient should be positive.

Intuitively, people alone cannot generally come up with technological breakthroughs if they lack infrastructure supporting

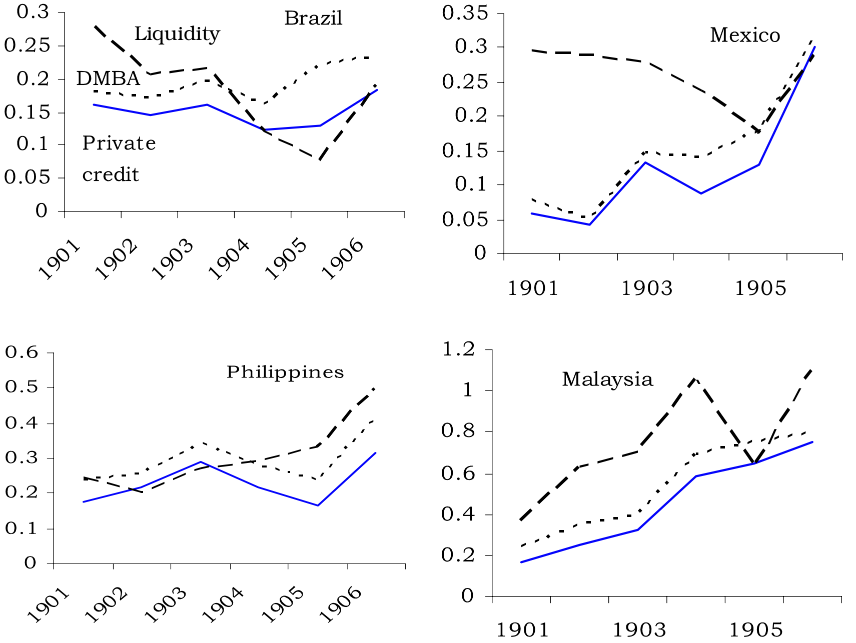


FIGURE 2
MOVEMENTS OF FINANCIAL DEVELOPMENT INDICATORS
FOR SELECTED COUNTRIES

their R&D activities. This infrastructure is generally funded by institutions such as government, private businesses and academic institutions. The volume of funds that supports R&D activities from these institutions is conventionally measured by R&D expenditure data. This data is generally widely available for developed countries but not for developing countries. Perforce, I use the real domestic private investment data to proxy for investment in R&D in my analysis. Then, I compute the average levels of domestic private investment in the five years immediately preceding each period in the sample (**Investment**). The literature is not clear on what the sign of the estimated coefficient should be. Depending on the nature of returns to scale, the estimated coefficient can be either positive or negative. So, I will let the data speak for itself.

Knowledge production may also depend on the past knowledge stock. All the models of endogenous growth incorporate this intertemporal spillover effect in one way or another. I use the initial level of real GDP *per capita* for each corresponding period (**Knowledge Stock**) to capture this potential effect. This variable also captures the ability of a country to translate its knowledge stock into a realized state of economic development and so yields an aggregate control for a country's technological sophistication (Porter and Stern 2000). Also, compared to other measures of the past knowledge stock such as the past patent stock, real GDP *per capita* provides a more comprehensive measure of the knowledge stock in the economy as the past patent stock may be industry-specific and does not convey information on the economy-wide knowledge stock. According to endogenous growth theories, the sign of the estimated coefficient should be positive. According to neoclassical growth theories, it should be negative. So, it would be interesting to see what the data says.

In addition to intertemporal spillover effects, there can also be a cross-country spillover effect. This will be especially true if a country is an active importer of sophisticated technologies as Japan had been in the 50's and 60's. Hence, an important way a country can learn from a technologically more developed country and hasten its own knowledge production is by importing technology embedded in goods. Based on this observation, I use **Openness** measured by the average levels of the sum of exports and imports divided by GDP in the five years immediately preceding each period in the sample to capture the potential cross-country spillover of knowledge. Again, the sign of the estimated coefficient is uncertain due to the fact that what I am considering here is patent applications filed in the U.S., the foreign country. If a catch-up effect is dominant, Openness should have a positive effect on the country's knowledge production. On the other hand, if a raising-the-bar effect is dominant, it should have a negative effect.

Finally, I include the average levels of inflation using the GDP deflator (**Inflation**) for each corresponding sample period to reflect the economic conditions of a country at the time when a patent application is filed. Generally, an inventor will be less likely to utilize her invention during times of economic turmoil. Hence, I expect the estimated coefficient to carry a negative sign to the extent that inflation signals economic turmoil.[11]

[11] Data for the variables are obtained from World Development Indicators, CD-ROM, 2000 unless noted otherwise.

TABLE 2

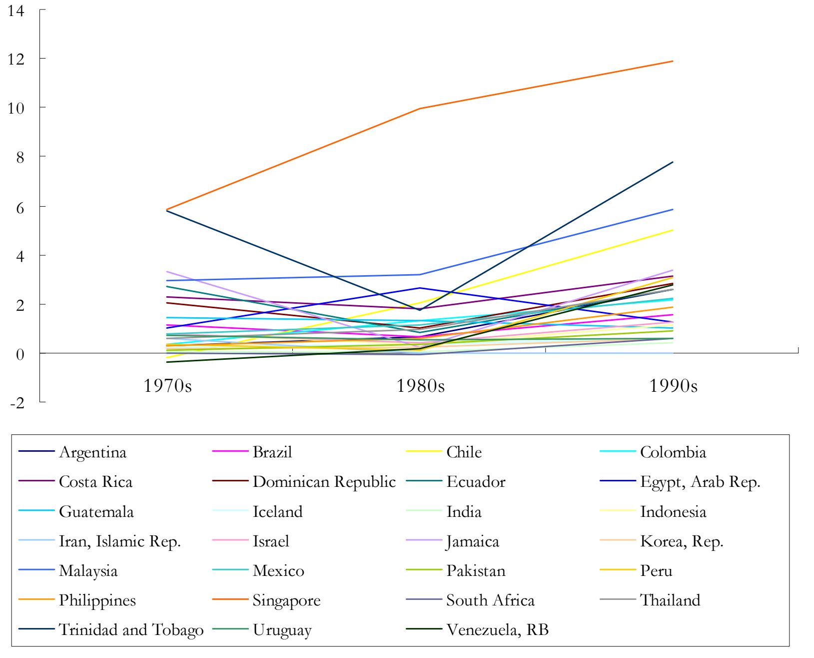
Dependent Variable: Patent growth rate (n= 153)				
		(1)	(2)	(3)
Financial Development Indicators	PC	0.9803(4.0682)		
	DMBA		0.7393(3.9644)	
	Liquidity			0.7329(3.1617)
Higher Education		0.0163(3.4646)	0.0174(3.7985)	0.0174(3.9505)
Openness		-0.0035(-1.3156)	-0.0023(-0.7881)	-0.0034(-1.6634)
Inflation		0.0002(7.5061)	0.0001(6.9708)	0.0002(10.955)
Investment		-0.0319(-1.9066)	-0.0323(-2.1686)	-0.0464(-3.6938)
Knowledge Stock		0.0695(0.9625)	0.0706(1.0969)	0.0714(1.2425)
$\bar{R}^2$		0.4103	0.4359	0.4627
DW		2.2329	2.2231	2.2337
F-Statistic		0.0000	0.0000	0.0000

Note: Numbers in the parenthesis are t-statistics.

D. Estimation

With the data in hand, Equation (14) is estimated by FGLS. Table 2 shows the results of estimation. All the measures of financial development come out positive and significant suggesting that financial development has a positive effect on the rate of technological change.

Higher education is generally positive and significant as expected. Openness comes out with a negative sign and is insignificant, which may suggest that the raising-the-bar effect is dominant. This is in line with Porter and Stern (2000)'s finding that a cross-country spillover is weakly negative. Investment is negative and insignificant. This suggests that, although a higher investment may produce more technological innovations, it does not necessarily yield a faster rate of technological change. A possible interpretation, then, would be that there is decreasing returns to investment in terms of the rate of knowledge production. Knowledge stock is positive but insignificant. Inflation comes out significant and weakly positive, which is in line with the R&D literature. However its effect seems to be fairly small. Overall, the results obtained so far yields a strong support for the finance-led growth hypothesis.



Source: WDI 2000 CD-ROM

FIGURE 3

NET INFLOWS OF FDI AS A PERCENTAGE OF GDP IN THE SAMPLE COUNTRIES

E. Robustness

a) Foreign Direct Investment (FDI)

Recently, much debate has ensued about the effects of FDIs on host county's economic activities. As innovators pursue their activities in response to changes in the economic structure of his or her own country, flows of FDI may also play an important role in how innovators behave in terms of knowledge production. Additionally, besides changing the incentive structure faced by the innovators, FDIs can be a direct source of knowledge from technologically more advanced countries upon which domestic innovators can draw.

Figure 3 shows the trend of FDI inflows in the countries considered in this study. Overall, FDIs take up only a small fraction

TABLE 3

Dependent Variable: Patent growth rate ($n=150$)				
		(1)	(2)	(3)
Financial Development Indicators	PC	0.7306(3.5305)		
	DMBA		0.6275(4.0432)	
	Liquidity			0.6018(3.5308)
Higher Education		0.0127(2.7805)	0.0122(3.1101)	0.0126(4.0682)
Openness		-0.0025(-1.0610)	-0.0014(-0.4802)	-0.0028(-0.7882)
Inflation		0.0002(8.2517)	0.0002(8.2935)	0.0002(13.6122)
Investment		-0.0465(-3.0204)	-0.0479(-3.3214)	-0.0533(-4.8977)
Knowledge Stock		0.0041(0.0591)	-0.0025(-0.0395)	0.0080(0.1617)
FDI		0.0444(2.4423)	0.0456(2.8025)	0.0378(3.0994)
$\bar{R}^2$		0.4623	0.484921	0.5739
DW		2.2646	2.264144	2.2700
F-Statistic		0.0000	0.000000	0.0000

Note: Numbers in the parenthesis are t-statistics.

of each country's GDP with minor exceptions. Also, although the flow of FDIs each country receives is increasing over time, there are no drastic changes in the amount of FDI inflows except for Singapore, Trinidad & Tobago, and Chile. However, it is still possible that the sample countries may depend largely on foreign sources as a provider of knowledge stock upon which they build their own technological innovations. Thus, I re-estimate the Equation (14) with FDI.

Table 3 shows the results. The overall results are similar to the original regression. It should be noted, though, that including FDI in the estimation reduces the size and the significance of financial development measures while slightly improving the fit of the model. Still, financial development indicators enter significantly in the equation. At the same time, FDI itself seems to be an important determinant of the rate of technological innovation, albeit its effect is rather weak.

b) Law and Trade

There is increasing evidence in the literature that legal structure such as intellectual property protection plays a non-negligible role in knowledge production processes (La Porta *et al.* 1996). This may be especially true for patent production. I use the initial values of a legal index compiled by Gwartney *et al.* (2002) to reflect the degree of IP protection within each country (**Law**). This is a composite index of judicial prudence, impartial courts, protection of intellectual property, military interference in rule of law and the political process and integrity of the legal system. It provides a more comprehensive coverage of the legal system than typical indexes used in the literature, which represents only a particular aspect of the legal framework of a given country. The literature predicts that it should have positive effects on knowledge production.

An examination of the sample countries reveals that many of them are Latin American countries. Hence, one can make a claim that these countries apply for a patent in the U.S. because of geographical proximity. In other words, some countries may choose to apply for a patent in the U.S. because the costs of doing so may be relatively smaller than other countries. However, a more valid argument would be that a country's willingness to apply for a patent in the U.S. may be significantly influenced by its trade patterns. If an innovator resides in a country that has a heavy trade relationship with the U.S., he or she may be more inclined to apply for a patent in the U.S. as the need for protection for his or her invention might be relatively stronger. For example, Korea is much further away from the U.S. than, say, Argentina, but the volume of patents applied for by Korea by the end of 1999 is fifty times that by Argentina. To measure this trade pattern, I use data from UNCTAD (United Nations Conference on Trade and Development). In the UNCTAD database, no data about the trade volume of a country with the U.S. is available. Hence, I use the initial values of a country's trade volume, both exports and imports, as a share of GDP with the North American region (the U.S. and Canada) instead (**Trade**).[12]

Additionally, note that Knowledge Stock and Openness are dropped from the regression as they were consistently insignificant in the previous analysis.[13]

[12] South Africa is dropped from the sample when Trade variable is included in the regression.

[13] Adding them doesn't change the results at all, but the fit is deteriorated. The results with these variables included are available upon request.

TABLE 4

Dependent Variable: Patent growth rate (n= 133)				
		(1)	(2)	(3)
Financial Development Indicators	PC	0.4104(2.2133)		
	DMBA		0.2949(1.9259)	
	Liquidity			0.3500(1.6892)
Higher Education		0.0242(6.6980)	0.0246(7.3736)	0.0230(7.3859)
Inflation		0.0002(16.2775)	0.0002(13.0640)	0.0003(17.0192)
Investment		-0.0916(-5.6451)	-0.0992(-6.4904)	-0.0925(-6.7840)
FDI		0.0104(0.7729)	0.0088(0.7296)	0.0063(0.5559)
Law		-0.0737(-4.7228)	-0.0789(-5.1641)	-0.0611(-4.3144)
Trade		1.5637(3.7069)	1.7621(4.1597)	1.6460(3.9818)
$\bar{R}^2$		0.6966	0.7599	0.5986
DW		2.4366	2.4346	2.4141
F-Statistic		0.0000	0.0000	0.0000

Note: Numbers in the parenthesis are *t*-statistics.

Table 4 shows the results of estimation when Law and Trade are included in the regression. Including these variables change the results somewhat. The effects of Trade seem enormous compared to other variables in the regression providing a valid ground to the claim that a country's propensity to patent in the U.S. has a lot to do with its trade patterns. However, although the effects of financial development indicators is noticeably reduced, financial development still seems to be an important determinant of patent growth, except for Liquidity. At the same time, FDI also loses its significance.

What is interesting is that Law comes significantly but with a negative sign. One plausible interpretation would be that a weak legal system of a home country induces firms/inventors to seek patent protection from abroad (the U.S.). In other words, if a home country provides adequate legal protection for innovations, firms/ inventors will be less motivated to apply for patent protection elsewhere. If this were true, then the frequency with which a foreign firm/individual applies for a patent protection in the U.S. may be negatively correlated with strength of the legal system in the home country. Hence, the negative sign I get here may simply be an artifact of using USPTO data instead of home country patent data.

The current analysis suggests that the rate of technological innovation is influenced mainly by educational quality of the population and the degree of financial development as the model presented here suggests. More to the point, it provides an answer as to how the financial sector promotes economic growth. In other words, one way that financial development enhances economic growth is through, at least partially, promoting innovative activities.

c) Outliers

Lastly, an examination of the data reveals that there are some countries whose patenting rates are quite different than the rest of the sample countries. They are Israel, Iceland, Korea, and Singapore. These countries' patent rates are higher than the rest by a factor of more than ten. The drastic difference in the patent rates between these countries and the rest may be due to a significantly different innovative structure. In addition, these countries have been highly successful in modernizing and developing their economies. Hence lumping them together with the other countries in the sample may yield inaccurate description of how financial development affects the innovative processes. Also, it is possible to imagine that these highly successful countries may be driving the results that were found previously. To consider these possibilities, I ran the regression without these four countries.

Table 5 shows the results. As can be seen, dropping Israel, Iceland, Korea, and Singapore does not change the results in any meaningful ways. Financial development indicators are still significant although its powers are somewhat less.

V. Conclusion

This paper investigates the relationship between the financial sector and economic growth by focusing on a specific channel of influence, innovation. The basic idea of this paper starts from the proposition that innovation and investment therein are an important determinant of economic growth. Then, the degree of development of the financial sector that distributes funds among various economic activities should matter for economic growth. This is the essence of the finance-led growth hypothesis.

TABLE 5

Dependent Variable: Patent growth rate (n = 112)				
		(1)	(2)	(3)
Financial Development Indicators	PC	0.5665(1.8977)		
	DMBA		0.5677(2.0966)	
	Liquidity			0.5838(1.7700)
Higher Education		0.0469(5.2754)	0.0445(5.0538)	0.0499(5.7289)
Inflation		0.0002(6.0451)	0.0002(4.6684)	0.0002(9.5164)
Investment		-0.0652(-2.3942)	-0.0611(-2.3042)	-0.0784(-4.5101)
FDI		-0.0404(-1.0379)	-0.0333(-0.8848)	-0.0423(-1.1747)
Law		-0.0990(-6.3027)	-0.1006(-6.5552)	-0.0900(-5.8472)
Trade		1.1652(2.8054)	1.2034(2.8413)	1.4824(3.6011)
$\bar{R}^2$		0.4890	0.5382	0.6619
DW		2.4806	2.4804	2.5048
F-Statistic		0.0000	0.0000	0.0000

Note: Numbers in the parenthesis are t-statistics.

In order to examine this issue, I test empirically the relationship between financial development and the rate of technological innovation. With a simple model of endogenous growth extended to consider the effects of agency costs serving as a theoretical motivation, empirical analysis using patent growth rates as a proxy for the rate of technological innovation is conducted on a panel of 27 developing countries from 1970 to 2000. The approach employed in this paper has two advantages over the current studies. Firstly, the channel of influence from the financial sector to the real sector is explicitly specified, which has been missing in the current literature. Secondly, my approach resolves the issue of endogeneity, at least better than the existing literature, so that interpretation of the results is clearer.

This paper sheds further light as to how development in the financial sector affects growth. My analysis indicates that financial development affects economic growth by promoting technological change, a fundamental driving engine of economic growth, rendering further support for the finance-led growth hypothesis.

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Comments and Discussion

*Comments by Kyoobok Lee**

It has been a pleasure to read and discuss Dr. Kim's paper. This paper studied how financial development can affect technological progress and he nicely showed that financial development is one of the most important sources for technological progress. Since he talked about both theoretical and empirical work, I shall say a few words on each.

Let me briefly share my opinion about his theoretical work. First, in his model, the certain portion of the final goods ($(1-s)Y$) is used for consumption and the remaining portion of the final goods (sY) is used for the production of intermediates and R&D. In addition to that, he implicitly assumes that the price of final goods is one. Therefore, I think that his r in the intermediate good sector's profit maximization (what he calls the cost of borrowing capital) has to be equal to one, which is the price of final goods. The price of intermediate goods should be ($1/\alpha$) which is so called monopoly pricing. Actually, the intermediate good producers do not need to borrow input because he can make a profit in each period. In this model, within one period, intermediate good producers can *buy* some input from final good producers with price one, *make* some intermediate goods and *sell* them to final good producers with price ($1/\alpha$). So the intermediate good producers get a profit ($(1-\alpha)x_i/\alpha$). It is completed in one period so the intermediate producers do not need to borrow anything in this model.

Second, in the research sector problem, he assumes that each researcher takes as given the actions of other researchers and the knowledge stock so that he faces the arrival rate of new technology that is depending on the number of intermediate goods and the total cost of R&D. I would like to say that this is not a standard assumption of a Romer type model. If he would like to use this

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arrival rate, he has to justify why the arrival rate increases as the number of intermediate goods increases and why each researcher can enjoy other researchers' capital. Basically, the arrival rate assumption implies that there is uncertainty and R&D competition between researchers because the first inventor can get a patent and enjoy a monopoly rent forever. So, there is no reason to share capital or knowledge.

Third, I think that his theory is too simple to explain agency costs because there are no special characteristics of agency costs in his model. He just makes a model such that the agency costs increase the researcher's cost of borrowing capital. After that, he just writes down the marginal cost of researcher is interest rate plus agency costs and asks reader to believe it. However, c can be not only agency cost, but also any other cost. Growth economist usually considers that c is a kind of risk premium not agency costs. Actually, there is a Romer type model in which the inventor of each intermediate goods cannot enjoy perpetual monopoly power, but this position would erode over time as competitors learned about the new product and imitated it or created close substitutes.[15] In this model, there is $r+c$ and c is a death probability (the probability the inventor will lose his monopoly power). This model can show that, if $c=0$, the model is exactly same as traditional Romer model and if $c=\infty$, the growth rate would be zero because there is no monopoly rent. So, I think that, if he changes his R&D sector into a more traditional Romer type model, his model will remain exactly the same, except that c is agency cost, not a death probability. If someone wants to see more about this model, please, read a growth textbook which is written by Barro and Sala-i-martin.

Now, let me move on to his empirical work, first, I think that the number of patents in his selected countries maybe too small. The number of patents in at least one third of your selected countries may be around 50 for thirty years. Especially, the number of patents in Dominican Republic, Jamaica, or Pakistan would be very small — around 20 or 25 for thirty years. Therefore, I am not sure that your law of large number argument is valid in this case and I could not believe that your result is robust from a time series perspective. If he does not start from 1970 or if he does not use 5 year time intervals,

[15] We know that, in a Romer model, the inventor of each intermediate goods can enjoy the monopoly power forever.

the results may be changed.

Second, he mentions several papers which talk about how the patent can reflect an important portion of innovative activities. However, I think those papers usually consider U.S or European countries or several fast growing Asian countries. I do not think that those papers consider his selected countries. In Figure 1, the growth rate of patents in 9 countries is negative and the growth rate of patents in 17-18 countries is below 1%. If we see the data after we exclude the countries whose patent growth rate is more than 1%, I guess that the result will change substantially.

Third, I think that he does not need to blame previous finance and growth literature because of endogeneity. He had better say that, unlike previous finance and growth literature in which they have studied how finance or financial development can affect general economic growth, he studies how financial development can affect technological progress which is considered as a main engine of growth among several growth factors. On the other hand, if he wants to say that there is an endogeneity problem in previous literature and his model can be one way to correct this problem, in addition to explaining why patent data can correct this problem verbally, it might be better to report the results of a granger-causality test. So, at least, he can show that his proxy for economic growth is better than previous ones like the growth rate of GDP. I suspect that technological progress in IT industries or computer industries can be a leading sector in the process of financial development. Therefore, there may be also bi-directionality or reverse causation between patent growth and financial development.

Again, I really enjoyed reading Dr. Kim's paper. The most fascinating contribution of this paper, in my view, is that he tried to test a relationship between finance and growth with patent data instead of the GDP growth rate. Therefore, he can be more focused on the effects of financial development on technological progress. So far, we know that empirical microeconomic studies have used patent data to examine innovation of firms or industries, but this paper tried to use patent data to study macroeconomic growth.