# *Financial Development and Technology*

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William Davidson Institute Working Paper Number 749
February 2005

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## ABSTRACT

Research in development economics reveals that the bulk of cross-country differences in economic growth is attributable to differences in productivity. By some accounts, productivity contributes to more than 60 percent of countries' growth in per capita GDP. I examine a particular channel through which financial development could explain cross-country and cross-industry differences in realized productivity. I argue that financial development induces technological innovations – a major stimulus of productivity - through facilitating capital mobilization and risk sharing. In a panel of industries across thirty eight countries, I find that financial development explains the cross-country differences in industry rates of technological progress, rates of real cost reduction and rates of productivity growth. I find that the effect of financial development on productivity and technological progress is heterogeneous across industrial sectors that differ in their needs for financing innovation. In particular, industries whose younger firms depend more on external finance realize faster rate of technological change in countries with more developed banking sector.

**JEL Classification:** G1, G21, G32, E44, O14, O31, O34, O4
**Key Words:** Financial Development, Productivity Growth, Technological Progress, Innovation

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## 1. Introduction

The role of financial development in economic growth has been extensively explored in recent years. The emerging consensus is that financial development has indeed a first-order positive relation with economic growth (see, e.g., Levine (1997), and Levine (2003) for review). Yet, despite the progress in exploring the finance-growth nexus, we are far from understanding the exact mechanisms through which the financial system could affect economic performance in the real sector. As Zingales (2003) notes, this lack of understanding has been one of the reasons why it has been so difficult to draw policy conclusions from the finance-growth literature. It is also one reason why we are not so sure if the documented first-order relations between financial development and growth imply causality running from the financial to the real sectors of the economy.

The consensus in the literature holds that financial development promotes economic growth through increasing the level and efficiency of capital and investments (see, Levine (2003) for review). In parallel, empirical research in development economics establishes that economic growth is predominantly driven by productivity growth rather than, as commonly thought, by capital accumulation (see, e.g., Solow (1957), Mankiw et al. (1992), Krugman (1993), and Hall and Jones (1999)). Total factor productivity (TFP) growth could account for as much as 60% of countries' growth in per capita GDP (see, e.g., Easterly and Levine (2003)). The importance of productivity as the primal source of economic growth implies that a search for the mechanisms for the finance-growth nexus should focus on the role of financial development in explaining the dynamics of productivity, and not just its role in explaining investment behavior and capital accumulation.

This paper attempts to trace the channels through which financial development could influence countries' economic performance by focusing on the relations between financial development and the components of productivity growth. I examine empirically the role of capital market development in explaining cross-country and cross-industry differences in productivity. Isolating the primal sources of productivity, I argue that an important channel by which financial development could influence growth is through facilitating technological innovations and low-cost production methods that could boost productivity. First, adoption of technologies requires large sums of capital that could easily be mobilized in well-developed financial systems. Second, well-developed capital markets and institutions encourage adoption of long-gestation productive technologies through reducing investors' liquidity risks. Finally, by providing hedging and other risk sharing possibilities, financial markets and institutions promote assimilation of specialized (vis-à-vis generalized), and hence productive, technologies. Hence, countries with mature banking sectors and capital markets should realize higher rates of technological progress that translate into larger productivity gains and, therefore, to higher economic growth.

In a panel of ten industries across thirty-eight countries, I carefully isolate the contributions of TFP to observed industry output growth. I then develop an empirical model of TFP growth that decomposes TFP into factors attributable to technological innovations, and those relating to industry-specific efficiencies. I explore the importance of financial development for technological innovations in two ways. First, in a cross-country analysis similar to King and Levine (1993) and Levine and Zervos (1998), I evaluate the total, average effect, of financial development to technological innovation. I test whether industries realize faster or slower technological progress if they are in countries with developed financial sectors. Second, to pin down exactly how financial development affects technology, in a cross-country cross-industry analysis similar to Rajan and Zingales (1998, henceforth RZ), I test whether financial development has a heterogeneous impact on technological progress *across* industrial sectors that differ in their financial needs for innovation.

RZ argue that sectors differ in their financial needs because of technology-specific factors, and construct a measure of external finance dependence for a large cross section of manufacturing industries. They find that industries that are more dependent on external finance grow faster in financially developed countries. Small firms are considered to have enormous comparative advantages for innovation, while critically constrained by lack of finance (see, e.g., Mazzucato, 2000, pp.16). To be prudent, one may argue that both large and small firms may have innovative capacities; however, while (internally-generated) financing is the critical *advantage* for large firms to innovate, (lack of) financing is the critical *impediment* for small firms to innovate (Mazzucato, 2000, pp.16-7). Corporate finance theory further suggests that firm's relative age affects their dependence on external finance, and RZ show that U.S. firms raise much of external finance only up to their 10 years of life. I ask, therefore, whether, all else equal, industries whose small and younger firms are dependent on external finance attain more or less technological progress in countries that are more financially developed.

In the cross-country analysis, the study finds that financial development has, on average, a positive effect on realized productivity and technological progress. The degree of capital mobilization and risk sharing as measured by the sizes of the stock market and the banking sector is significantly positively related to realized technological change. In particular, I find that the share of productivity gain due to technological innovations is significantly larger in countries with well-developed banking sector, and to some extent with larger stock markets. However, the impact of equity markets on technological progress appears to be very weak. Given the multitude of factors that can have impacts on technological innovations, the contribution of the financial system is also economically meaningful. A one standard deviation increase in the size of the intermediary sector in an economy would increase the rate of technological progress of the average industry by 0.0658 percent per annum compared to the actual average rate of technological progress of 1.9 % percent observed over the sample period. In my sample, Peru has the lowest score on banking development with the domestic credit to GDP ratio of 0.1609. If Peru were to develop its banking sector to the level of that of Japan's, it would increase its rate of technical progress by 0.223 percent per year.

Technological advancement is commonly accompanied by real cost reduction in the production process. I find evidence that industries in countries with well-developed banking sector realize significantly higher rates of real cost reduction. The evidence is consistent with the notion that financial development spurs productivity through encouraging technological innovations and adoptions, via making large external capital available at lower cost. Other things equal, if Peru were to reach the level of banking development of Japan, it would, on average, reduce real costs by a rate of 13.3 basis points per year.

In the cross-country cross-industry analysis, I find that the effect of financial development on technological progress and real cost reduction is heterogeneous across industrial sectors, and that, in fact, certain types of firms and industries appear to benefit especially from banking development. I find that industries whose younger firms are especially externally dependent realize rapid technological progress in countries where the banking sector is more developed. In my sample, the most externally dependent industry is Plastic Products (ISIC 356) with external dependence ratio of 1.14 while Apparel (ISIC 322) is the least externally dependent with a ratio of 0.27. The results predict that the difference in technological progress between these two industries would be about ½ percent per year higher in Japan, which has a more developed banking sector, than in Peru. In cost terms, the difference in the rate of cost *reduction* between the two industries is about 33 basis points per year higher in Japan than in Peru. This might also represent the cost of capital advantage of an externally dependent industry (ISIC 356) over a less dependent industry (ISIC 322) in a more financially developed country, Japan, relative to Peru.

The observed correlations between the measures of financial development and technical progress are robust to alternative model specification in which I use legal and institutional variables that are deemed to be more exogenous as instruments, suggesting that the relations identified could be causal. The empirical results are robust to alternative definitions of the focal variables and alternative specifications of the latent variables as random- or fixed-effects; as well as to omitted variables bias such as the possibility that protection of property rights or better patent laws might be the driving factors. In interpreting the results, however, the usual caveats related to possible weaknesses in the data and the choice of a particular time period and country sample, as well as methodological issues should apply. Moreover, one has to be cautious in interpreting the findings. I argue only that financial development liberates firms from the necessity of generating internal funds to finance innovations. Technological progress ultimately comes from the innovative ability of the firm, and the study has little to say about the ultimate source of innovation.

The study complements the recent empirical literature examining the link between financial development and economic growth. Levine and Zervos (1998) presents evidence of relations between indicators of banking and stock market developments and per capita GDP growth, rate of capital accumulation and productivity growth. Noting that productivity growth partly stems from technological advancement, this paper attempts to identify a particular channel through which financial development could contribute to economic growth. Rajan and Zingales (1998) examine whether industries that are more dependant on external finance grow faster in more developed financial markets than in less developed markets. Similarly, using firm-level data across thirty countries, Demirguc-Kunt and Maksimovic (1998) examine whether firms with access to more developed financial markets grow at faster rates than those with access to less developed markets. This paper focuses on a particular source of growth – technological progress

– and attempts to explain its variations between and within countries based on differences in financial development. By focusing on and identifying the mechanisms through which financial development may influence the growth process, the paper fills an important void in the finance-growth literature. Zingales (2003) notes the lack of attention afforded to identifying these channels, and attributes to this neglect the fact that the literature has little success in influencing financial reform policies.

The paper is also related to a strand of literature originating in the development economics tradition that attempts to link activities in the financial systems to the technological choice of the firm [e.g., Hicks (1969), Bencivenga, Smith and Starr(1995), Bencivenga and Smith(1991), Saint-Paul(1992), and Greenwood and Jovanovich(1990)]. Financial markets and institutions provide risk-pooling and risk-sharing facilities to investors and entrepreneurs. They arise to ease the trading, hedging and pooling of risk. This risk-amelioration role influences the technological choice of the firm in that greater risk sharing (i.e. more liquidity and risk diversification) allows firms to shift into high-return and longer-gestation technologies. The present work argues that the distinct functions of the financial system identified in the literature – namely, capital mobilization and risk sharing – could explain observed cross-country differences in rates of technological progress and productivity and ultimately economic growth.

The reminder of the paper is organized as follows. Section 2 provides the theoretical framework and develops the hypotheses to be investigated. I describe the data in Section 3. Section 4 provides the main results, and Section 5 presents additional sensitivity tests. I summarize the results in Section 6.

## 2. Financial development and TFP: Hypotheses

Financial development is significantly correlated with economic growth (see, e.g., Levine and Zervos (1998), and Rajan and Zingales (1998)). A straightforward approach to trace this channel from finance to real growth involves examining the impacts of finance on the sources of growth. A portion of real output growth is a reflection of growth in the input factors – namely, physical and human capital accumulation. The remaining is attributable to changes in total factor productivity (TFP).

### 2.1 The Importance of the TFP

Empirical research reveals that a large portion of countries' economic growth rates can not be fully accounted by accumulation of factors of production. After accounting for factor inputs, such as physical capital stock and human capital, TFP growth accounts for the largest share of countries' economic growth. Easterly and Levine (2001) documents that TFP growth accounts for about 60 % of the growth in output per worker in the average country (see also Hall and Jones (1999)). Earlier studies by Solow (1957) and Denison (1967) estimate the contribution of TFP to be greater than 50 percent for the U.S. and other industrial countries while that of capital accumulation is only between 12 and 25 percent. Cross-country variations in TFP explain the bulk of cross-country variations in per capita GDP growth – about 60% according to Easterly and Levine (2001).

There is also growing evidence that capital accumulation does not cause faster economic growth. For example, Blomstrom, Lipsey, and Zejan (1996) and Carroll and Weil (1994) show that causality runs from output growth to investments and savings and not vice versa.

Understanding the precise role of financial development in the economic growth process, therefore, requires explaining the role of financial development in the dynamics of TFP. However, deciphering TFP and understanding its dynamics has been a difficult exercise, partly because of the lack of consensus as to its sources and contents. Traditionally, TFP is understood to be the part of economic growth that is not explicitly explained by constituent factors of production (see, e.g., Solow (1957). It is the unexplained 'residual'. Interpretations of what constitutes TFP vary. While some emphasize the role of economic externalities (e.g., Romer (1986) and Lucas (1988)), others (e.g., Solow (1957)) view TFP as a manifestation of better technologies – better methods for converting raw materials into finished products. In this view, the increased level of output for the given mix of factor inputs represents a shift in the underlying technology due to infusion of technological innovations.

On the other hand, Herberger (1998) views TFP as a description of the amalgam of factors that causes real cost reduction at a firm level. In this view, the net effect of a productivity gain, from at least an entrepreneur's perspective, is a visible reduction in costs regardless of its source. Such interpretation of productivity could provide us with many advantages in identifying linkages to the role of financial development. First, it suggests an alternative, yet more intuitive depiction of productivity gain and technological improvements – it is the rate of observed real cost reduction to be potentially explained by financial development and other factors. Second, productivity as cost reduction provides a direct role for financial development as a potential cause in that financial development allows firms to reduce the costs of raising external capital.

## 2.2 Financial development and TFP

The foregoing discussion suggests two main channels through which financial development could influence TFP. First, financial development could facilitate adoption of better technologies through providing the requisite large capital as well as through creating mechanisms to pool and share risks associated with new technologies. This role corresponds to the technology interpretation of what constitutes TFP. Second, corresponding to the cost reduction interpretation of the TFP, financial development allows firms to reduce the costs of raising capital that translates into reduction in the real costs of doing business.

### 2.2.1 Financial Development and Technological Innovation

Strong banking and well-developed capital markets may promote technological advancement and productivity in a number of ways. First, adoption of technologies requires large amount of capital that could easily be mobilized in well-developed financial systems. The intimate relation between financial markets and technological choices was first emphasized by Hicks (1969) in his quest to explain the genesis of the industrial revolution. Hicks (1969) argues that an essential feature of industrial development is adoption of technologies that require large scale illiquid capital investments. Financial markets that provide risk-sharing possibilities to investors make it economically feasible to implement such technologies. For Hicks, the industrial revolution was not associated with the discovery of any particular new technology. He argues that most of the technical innovations had been made before the onset of the industrial revolution. However, their adoption and full implementation on an economical scale required the commitment of large-scale investments for a long period in an illiquid-capital form. Financial markets that provide investors with liquidity made investments in such technologies feasible. Thus, countries' technological progress and the maturity of their financial systems in mobilizing capital are directly related.

Second, well-developed capital markets and institutions encourage adoption of long-gestation productive technologies through reducing investors' liquidity risks (e.g., Bencivenga, et al. (1995), Bencivenga and Smith (1991), and Greenwood and Jovanovic (1990)). Well-developed financial systems insure investors against liquidity risk, leading to the financing of longer-term and riskier, yet productive, projects. In Bencivenga and Smith (1991), financial intermediaries promote real growth through providing a means for reducing liquidity risk. First, banks permit risk-averse savers to hold bank deposits rather than liquid (and unproductive) assets, thereby increasing funds available for productive capital. Second, by eliminating self-financed capital investment, banks prevent unnecessary capital liquidation by entrepreneurs due to liquidity needs.

Finally, by providing hedging and other risk sharing possibilities, financial markets and institutions promote adoption of specialized vis-à-vis generalized, and hence risky, technologies. Saint-Paul (1992) provides a model in which financial markets interact with the technological choice of the firm in that financial markets allow riskier but more productive technologies, and the technological choice, in turn, affects the viability of financial markets. By enabling agents to hedge against risk through holding diversified portfolio, financial markets permit more division of labor in the real sector, leading to higher productivity. Financial markets and technology are, therefore, strategically complementary in that both are instruments for risk diversification. Where capital markets provide limited and poor risk sharing services, diversification occurs through the choice of inferior technologies which are both less specialized and less productive. Cross-sectionally, underdeveloped financial markets are associated with unproductive flexible technologies and less division of labor, and developed financial markets are associated with specialized and risky technology. In Greenwood and Jovanovic (1990) *financial intermediaries* facilitate high-yield investments and growth by pooling idiosyncratic investment risks across a large number of investors.

The empirical implication is that measures of the capital mobilization (e.g., Hicks (1969)) and risk sharing and pooling functions (e.g., Hicks (1969), Saint-Paul (1992), Greenwood and Jovanovic (1990), Bencivenga, et al (1995), Bencivenga and Smith (1991)) of financial markets and institutions should be positively related to productivity growth and measures of technological progress defined to be the productivity growth component attributable to technical innovation and adoption. In a cross section of countries, one would expect to find a positive relation between measures of financial development and technological progress.

Furthermore, because financial development encourages technological innovation primarily via making financial capital available, one would expect that those firms that rely on external finance for financing innovation – or firms for which lack of finance could be a binding constraint in realizing innovation – to benefit more from financial development.

It is widely recognized that small firms are entrepreneurial, and contribute significantly to the process of innovation. For example, according to the U.S. Office of Management and Budget, businesses employing less than 1000 employees accounted roughly half of the nation's innovations between 1953 and 1973 (Storey, 1983, p. 23). During the period 1945 through 1980, small firms, with fewer than 500 workers, made 17-40% of innovations in the U.K. (Storey, 1983, p. 105), and small firms perform 22% of R&D in Holland (Kleinknecht (1987)). And yet, the ability of small and young firms to unleash and realize their innovative energies is critically dependent on their ability to raise the requisite financial resources. Lack of finance becomes a binding constraint for such firms determining their ability to pursue innovation.

There is a large literature on how firms' rate of innovation relates to firm size and age (see, e.g., Cohen (1995) for review). Small firms are understood to possess certain advantages conducive for fostering innovation, including their greater managerial control and flexibility, their motivation to foresee future changes in technology, and their ability to attract scientists and entrepreneurs who are disillusioned by large bureaucracy (Mazzucato, 2000). The empirical evidence also supports small firm's advantage in innovation. Bound et al. (1984), for example, find that R&D intensity is highest among small firms. Based on a database of references on innovation, Acs and Audretsch (1988) provide evidence that small firms disproportionately contribute to innovation. A number of theoretical models also predict that younger firms might be more effective in innovation. For example, Holmstrom (1989) argues that the organizational structure of mature firms, which is designed around the production and marketing of existing products, might compromise the incentive to innovate. Aron and Lazear (1990) present a model where new firms are less risk-averse and, as a result, are more likely to undertake risky R & D activity and introduce new products. In a study of the photolithographic industry, Henderson (1993) finds that established firms were less successful in pursuing major technological opportunities. Prusa and Schmitz (1994) finds similar results in the software industry.

In addition to firm size and age, financial resources could affect firms' ability to pursue innovations. In general, theory holds that informational problems surrounding R&D projects make it difficult to raise external capital for their financing (see, e.g., Myers and Majluf (1984)). Evidence also shows that financial constraints might be important for innovation. For example, Himmelberg and Peterson (1994) report that R&D investments are sensitive to firm cash flow in a panel of small firms, while Hall (1990) shows that increases in leverage is associated with R & D spending.

Though the role of small firms to innovation cannot be overemphasized, it might be prudent to assume that innovative capacity might be random irrespective of firm size. However, while (internally-generated) financing is the critical *advantage* for large firms to innovate, (lack of) financing is the critical *impediment* for small firms to innovate (Mazzucato, 2000, pp.16-7). The comparative advantages of small firms in innovation include their greater managerial control and flexibility, their motivation to foresee future changes in technology, and their ability to attract scientists and entrepreneurs who are disillusioned by large bureaucracy (Mazzucato, 2000, p. 17). Yet, the ability of small firms to unleash their creative energies and realize their innovative capacities is critically dependent on their ability to obtain (external) finance. For example, Rajan and Zingales (1998) show that, on average, U.S. firms raise significant amounts of external finance in the first ten years since their formation. RZ also shows that this degree of external dependence by young firms vary across industrial sectors. Hence, evidence that externally dependent small and young firms realize faster rates of innovation in financially developed countries provides a strong test of the role of financial development to technological progress and productivity. In summary, we have two hypotheses:

H 1: Technological progress is faster in countries with more developed financial systems.

H 1a: Industries that are more externally dependent for financing technological innovations realize faster technological progress in countries with developed financial systems.

### 2.2.2 <u>Financial development and the Cost of Capital</u>

Technological innovations, partly attributable to availability of capital, lead to reduction in costs of production. In addition, more directly, financial development may reduce the costs of raising capital contributing to real cost reduction. The costs of capital in financially developed countries should be lower for a variety of reasons. First, financial development leads to improved savings and capital mobilization, increasing the supply of capital for investment. The lower cost could be a result of a number of factors including lower transaction costs and improved liquidity that accompany improved capacity of the financial system in mobilizing large capital. Second, financial development improves corporate governance leading to amelioration of agency problems and informational asymmetry. Well-developed, liquid financial markets improve managerial discipline and performance through facilitating external monitoring in the form of shareholder activism, the threat of takeover, and increased transparency.

Real cost reduction could be a result of technological progress, which in turn can be attributed to financial development's effect on capital mobilization and risk sharing. The link between real cost reduction and technological innovation is such that the technological attributes of an economic unit can be inferred from its cost characterization. In other words, one can characterize a given technology by its cost function. Thus, to the extent that cost reduction and technological progress are alternative conceptualizations of TFP, it would be difficult to isolate the impact of financial development on cost reduction from that on technological innovation. My second set of hypotheses is summarized as follows:

H 2: Real cost reduction is higher in countries with more developed financial systems.

H 2a: Industries that are more externally dependent for financing innovation realize a higher cost reduction in more financially developed countries.

In summary, I have two complementary sets of hypotheses on the role of financial development in explaining TFP growth. First, more developed financial systems facilitate adoption of better technologies, via providing the requisite large capital and creating mechanisms for pooling and sharing risk associated with new technologies – The Technology Effect. Second, more developed financial systems, other things equal, lead to cost reduction through lowering the costs of raising capital – the Cost of Capital Effect. Empirically, it would be difficult to isolate the two hypotheses, because real cost reduction could be a result of adoption of new technologies. Hence, the empirical tests are alternative tests of the impacts of financial development on technology.

## 3. Data and measurement of proxies

I utilize three sets of data to empirically explore the proposed relations. First, I use industry-level production data for ten manufacturing industries over the period 1980 to 1995 for thirty-eight countries from the United Nations Industrial Statistics database to estimate sources of TFP – the dependent variables. Second, I construct financial development indicators – independent variables – from various sources. These include stock market capitalization, and turnover obtained from the Emerging Markets Database, and the size of domestic credit and size of the private credit sector from the International Financial Statistics (IFS) published by the IMF.

The stock market data is available on a systematic manner starting 1980, thus limiting the study period. Finally, I obtain measures of industry external dependence – independent variable – from Rajan and Zingales (1998).

### 3.1 Measurement of economic performance

The economic performance variables that are the focus of the study are TFP growth, the rate of technological progress, and the rate of cost reduction. An aggregate index of improvement in an economic unit, extensively used in the literature, is the growth rate in output ( $\dot{y}$ ). Based on inter-country production and cost functions, I first isolate the contributions of input factors (such as capital accumulation) to output growth from the contributions of TFP. I then model the TFP component of growth to be arising from either technological innovations or firm-specific efficiencies.

To that end, I estimate stochastic production frontiers in which I isolate technological change from production efficiency. The latter is measured as the proportion of actual output to the maximum level attainable if inputs were combined efficiently, *holding technology constant*. Alternatively, I estimate stochastic cost functions which isolate technological progress from economic efficiency, defined to be the proportion of the minimum attainable cost to the actual cost. Technological progress is measured as the shift in the production frontier over time holding input quantities at the same level and, alternatively as the downward shift in the average cost of production over time holding constant input prices and output level. These two alternative measures provide the dependent variables we wish to explain using financial development.

Structurally, I assume that there exists an unobservable function, the production frontier, which represents the maximum attainable output level for a given combination of inputs. Letting g[.] to represent this best-practice technology, the potential output level on the frontier at time t given a vector of factors of production x(t), would be,

$$y_{ci}^{F}(t) = g[x_{ci}(t), t] \tag{1}$$

Any observed output $y_{ci}(t)$ of industry i in country c using $x_{ci}(t)$ as inputs can then be expressed as

$$y_{ci}(t) = y_{ci}^F(t)e^{u_{ci}(t)} = g[x_{ci}(t), t]e^{u_{ci}(t)}$$

(2)

where $u_{ci}(t) < 0$ is the level of (in)efficiency corresponding to actual output $y_{ci}(t)$, and represents the shortfall of actual output from the maximum, holding the level of technology constant. Differentiating the log of eq. (2) with respect to time, we have:

$$\frac{\dot{y}_{ci}(t)}{y_{ci}(t)} = g_x \frac{\dot{x}_{ci}(t)}{x_{ci}(t)} + \underbrace{g_t + \dot{u}_{ci}(t)}_{T\dot{F}P}.$$

(3)

Eq. (3) decomposes output growth into a combined effects of factor accumulation and scale economies (first term), the shifts in the production technology ($g_t$), and efficiency changes during period t. Empirically, I represent eq. (2) by a translog stochastic production frontier (see Appendix 1). I then generate the values of realized rates of technological change based on the parameter estimates of the frontier. The empirical proxy thus obtained is **ΔTECH1**, and it operationalizes $g_t$. I also generate the values of realized TFP growth ($T\dot{F}P$) as the sum of the predicted rates of technical change and changes in efficiency.

In the foregoing, the underlying technology is represented by g[.]. Duality theory suggests that under certain regularity conditions[1], if producers pursue cost minimizing objective, the production function can be uniquely represented by a cost function. Letting h(.) be the best practice variable cost frontier, the minimum possible cost for period t, given input price of w, the level of fixed input I , and output y is given by

$$C_{ci}^F(t) = h(w_{ci}(t), I_{ci}(t), y_{ci}(t), t)$$

(4)

Observed cost, $C_{ci}(t)$ of industry i in country c for period t can then be expressed as:

$$C_{ci}(t) = C_{ci}^F(t)e^{\theta_{ci}(t)} = h(w_{ci}(t), I_{ci}(t), y_{ci}(t), t)e^{\theta_{ci}(t)}$$

(5)

[1]To be a valid representation of the technology, a cost function should be a non-negative, non-decreasing function of output y; a non-negative, non-decreasing concave function in input prices; and twice differentiable with respect to input prices. Furthermore, a restricted (variable) cost function should be a non-positive and convex function of quasi-fixed input quantities.

where $\theta_{ci}(t) \geq 0$, represents the degree of economic efficiency and measures the excess of actual cost over the minimum, holding the level of technology, input prices and output constant. Differentiating the log of eq. (5) with respect to t, and noting that improvements in terms of cost mean cost diminution, we obtain:

$$-\frac{\dot{C}_{ci}(t)}{C_{ci}(t)} = -\left\{ h_w \frac{\dot{w}_{ci}(t)}{w_{ci}(t)} + h_I \frac{\dot{I}_{ci}(t)}{I_{ci}(t)} + h_y \frac{\dot{y}_{ci}(t)}{y_{ci}(t)} + h_t + \dot{\theta}_{ci}(t) \right\} \tag{6}$$

Eq. (6) decomposes the rate of cost diminution into share-weighted rate of growth in input prices (first term), shadow values of fixed inputs (second term), output scale economies (third term), technological progress (fourth term) and efficiency improvements. $h_t$ represents the downward shift in the cost frontier over time and is considered to be the cost effects of technological progress. Empirically, I represent eq. (5) by a translog stochastic cost frontier (see Appendix 1). I then generate the predicted values of realized rates of real cost reduction based on the parameter estimates of the frontier. The proxy thus obtained is **ΔTECH2**, and is an empirical equivalent of $h_t$.

The interpretation of these empirical measures is as follows. **Δ**TECH1 represents increases in output yield due to shifts in the best-practice technology, g[.]. This closely fits the technology interpretation of TFP, and would be used to directly test the Technology Effect of financial development. By duality, **Δ**TECH2 also measures the change in technology – shifts in the best-practice cost frontier h[.] - but, in fact, represents the rate of cost reduction over time. This representation closely fits Harberger (1998)'s idea of TFP as an amalgam of factors behind cost reductions. The variable is used to test the Cost of Capital Effect of financial Development.

Appendix 1 provides details on the estimation of these variables. Tables 1 presents a summary of the performance measures based on the specifications. There is a wide variation in the estimates across countries (Panel A). Growth is slower in advanced countries, as would be expected, reflecting initial conditions. In Table 2, the growth rate in real value added is strongly negatively correlated with per capita real GDP. Growth in productivity does not appear to be related to countries' level of economic development (correlation with log of per capita GDP is not different from zero). Realized productivity growth in the U.S. (3.1% per annum) compares well with that of the Philippines (3.3%), the highest being that of Korea

(4.9%) and of Sri Lanka (5.4%). On the other hand, technical progress is much faster in developed countries than in emerging economies. Realized rate of technical change ranges from 3.6% per annum in Japan to –1.1 % in Bangladesh. This may be a reflection of developed countries' larger resources to spur technological innovations and inventions. There are also variations across industries (Panel B), with the highest rate of technical progress registered in Industrial Chemicals industry (2.6%) and the lowest in the Apparel industry (0.8 %). Table 1 (Panel C) also presents a summary of the variables for the entire sample of 3605 industry-country-years. There are wide variations in realized performance measures. The median industry growth rate in real value added is 2.7% for the entire sample. The average industry realizes an annual productivity growth of 1.5%, and an annual cost reduction at a rate of 2.6%. Yet, the rate of cost reduction ranges from –0.3% to 5.6%. The average industry contributes about 5% of the manufacturing sectors' real output.

### 3.2 Measurement of Financial Development

Ideally, I would like to have a measure of the ability of firms to raise capital to meet their financial needs, and the ability of the financial system in pooling and sharing risk. I use measures of financial system size (relative to GDP) as proxies. These size variables include (1) stock market capitalization to GDP ratio (MKTCAP); (2) domestic credit to GDP ratio (BANK); and (3) claims against the private sector relative to GDP ratio (PRIVATE). I also include a measure of stock market liquidity (TURNOVER). Appendix 2 provides a detail definition of the variables. Levine and Zervos (1998) found this variable to be linked with productivity growth.

Table 1 presents a summary of these variables for the thirty-eight countries in the sample. Panel A of the table shows averages of the variables over the sample period for each country. We observe a number of patterns. Stock market size (MKTCAP) does not necessarily go hand in hand with stock market liquidity. For example, Chile has a relatively large market (MKTCP 0.4717) and yet is one of the least liquid with a TURNOVER of 0.0661. On the other hand, Turkey has one of the smallest markets (MKTCAP 0.0624) and is relatively liquid (TURNOVER 0.5041). The correlation between MKTCAP and TURNOVER is not statistically different from zero (Table 2). In general, developed countries have more advanced financial systems than emerging countries. The correlation (Table 2) between log of real per capita income and each of the financial development variables is significantly positive.

### 3.3 Measurement of Industry Characteristics

I use the external financial dependence of industries as an industry attribute relevant for the degree of impact of the financial system on the industry's technological innovation. This is because theory, as discussed in Section 1, suggests that the impact of financial development on technical innovation is primarily via its ability to make large financial capital available. Small firms are considered to have enormous comparative advantages for innovation, while critically constrained by lack of finance (e.g., Mazzucato, (2000)). Rajan and Zingales (1998) find that U.S. firms raise much of external finance only up to their tenth year of life. This also corresponds to the fact that the external financing need for funding innovation is much stronger when firms are younger. I, therefore, use the external financial dependence of younger firms in the U.S. industries from RZ as a measure of the industries' need for external finance for innovation. RZ construct the measure of external dependence for each U.S. industry, arguing that the dependence of U.S. firms on external finance is a good proxy for the natural demand for external funds by similar firms in other countries.

## 4. Financial development and technology: Results

The empirical results are presented in the following order. Tables 3 and 4 summarize the results of a cross-country regression model designed to test for Hypotheses 1 and 2 above. Tables 5 and 6 present the results of a Rajan and Zingales (1998) type cross-country cross-industry regression which tests for Hypotheses 1a and 2a, providing stronger evidence of the finance-technology nexus.

### 4.1 Cross-country Regressions

To explore the hypothesized relations, I first estimate a cross-country regression model of the following form:

$$Growth_{cit} = \sum_k \beta^k F_{ct}^{\ k} + \gamma Z_{cit} + \varepsilon_{cit} \qquad (7)$$

The model relates financial development to the rates of technological progress and cost reduction across countries, *regardless* of industry characteristics, thus providing tests of hypotheses 1 and 2. $\text{Growth}_{cit}$ represents the economic performance measures I set out to explain. The focal variables are ΔTECH1 and ΔTECH2. I also provide regression results for the growth rate in TFP, and the growth in real value-added. All these variables are for industry i in country c over period t. c=1,…,C; i=1,…,$I_c$ ; and, t=1,…,$T_{ci}$. $F_{ct}^{\ k}$ is the $k^{th}$ financial development variable for country c in period t. These are MKTCAP, TURNOVER, BANK, and PRIVATE. The control variable $Z_{cit}$ represents the relative significance of industry i in country c during period t. I use the share of value added of the industry in the total value added of the manufacturing sector of the country. The model is a four-way error-component (random effects) specification with the following error structure:

$$
\begin{aligned}
&\varepsilon_{cit} = \alpha_c + \eta_i + \lambda_t + \nu_{cit} \\
&where, \\
&\alpha_c \approx IID(0, {\sigma_\alpha}^2), \\
&\eta_i \approx IID(0, {\sigma_\eta}^2), \\
&\lambda_t \approx IID(0, {\sigma_\lambda}^2), and \\
&\nu_{cit} \approx IID(0, {\sigma_\nu}^2).
\end{aligned} \qquad (8)
$$

$\alpha_c$, $\eta_i$, $\lambda_t$ and $\nu_{cit}$ are independent from each other and also independent of the F and Z variables in Eq. (7) above. $\alpha_c$ is unobservable time and industry invariant, country specific effects; $\eta_i$ is unobservable country and time invariant, industry effects; $\lambda_t$ represents unobservable country and industry invariant, time effects; and, $\nu_{cit}$ is a random disturbance term. The random-effects specification has the advantage of (i) capturing intra-country, intra-industry and intra-year correlations in the error terms, and (ii) controlling for all other non-observable country, industry and time related sources of differences in the dependent variable. I estimate the model by the method of maximum likelihood (ML) under the distributional assumption of normality for the error components and the residual. The ML estimates are consistent and asymptotically efficient, and have a known asymptotic sampling information matrix[2].

### 4.1.1 Financial Development and Aggregate Measures of Performance

[2]Alternative estimation methods that include ANOVA type, ML, restricted maximum likelihood (REML), and Minimum Quadratic Unbiased Estimation (MINQUE) vary in the way the variances of the error components are estimated. Simple ANOVA type estimates no longer apply for unbalanced panel with three error-components. We use REML, a procedure in which variance components are estimated based on the portion of the likelihood function that depends on the error components alone. In a balanced data, the REML estimators of the variance components are identical to ANOVA estimators, which have optimal minimum variance properties. The results do not change when we estimate the models by ML, and by MINQUE procedures.

Table 3 reports the empirical relations between financial development and the aggregate measures of performance, namely, growth in value added and growth in TFP. Panel A shows that the growth in industry real value added is positively related with stock market liquidity and measures of bank development. Consistent with Levine and Zervos (1998), both market liquidity and bank development are significantly correlated with growth, while market size (MKTCAP) is not. In Panel B, consistent with previous research, both bank development and stock market development are positively correlated with productivity gains. Again, stock market liquidity appears to be more important than stock market size. The results confirm the familiar finance-growth link.

Industries that account for a larger portion of the country's manufacturing have higher growth rates in real value added and faster productivity improvements. This may be a reflection of the effects of other sources of comparative advantage (i.e. other than financial development) [3]. Developed countries have lower growth rates in manufacturing (the coefficient of log per capita GDP (not reported) is significantly negative) reflecting the convergence effect[4].

#### 4.1.2 Financial Development and Rate of Technological Progress

Having confirmed the first-order relation between financial development and productivity, Table 4 presents the focal empirical relations between financial development, and the rate of technological progress (**Δ**TECH1), and the rate of real cost reduction (**Δ**TECH2). In Panel A of the table, the main result to highlight is that while the measures of bank development (BANK and PRIVATE) carry significant positive coefficients, stock market development has at best a marginal effect. Stock market liquidity (TURNOVER) fails to be statistically significant, and MKTCAP, the measure of equity market capital mobilization, enters positively but is only marginally significant at 10%. Increasing banking development is associated with faster technological progress. In economic terms, raising the size of domestic credit (BANK) by one

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[3] It could be that an industry's performance (in fact, its presence or absence in a country) may reflect comparative advantages of the country, other than financial development, in fostering a specific type of industrial activity. These may include advantages related to natural endowments, better business environment etc. Sources of comparative advantages are numerous, vary from country to country as well as from industry to industry, and are generally difficult to exhaustively incorporate in a model. Omission of such variables would be of concern only to the extent that they could be correlated with the financial variables for which I do not have a priori reasons to suspect so. However, as strength to the specification, I can adequately control for these variations. First, limiting the sample to only manufacturing (for example, avoiding mining industries) eliminates natural resource endowment as a source of comparative advantage. Second, all unobservable industry and time invariant sources of comparative advantages are captured by the random country effect. Even within the manufacturing sector, a country's comparative advantage may not benefit all industries identically, however. The index of the importance of an industry in a country's manufacturing, inter alia, is meant to capture this type of variations in comparative advantages (industry-variant comparative advantages). The inclusion of such variables is made possible because of the random-effects specification.

[4] The results here and in the sections to follow are not sensitive to inclusion or exclusion of these variables.

standard deviation (0.329) increases the rate of technological progress of the average industry by about 0.07 percent per annum, or raising the size of credit to the private sector (PRIVATE) by one standard deviation increases the rate of technical change by 0.06 percent.

The coefficient estimates for BANK and PRIVATE are also robustly positive on the margin when controlling for the effects of equity markets in specifications VI through IX. Finally, in versions X and XI which include BANK and PRIVATE respectively in a model that contains both TURNOVER and MKTCAP, only the banking development variables are significant. Both TURNOVER and MKTCAP are not significantly different from zero. Thus controlling for equity markets development, raising bank development increases the rate of technological progress.

Industries that account for a larger portion of the country's manufacturing realize higher technical progress, reflecting effects of sources of comparative advantage other than financial development. Also, not surprisingly, industries in developed countries achieve higher rate of technical change (per capita GDP (not shown) is positive and significant). The estimates of the error components (not reported) indicate that the unobservable country, industry and time effects are also important in explaining variations in industry technical progress (about 75% of unexplained variation is attributable to these latent variables). Moreover, country effects are more important: latent country factors account for about 40% of total unexplained variations in technical change (in contrast industry factors account for 33% and time effects account for 11% of the variation)[5].

Overall, the results appear to be consistent with the Technological Effect of financial development – Hypothesis 1. The ability of capital markets to mobilize capital (measured by the size variables) is associated with the rate of technological progress. Industries that are supported by financial systems with greater capital mobilization ability exhibit faster rates of technological change. The results also imply that, in its role as capital mobilizer, the intermediary sector appears to have larger impact on technological progress than stock markets. In models that contain stock market capitalization, the effects of domestic credit and size of private credit on technological change persists to be significantly positive.

[5] Not including GDP per capita explicitly in the model drives up the variation due to country factors to about 60 percent of the total unexplained variation. Exclusion or inclusion of the control variables does not affect the significance of the main variables, however.

### 4.1.3 Financial Development and the Rate of Real Cost Reduction

To further document the relations between financial development and technology, Panel B of Table 4 presents estimates of regression of realized industry rates of cost reductions (ΔTECH2). In specifications I through IV, raising bank development (BANK or PRIVATE) increases the rate of realized cost reduction, while improving stock market development has no perceptible impact on real costs. Raising the size of domestic credit (BANK) by one standard deviation (0.329), increases the rate of cost reduction of the average industry by about 0.04 percent per annum.

Increasing bank development is also associated with increases in the rate of real cost reduction on the margin after controlling for stock market development. This is seen in specifications VI through XI where the coefficients of BANK and PRIVATE are consistently significant. Neither TURNOVER nor MKTCAP enter the regressions with significance.

The results are consistent with the Cost of Capital effects of financial development – Hypothesis 2. Capital markets contribute to productivity improvement by facilitating cost reduction either directly through enabling acquisition of large capital at low cost or indirectly through mitigating agency problems and information asymmetries endemic to the modern firm.

### 4.2 Cross-Country Cross-Industry Regressions

The approach outlined above enables us to determine the average economy-wide effect of financial development. However, as noted by Rajan and Zingales (1998), such a cross-country approach suffers from omitted variables and endogenity bias whereby inferring causality from the evidence is problematic. RZ provide a methodology that addresses both problems. They examine whether financially dependent industries grow faster in financially developed countries. By including an interaction of a country variable (financial development) against an industry characteristic (industry financial dependence) in the cross-country regression, the RZ methodology resolves the identification problem. In addition, the finding of a heterogeneous impact across industries provides, in RZ's words "the smoking gun" in the debate about causality.

I explore the within-country between-industry differential impacts of financial development to further pin down the exact process by which financial development could affect productivity and technology. Industries that rely on external finance for financing innovation benefit more from financial development because the financial sector's role in facilitating technological innovation is primarily through making the requisite capital available. Financial constraints critically impede the pace of innovation by small firms that have otherwise comparative advantages to innovate. I use the external financial dependence of young firms in the U.S. industries as a measure of the industries' reliance on external finance for innovation. The model I use to explore the heterogeneous effects of financial development, thereby testing hypotheses 1a and 2a, is of the following form:

$$Growth_{cit} = \sum_k \beta^k F_{ct}^{\ k} * EX^i + \gamma Z_{cit} + \varepsilon_{cit} \quad (9)$$

where $Growth_{cit}$ represents the economic performance measures I wish to explain, in particular, it represents either the rate of technological progress (ΔTECH1) or the rate of real cost reduction (ΔTECH2) of industry i in country c in period t. $EX^i$ is the external financial dependence of young firms in industry i from RZ. $F_{ct}^{\ k}$ is the kth financial development variable for country c in period t. These are MKTCAP, TURNOVER, BANK, and PRIVATE. Again the model is a four-way error-component (random effects) specification with the error structure in eq. (8). Furthermore, because the U.S. is used as a benchmark to construct the degree of external dependence, I drop the U.S. for this part of the analysis, following RZ, to reduce the potential problem of endogeniety.

### 4.2.1 Financial Development, External Dependence and Technological Progress

Table 5 reports the results. Panel A of the table shows that the impact of financial development (particularly of the banking sector) on technological progress is heterogeneous across industries. In the specifications where each financial development variable is interacted with external dependence (specification I through III), the coefficients of the interactions with TURNOVER (specification I) and with MKTCAP (specification II) are not statistically different from zero. This provides additional credence to the previous finding that stock market development has little effect on technology. On the other hand, the coefficients of the interaction with BANK and with PRIVATE are positive and significant at 1% level. Hence, industries that are more dependent on external finance realize more rapid technological progress in countries that have more developed banking sector. The impact of bank development on technological progress of financially dependent industries is in addition to the effects of the equity markets. The coefficients of the interaction terms are positive and of same magnitude when I include, as controls, the interactions of external dependence with TURNOVER (specification V and VI), with MKTCAP (specification VII and VIII), and the interactions with both TURNOVER and MKTCAP (specification IX and X).

To gauge the economic significance of bank development, I perform a standard comparative dynamics exercise. Specifically, I ask what the technological advantage of a more externally dependent industry (Plastic Products (external dependence ratio 1.14%)) over an industry with less external dependence (Apparel (external dependence ratio 0.27) would be, if the industries were located in a country with a more developed banking system (say, Japan (BANK, 1.27)) rather than in a country with a less developed banking sector (e.g. Peru (BANK 0.16). Based on the estimates of specification III, the difference in rate of technological progress between the two industries would be about ½ percent per annum *higher* in Japan than in Peru. For comparison, the average rate of technological change in the sample is 1.9 % per year. Hence, a differential rate of ½ percent due to improvements in bank development is significantly large.

### 4.2.2 Financial Development, External Dependence and the Rate of Cost Reduction

In Panel B of Table 5, I highlight the fact that the interaction between external financial dependence and bank development is again positive and statistically significant (specification III and IV), suggesting that banking development has a heterogeneous impact on realized rates of cost reduction **(**$\Delta$TECH2) across industries. The interaction terms with TURNOVER and with MKTCAP remain statistically not different from zero both in the individual regressions (specification I and II), and in the regressions that include the interaction terms with BANK and PRIVATE. Consistent with the evidence so far, stock market development has little impact on differences in cost reduction across industries. On the other hand, externally dependent industries realize larger cost reduction in countries with more developed banking system.

In economic terms, based on specification III of Panel B, the least externally dependent industry (Apparel) would receive a cost saving of about 11 basis points per year in going from the country with less developed banking sector (Peru) to the country with more developed banking sector (Japan). The more externally dependent industry (Plastic and Products) would receive instead a cost saving of 44 basis points per year. These results confirm the robustness of those obtained in Table 4 using cross-country regressions. Moreover, the financially dependent industry realizes 33 (i.e. 44 less 11) basis point per annum more in cost saving over that of the less financially dependent industry by going from the country with less bank development (Peru) to that with high bank development (Japan). Noting that the average rate of cost reduction is 260 basis points, a differential cost saving of 33 basis points due to improvements in bank development is economically large. Overall, the evidence in Table 5 is supportive of the theoretical priors, in hypotheses 1a and 2a.

## 5. Statistical Robustness Tests

I now turn to present a battery of robustness tests, for which I focus on the cross-country cross-industry specification of equation (9). I have also conducted the relevant robustness tests on specification (7), and found the results of that model to be very robust. I will report on some of those tests when found to be relevant. Also, for brevity, I report the results using the variable BANK as a measure of bank development, but the results hold for PRIVATE as well.

### 5.1 Could the results be due to better property rights protection?

The importance of property rights protection for fostering growth and innovation is increasingly recognized (see Basley, 1995; Claessens and Laeven, 2003). Stern et al (2000) provides strong evidence that the degree of protection afforded to intellectual property rights affects countries' innovative capacity. It might, therefore, be argued that financial development simply measures the degree of property rights protection in the country and so the effects documented could be effects of better property rights instead of financial development. I check for this possibility by explicitly including measures of property rights protection. I use six alternative measures of the degree to which countries protect property rights. These are (1) a rating of protection of property rights from the index of economic freedom (PROPFREE), (2) a rating of protection of intellectual property rights based on the "special 301" placements of the US Trade representative (INT301), (3) a patent rights index by Ginart and Park (1997) (PATENT), (4) an index of the general legal protection of private property from the World Economic Forum (WEF), (5) index of intellectual property rights from the World Economic Forum (INTWEF), and (6) a property rights index from the International Country Risk Guide

(PROPICRG). These variables, defined in detail in Appendix 2, have been used in previous research (e.g. Claessens and Laeven (2003)).

Table 6 shows that the main results are robust to inclusion of measures of property rights. In specifications I through VI of Panel A, I include the property rights proxies in the cross-country specification with BANK, the measure of financial development. The coefficient of BANK is robustly positive. Similar to Claessens and Laeven (2003), the results do not show an average effect of property rights on performance. In a specification similar to Rajan and Zingales (1998) and equation (9), Claessens and Laeven(2003) also examine if property rights protection affects growth by encouraging the growth of industries that are more sensitive to such protections. To do this, they construct an intangible intensity measure (INTANGIBLE) for U.S industries, and interact this measure against the country property rights indices. They find that the coefficient of this interaction term to be positive, indicating that industries that are intensive in their deployment of intangible assets grow faster in countries with more rights protection. I test the robustness of my results in Table 5, by including the interaction of industry intangible intensity and property rights index in the basic regression that includes the interaction of external dependence and BANK. Specifications VII through XII show that the interaction with BANK is significantly positive. Consistent with Claessens and Laeven(2003), the coefficients of the interactions between property rights and intangible intensity are significantly positive. Panel B of Table 6 shows that the results using the rate of cost reduction are also robust to inclusion of the measures of property rights protection.

### 5.2. Could the results be driven by omitted variables?

It may be argued that differences in other country specific comparative advantages (not financial development) or industry-specific characteristics (not external dependence) may be behind the observed relations. The results cannot be explained, however, unless the industry dependence on that comparative advantage is correlated with external dependence, and financial development is a proxy of the comparative advantage in question. I minimize the possibility of this type of omitted variable bias by focusing on manufacturing industries only, thereby reducing the influence of availability of natural resources, for example.

In addition, I can directly test if financial development or external dependence stands for something else. It could be that externally dependent industries could be dependent on human capital as well, and to the extent that bank development is correlated with human capital, the observed effect might proxy for the interaction of human capital dependence and availability of trained human capital. To test for this possibility, I include the interaction of human capital and bank development in the basic regression. I use the fraction of the population that has attained secondary school education from Barro and Lee (1993) for human capital. In Table 7 (specification I), the coefficient of the interaction is not significant while the interaction between external dependence and BANK is significant and same magnitude.

It might be argued that external dependence reflects industry growth opportunities. Given that bank development is high, it may not be externally dependent industries that realize technical progress instead those with better growth opportunities. If industrial growth opportunities are systematically correlated with bank development, the reported relations between technical progress and the interaction term will be spurious. To check for this possibility, specification II of Table 7 includes an interaction of a measure of industry growth opportunity and bank development in the basic model that contains the interaction between external dependence and bank development. I use the average growth rate in sales of U.S. industries from Fisman and Love (2002) as a measure of industrial investment opportunities. The coefficient of the interaction between BANK and external dependence is robustly positive, suggesting that external dependence may not be a proxy for growth opportunities.

Another concern could be that financial development might be a proxy for the general country-wide investment opportunities or for the general level of economic development. In that case, any relation between technological change and the interaction term is spurious because it may reflect differences in growth opportunities rather than the financial system's ability to provide funding for industries' innovation. To check for this, I add the interaction of the log of per capita with external dependence in the basic model which includes the interaction of bank development and external dependence. The coefficient of the bank development interaction remains significantly positive. Consistent with Rajan and Zingales (1998), the interaction with income is also positive.

### 5.3 Are the results robust to changes in the measures of stock market development?

I use stock market capitalization and turnover to measure the ability of the stock market to mobilize capital to the private sector, and examine the role such service plays to industry performance. The evidence so far suggests that stock market development is not related to productivity growth and, at best, marginally related to technological change and real cost reduction. To the extent that the proxies measure capital mobilization, the evidence points to the stock markets' minimal role as financer of innovations. Before making such inference, however, I further closely examine the evidence with the objective of ruling out mechanical explanations.

An alternative way to measure stock market development is to use the quality of accounting standards that are the basis for information flow in capital market. Rajan and Zingales(1998) use an index of accounting disclosure quality for financial development. Specification IV of Table 7 shows that stock market development measured by this index has no impact on technological progress. The interaction term between the index and external dependence is not different from zero. The variable is also not significant in the cross-country models (not reported).

I use the market capitalization to GDP as a level and find no significant role for the stock market. It may be argued that what we need to measure is the change (not the level) partly because we are measuring the effect of infusion of new equity capital and also because the dependent variables are measured as changes. I run the regressions redefining market capitalization as first differences rather than as a level. The results (not reported) show that measured in this way, market capitalization has no statistically significant impact.

Finally, I use information on recent IPO activities as an alternative measure of stock market development. The best I could find is the ratio of the number of IPOs to the size of population over the period 1995-1996 from La Porta et al (1997). The variable ranges from 0.02 for South Korea to 4.50 IPOs per millions of population in Norway. Other countries include U.S. (3.11), U.K. (2.01), Canada (4.93), Columbia (0.05) and Mexico (0.03). Measured in this way, stock market's interaction with external dependence again is not statistically significant (specification V of Table8).

Stock market development measured as market capitalization, turnover, changes in market capitalization, number of IPOs, and accounting standards does not explain variations in technological progress and rates of cost reduction. This simply confirms previous findings by Rajan and Zingales (1998) where no effect of stock market was found on the relative growth of industries. Levine and Zervos (1998) also fail to find relation between market capitalization and growth in per capita GDP over the period 1976 to 1993. Rajan and Zingales (1998) note that equity markets may have impact on growth for reasons unrelated to availability of external finance.

## 5.4 Reverse Causality

In examining the association between the components of TFP and financial development, I measure the latter using variables that I assume to be exogenous and predetermined. It may be argued that the proxies for financial development may not be exogenous enough in that financial development may simply be “a leading indicator rather than a causal factor”.

The cross-country cross-industry results are less susceptible than the cross-country regression results. First, I present a reasonable explanation of the mechanism through which financial development could lead to differential degree of technical progress among firms that differ in their need for external finance for funding innovation. As an advantage over the traditional cross-country methodology, a finding of within-country between-industry difference in technological progress based on their degree of external dependence is, in the words of RZ, “the smoking gun” in the debate about causality. Second, by design, I use the U.S. industries external dependence to explain technical progress in other countries, thereby reducing a potential endogeniety problem if I include the U.S. in the sample. Third, I explicitly account for potential omitted variables, such as property rights and others.

To address any remaining reverse causality concerns, I estimate the basic model using instrumental variables. The ideal instruments are variables that might affect financial development but less likely to be affected by it. I use three institutional variables. These are indices of investor-protecting legal codes (from La Porta et al (1998)), the colonial origin of country’s legal system (from La Porta et al (1998)), and mortality rates of early European settlers in colonies in the 17$^{th}$, 18$^{th}$ and 19$^{th}$ centuries (from Acemoglu et al (2001)). La Porta et al (1997) argue that legal protections afforded to investors and country’s legal origin determine financial development, and that these, in turn, are primarily determined by a country’s colonial history. Hence, the two sets of variables would be ideal instruments for financial development in that while the variables are strongly correlated with financial development, they do not directly correlate with the dependent variables. RZ and Levine and Zervos (1998) use these variables as instruments for financial development as well. Acemoglu et al (2001) uses the settler mortality rates as instruments for institutional quality arguing that the willingness of colonial powers to settle and develop institutions depended on their ability to survive physically.

Specifications VI, VII and VIII of Table 7 present the instrumental variables results using legal protection, legal origin and mortality rates as instruments respectively. For mortality rates, I have relevant data only for 16 countries. The coefficients of the interaction term between external dependence and bank development is strongly positive when estimated using instrumental variables. These exogenous components of bank development (BANK) predetermined by the extent of legal protection afforded to investors, by legal origin and by settler mortality rates have also statistically significant positive impacts on technical progress and rate of cost reduction in the cross-country specifications (not reported). Hence, the relations between technological progress and bank development identified in this study are less likely to be explained by endogeneity.

## 6. Conclusion

Overwhelming empirical evidence in development economics establishes that economic growth has a lot more to do with productivity improvements than capital accumulation. The bulk of cross-country differences in the level or growth of GDP per capita – by some account up to 60% of variations – is attributable to productivity differences.

In light of this evidence, the paper examines the role of financial development in explaining cross-country differences in productivity. I argue that an important channel by which financial development could influence growth is through facilitating technological innovations and low-cost production methods that could boost productivity. First, adoption of technologies requires large sums of capital that could easily be mobilized in well-developed financial systems. Second, well-developed capital markets and institutions encourage adoption of long-gestation productive technologies through reducing investors' liquidity risks. Finally, by providing hedging and other risk sharing possibilities, financial markets and institutions promote assimilation of specialized (versus generalized), and hence productive, technologies.

Based on a panel of ten industries across thirty-eight countries, I find a strong positive relation between industries' realized technological progress and the level of development of their supporting financial sector. In particular, I find that the share of productivity gain due to technological innovations is significantly larger in countries with well-developed banking sector, and to some extent with larger stock markets. However, the impact of equity markets on technological progress appears to be very weak. Technical advancement generally leads to real cost reduction in transforming inputs into outputs. I find evidence that industries in countries with well-developed banking sector realize significantly higher rates of real cost reduction. The evidence is consistent with the notion that financial development spurs productivity through encouraging technological innovations and adoptions, via making large external capital available at lower cost.

The impact of financial development on technological progress appears to be heterogeneous. In particular, industries whose young firms are dependent on external finance realize faster technological progress accompanied by higher rates of cost reduction in financially developed countries. The evidence of heterogeneous effect implies that financial development plays an important role in shaping the industrial structure of the country. The combined evidence indicates that financial development partially dictates the pace of countries' technological progress.

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## Table 1: Financial Development Variables and Measures of Economic Performance: Averages over the period 1980-1995.

Turnover Ratio is total market value of equity traded during the year relative to total stock market capitalization at the end of the year. Stock Market Capitalization to GDP is total market value of publicly traded equity at end of year as reported by IFC divided by the Gross Domestic Product of that year. Domestic credit to GDP ratio is the sum of assets held by the monetary authority and depository institutions excluding inter-bank deposits (i.e. IFS lines 32a-32f excluding 32e) divided by GDP. The ratio of private credit to GDP is the proportion of claims against the private sector (IFS line 32d) divided by GDP. Growth in real value added is the annual compounded growth rate in real value added for each of the ten industries in each of the thirty-eight countries over the period 1980 to 1995. Technological change measures the shift in the production frontier over time, and represents increases in real output due to adoption of better technology. Rate of real cost reduction measures the rate of downward shift in the cost function over time, holding output constant and represents the decrease in total cost due to better technologies. Industry Share in Manufacturing is calculated by dividing the real output of the industry in the country by the total real output of the manufacturing sector of the country.

| | *Turnover Ratio* (TURNOVER) | *Stock Market Cap./GDP* (MKTCAP) | *Domestic Credit/GDP* (BANK) | *Private Credit/GDP* (PRIVATE) | *Growth in Real Value Added* ($\dot{y}$) | *Growth in Productivity* ($T\dot{F}P$) | *Technical Change* ($\nabla TECH1$) | *Rate of Real Cost Reduction* ($\nabla TECH2$) | *Industry Share in Manufacturing* (SHARE) | *Log(Per Capita GDP)* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Summary by Country** | | | | | | | | | | |
| Australia | 0.2923 | 0.4712 | 0.6133 | 0.4930 | 0.008 | 0.020 | 0.023 | 0.030 | 0.043 | 9.704 |
| Austria | 0.4422 | 0.0783 | 1.1361 | 0.8656 | 0.019 | 0.028 | 0.023 | 0.027 | 0.038 | 9.856 |
| Bangladesh | 0.0327 | 0.0158 | 0.2976 | 0.1732 | 0.045 | -0.064 | -0.011 | 0.009 | 0.034 | 5.234 |
| Belgium | 0.1202 | 0.2767 | 0.9036 | 0.3970 | -0.001 | 0.003 | 0.027 | 0.031 | 0.032 | 9.791 |
| Canada | 0.3084 | 0.4687 | 0.5763 | 0.5021 | 0.030 | 0.019 | 0.024 | 0.029 | 0.029 | 9.899 |
| Chile | 0.0661 | 0.4717 | 0.7692 | 0.5848 | 0.053 | 0.038 | 0.012 | 0.022 | 0.026 | 6.086 |
| Colombia | 0.0863 | 0.0725 | 0.2091 | 0.1587 | 0.039 | 0.011 | 0.014 | 0.024 | 0.061 | 7.711 |
| Denmark | 0.2086 | 0.2386 | 0.5974 | 0.4461 | 0.029 | 0.018 | 0.020 | 0.026 | 0.050 | 7.096 |
| Egypt | 0.0636 | 0.0442 | 0.9532 | 0.2618 | 0.029 | 0.013 | 0.015 | 0.026 | 0.061 | 10.085 |
| Finland | 0.2019 | 0.1936 | 0.6882 | 0.7063 | 0.000 | 0.021 | 0.020 | 0.024 | 0.042 | 10.081 |
| Germany | 1.0394 | 0.1995 | 1.1282 | 0.8856 | 0.025 | 0.022 | 0.033 | 0.035 | 0.045 | 9.963 |
| Greece | 0.1218 | 0.0881 | 0.7134 | 0.2482 | 0.022 | 0.038 | 0.017 | 0.023 | 0.054 | 8.968 |
| India | 0.4261 | 0.1460 | 0.5075 | 0.2602 | 0.089 | 0.027 | 0.015 | 0.028 | 0.051 | 5.780 |
| Indonesia | 0.1855 | 0.0669 | 0.2557 | 0.2655 | 0.171 | 0.030 | 0.007 | 0.021 | 0.040 | 6.315 |
| Israel | 0.6492 | 0.3208 | 1.2850 | 0.6854 | -0.019 | -0.013 | 0.014 | 0.022 | 0.037 | 9.287 |
| Italy | 0.2986 | 0.1285 | 0.7939 | 0.3591 | -0.015 | -0.018 | 0.028 | 0.032 | 0.051 | 9.757 |
| Japan | 0.4329 | 0.7859 | 1.2702 | 1.0759 | 0.042 | 0.018 | 0.036 | 0.036 | 0.046 | 9.966 |
| Jordan | 0.1571 | 0.5552 | 0.8809 | 0.6056 | 0.008 | -0.021 | 0.022 | 0.023 | 0.123 | 7.008 |
| Korea | 0.8502 | 0.2710 | 0.5470 | 0.5155 | 0.113 | 0.049 | 0.022 | 0.027 | 0.055 | 8.527 |
| Kuwait | 0.2363 | 0.5051 | 0.6614 | 0.6219 | 0.030 | 0.007 | 0.000 | 0.013 | 0.026 | 9.632 |
| Malaysia | 0.2392 | 1.2054 | 0.7274 | 0.6362 | 0.108 | 0.019 | 0.016 | 0.023 | 0.043 | 7.730 |
| Mexico | 0.5394 | 0.1551 | 0.3576 | 0.1958 | 0.021 | 0.009 | 0.016 | 0.023 | 0.055 | 7.975 |
| Netherlands | 0.3656 | 0.4485 | 0.9683 | 0.7700 | 0.017 | 0.016 | 0.025 | 0.028 | 0.057 | 9.786 |
| New Zealand | 0.1854 | 0.4242 | 0.5030 | 0.4306 | -0.016 | 0.009 | 0.015 | 0.023 | 0.068 | 9.444 |
| Norway | 0.3265 | 0.1624 | 0.6211 | 0.5155 | -0.002 | 0.024 | 0.021 | 0.027 | 0.043 | 10.179 |
| Pakistan | 0.1413 | 0.0945 | 0.5135 | 0.2771 | 0.075 | -0.029 | 0.006 | 0.019 | 0.043 | 5.794 |
| Peru | 0.1630 | 0.0649 | 0.1606 | 0.1020 | -0.118 | -0.049 | 0.019 | 0.026 | 0.051 | 7.524 |
| Philippines | 0.2161 | 0.2419 | 0.3489 | 0.2544 | 0.017 | 0.033 | 0.010 | 0.022 | 0.058 | 6.566 |
| Portugal | 0.1537 | 0.0968 | 0.9816 | 0.5543 | 0.013 | 0.022 | 0.022 | 0.028 | 0.048 | 8.690 |
| Singapore | 0.3254 | 1.3511 | 0.6614 | 0.8564 | 0.040 | 0.012 | 0.013 | 0.021 | 0.037 | 9.422 |
| Spain | 0.2695 | 0.1966 | 0.9965 | 0.6928 | 0.011 | 0.013 | 0.025 | 0.029 | 0.045 | 6.496 |
| Sri Lanka | 0.0694 | 0.1333 | 0.4171 | 0.2138 | 0.155 | 0.054 | -0.005 | 0.014 | 0.079 | 9.344 |
| Sweden | 0.2984 | 0.4141 | 0.7613 | 0.4552 | 0.008 | 0.018 | 0.021 | 0.028 | 0.040 | 10.123 |
| Turkey | 0.5041 | 0.0624 | 0.3672 | 0.1894 | 0.054 | 0.028 | 0.018 | 0.025 | 0.046 | 7.880 |
| U. K. | 0.3783 | 0.8100 | 0.8814 | 0.7901 | 0.002 | 0.021 | 0.030 | 0.033 | 0.044 | 6.984 |
| U.S. | 0.5379 | 0.6273 | 0.8337 | 0.6891 | 0.033 | 0.031 | 0.035 | 0.034 | 0.039 | 9.654 |
| Venezuela | 0.1275 | 0.0717 | 0.2965 | 0.2271 | -0.005 | -0.005 | 0.024 | 0.029 | 0.047 | 9.949 |
| Zimbabwe | 0.0653 | 0.1705 | 0.2849 | 0.1286 | 0.027 | -0.032 | 0.004 | 0.016 | 0.071 | 7.876 |
| **Panel B: Summary by Industry** | | | | | | | | | | |
| Food Products (ISIC 311) | | | | | 0.036 | 0.012 | 0.022 | 0.029 | 0.116 | |
| Beverages (ISIC 313) | | | | | 0.041 | 0.023 | 0.023 | 0.028 | 0.041 | |
| Tobacco (ISIC 314) | | | | | 0.014 | 0.014 | 0.019 | 0.024 | 0.028 | |
| Textiles (ISIC 321) | | | | | -0.003 | 0.011 | 0.021 | 0.028 | 0.056 | |
| Wearing Apparel (ISIC 322) | | | | | 0.037 | 0.013 | 0.008 | 0.010 | 0.029 | |
| Industrial Chemicals(ISIC351) | | | | | 0.041 | 0.030 | 0.026 | 0.030 | 0.050 | |
| Rubber Products (ISIC355) | | | | | 0.006 | 0.006 | 0.017 | 0.024 | 0.015 | |
| Plastic Products (ISIC 356) | | | | | 0.062 | 0.015 | 0.014 | 0.023 | 0.021 | |
| Iron and Steel (ISIC 371) | | | | | -0.008 | 0.014 | 0.026 | 0.031 | 0.041 | |
| Machinery, except Electrical (ISIC 382) | | | | | 0.043 | 0.016 | 0.016 | 0.024 | 0.067 | |
| **Panel C: Summary of Overall Sample** | | | | | | | | | | |
| No. of observations | 3420 | 3203 | 3558 | 3558 | 3301 | 3272 | 3577 | 3577 | 3508 | 38 |
| Mean | 0.282 | 0.272 | 0.668 | 0.476 | 0.027 | 0.015 | 0.019 | 0.026 | 0.047 | 8.477 |
| Median | 0.210 | 0.140 | 0.640 | 0.440 | 0.026 | 0.016 | 0.019 | 0.026 | 0.031 | 9.344 |
| Standard Dev. | 0.294 | 0.345 | 0.329 | 0.279 | 0.205 | 0.180 | 0.013 | 0.008 | 0.044 | 1.527 |
| Minimum | 0.005 | 0.001 | 0.078 | 0.021 | -0.976 | -1.076 | -0.029 | -0.003 | 0.001 | 5.234 |
| Maximum | 2.000 | 3.500 | 2.300 | 1.7600 | 0.960 | 0.950 | 0.056 | 0.053 | 0.326 | 10.179 |

## Table 2: Correlation Matrix

| | Market Capitalization (MKTCAP) | Turnover Ratio (TURNOVER) | Domestic Credit (BANK) | Credit to Private sector (PRIVATE) | Growth in value added ($\dot{y}$) | Growth in productivity ($T\dot{F}P$) | Technical change ($\nabla TECH1$) | Rate of Cost Reduction ($\nabla TECH2$) |
|---|---|---|---|---|---|---|---|---|
| Turnover Ratio (TURNOVER) | 0.188 | | | | | | | |
| Domestic credit (BANK) | 0.303[c] | 0.389[b] | | | | | | |
| Credit to Private Sector (PRIVATE) | 0.635[a] | 0.453[a] | 0.778[a] | | | | | |
| Growth in value added (GV) | 0.050 | 0.051 | -0.149 | -0.029 | | | | |
| Growth in productivity ($T\dot{F}P$) | 0.063 | 0.213 | 0.042 | 0.205 | 0.592[a] | | | |
| Technical change ($\nabla TECH1$) | 0.240 | 0.447[a] | 0.513[a] | 0.518[a] | -0.378[b] | 0.066[a] | | |
| Rate of Cost Reduction ($\nabla TECH2$) | 0.152 | 0.425[a] | 0.433[a] | 0.410[a] | -0.307[c] | 0.127 | 0.970[a] | |
| Per capita GDP | 0.386[b] | 0.350[b] | 0.484[a] | 0.621[a] | -0.431[a] | 0.137 | 0.693[a] | 0.605[a] |

[a] Significant at 1%; [b] Significant at 5%; [c] Significant at 10%

## Table 3: Aggregate Performance and Financial Development

The parameter estimates are maximum likelihood estimates of four-way error component models containing random country, industry and time effects. The dependent variables are the annual compound growth rate in the real value added and the annual compound growth rate in the Total Factor Productivity for each of the ten industries over thirty-eight countries for the period 1980-1995. Turnover Ratio is the value of total shares of stocks traded divided by market capitalization. Stock Market Capitalization is the ratio of the total market value of publicly traded equity to GDP. Domestic Credit is the sum of assets held by the monetary authority and depository institutions excluding inter-bank transfer divided by GDP. Credit to Private Sector equals claims against the private sector divided by GDP. Industry Share in Manufacturing is calculated by dividing the real output of the industry in the country by the total real output of the manufacturing sector of the country. Coefficients of the intercept are not reported. Asymptotic standard errors are given in parenthesis.

| **Dependent Variable** | **Panel A** Growth in Real Value Added ( $\dot{y}$ ) | | | | **Panel B** Growth in Total Factor Productivity $(\dot{TFP})$ | | | |
|---|---|---|---|---|---|---|---|---|
| **Independent Variables** | **I** | **II** | **III** | **IV** | **I** | **II** | **III** | **IV** |
| Turnover Ratio (TURNOVER) | 0.0570[a] (0.015) | | | | 0.0389[a] (0.011) | | | |
| Stock Market Capitalization (MKTCAP) | | 0.0161 (0.016) | | | | -0.0077 (0.010) | | |
| Domestic Credit (BANK) | | | 0.0706[a] (0.021) | | | | 0.0267[b] (0.012) | |
| Credit to Private Sector (PRIVATE) | | | | 0.0940[a] (0.024) | | | | 0.0426[a] (0.015) |
| Industry's Share in Manufacturing (SHARE) | 0.6178[a] (0.097) | 0.6008[a] (0.098) | 0.6159[a] (0.102) | 0.6187[a] (0.102) | 0.2431[a] (0.072) | 0.2458[a] (0.073) | 0.2486[a] (0.072) | 0.2619[a] (0.073) |
| Error Components | | | | | | | | |
| $\sigma_\alpha^2$ | 0.0018[a] | 0.0013[a] | 0.0020[a] | 0.0015[a] | 0.0001 | 0.0001 | <0.0001 | <0.0001 |
| $\sigma_\eta^2$ | 0.0007[c] | 0.0007[c] | 0.0006[c] | 0.0006[c] | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| $\sigma_\lambda^2$ | 0.0008[b] | 0.0009[b] | 0.0009[b] | 0.0009[b] | 0.0008[b] | 0.0008[b] | 0.0009[b] | 0.0009[b] |
| $\sigma_\nu^2$ | 0.0307[a] | 0.0317[a] | 0.0365[a] | 0.0366[a] | 0.0267[a] | 0.0272[a] | 0.0300[a] | 0.0300[a] |

[a] Significant at 1%; [b] Significant at 5%; [c] Significant at 10%

# Table 4: Technological Progress and Financial Development

The parameter estimates are maximum likelihood estimates of four-way error component models containing random country, industry and time effects. The dependent variables are the rate of technological change (in Panel A), computed based on estimate of the production frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995; and the rate of real cost reduction (in Panel B), computed as the annual rate of real cost reduction, computed based on estimate of the stochastic cost frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995.. Turnover Ratio is the value of total shares of stocks traded divided by market capitalization. Stock Market Capitalization is the ratio of the total market value of publicly traded equity to GDP. Domestic Credit is the sum of assets held by the monetary authority and depository institutions excluding inter-bank transfer divided by GDP. Credit to Private Sector equals claims against the private sector divided by GDP. Industry Share in Manufacturing is calculated by dividing the real output of the industry in the country by the total real output of the manufacturing sector of the country. Coefficients of the intercept are not reported. The coefficients of the random country, industry and year effects are not reported. Asymptotic standard errors are given in parenthesis.

**Panel A: Dependent Variable: Rate of Technological Change (ΔTECH1)**

| Variable | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Turnover | 0.0007 | | | | 0.0007 | | 0.0007 | 0.0007 | | 0.0007 | 0.0007 |
| Ratio (TURNOVER) | (0.0005) | | | | (0.0005) | | (0.0005) | (0.0005) | | (0.0005) | (0.0005) |
| Stock Market | | 0.0010[c] | | | 0.0009 | 0.0008 | | | 0.0008 | 0.0008 | 0.0007 |
| Capitalization (MKTCAP) | | (0.0006) | | | (0.0006) | (0.006) | | | (0.0006) | (0.0006) | (0.0006) |
| Domestic | | | 0.0020[a] | | | 0.0025[a] | 0.0026[a] | | | 0.0024[a] | |
| Credit (BANK) | | | (0.0007) | | | (0.0008) | (0.0008) | | | (0.0008) | |
| Credit to Private | | | | 0.0023[a] | | | | 0.0034[a] | 0.0030[a] | | 0.0030[a] |
| Sector (PRIVATE) | | | | (0.0008) | | | | (0.0009) | (0.0010) | | (0.0010) |
| Industry's Share in | 0.0671[a] | 0.0667[a] | 0.0660[a] | 0.0660[a] | 0.0656[a] | 0.0671[a] | 0.0674[a] | 0.0674[a] | 0.0671[a] | 0.0674[a] | 0.0674[a] |
| Manufacturing (SHARE) | (0.003) | (0.003) | (0.003) | (0.003) | (0.0032) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |

**Panel B: Dependent Variable: Rate of Real Cost Reduction (ΔTECH2)**

| Variable | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Turnover | 0.00006 | | | | 0.00006 | | 0.00005 | 0.00007 | | 0.00005 | 0.00007 |
| Ratio (TURNOVER) | (0.0004) | | | | (0.0004) | | (0.0004) | (0.0005) | | (0.0004) | (0.0004) |
| Stock Market | | 0.0002 | | | 0.0002 | 0.0001 | | | 0.0001 | 0.0001 | 0.0001 |
| Capitalization (MKTCAP) | | (0.0004) | | | (0.0004) | (0.0004) | | | (0.0004) | (0.0004) | (0.0004) |
| Domestic | | | 0.0012[b] | | | 0.0015[b] | 0.0014[b] | | | 0.0015[b] | |
| Credit (BANK) | | | (0.0005) | | | (0.0006) | (0.0006) | | | (0.0006) | |
| Credit to Private | | | | 0.0012[b] | | | | 0.0017[b] | 0.0017[b] | | 0.0017[b] |
| Sector (PRIVATE) | | | | (0.0006) | | | | (0.0007) | (0.0007) | | (0.0007) |
| Industry's Share in | 0.0421[a] | 0.0418[a] | 0.0410[a] | 0.0410[a] | 0.0421[a] | 0.0420[a] | 0.0422[a] | 0.0422[a] | 0.0420[a] | 0.0423[a] | 0.0422[a] |
| Manufacturing (SHARE) | (0.0023) | (0.002) | (0.0022) | (0.0022) | (0.0023) | (0.0024) | (0.0023) | (0.0023) | (0.0024) | (0.0024) | (0.0024) |

[a] Significant at 1%; [b] Significant at 5%; [c] Significant at 10%

## Table 5: The Differential Effects of Financial Development on Technological Progress

The parameter estimates are maximum likelihood estimates of four-way error component models containing random country, industry and time effects. The dependent variables are the rate of technological change (in Panel A), computed based on estimate of the production frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995; and the rate of real cost reduction (in Panel B), computed as the annual rate of real cost reduction, computed based on estimate of the stochastic cost frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995. Turnover Ratio is the value of total shares of stocks traded divided by market capitalization. Stock Market Capitalization is the ratio of the total market value of publicly traded equity to GDP. Domestic Credit is the sum of assets held by the monetary authority and depository institutions excluding inter-bank transfer divided by GDP. Industry Share in Manufacturing is calculated by dividing the real output of the industry in the country by the total real output of the manufacturing sector of the country. External Dependence is a measure of the external financial needs of young firms in the industry from Rajan and Zingales (1998). Coefficients of the intercept are not reported. The coefficients of the random country, industry and year effects are not reported. Asymptotic standard errors are given in parenthesis.

| | I | II | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Dependent Variable: Rate of Technological Change (ΔTECH1)** | | | | | | | | | | |
| External Dependence X TURNOVER | 0.0006<br>(0.0007) | | | | 0.0000<br>(0.0007) | 0.0004<br>(0.0007) | | | 0.0001<br>(0.0007) | 0.0004<br>(0.0007) |
| External Dependence X MKTCAP | | 0.0008<br>(0.0007) | | | | | 0.0001<br>(0.0007) | 0.0002<br>(0.0007) | 0.0001<br>(0.0007) | 0.0001<br>(0.0007) |
| External Dependence X BANK | | | 0.0042[a]<br>(0.0008) | | 0.0050[a]<br>(0.0008) | | 0.0050[a]<br>(0.0009) | | 0.0050[a]<br>(0.0009) | |
| External Dependence X PRIVATE | | | | 0.0025[a]<br>(0.0008) | | 0.0028[a]<br>(0.0009) | | 0.0028[a]<br>(0.0010) | | 0.0025[b]<br>(0.0011) |
| Industry's Share in Manufacturing | 0.0640[a]<br>(0.003) | 0.0636[a]<br>(0.003) | 0.0622[a]<br>(0.0029) | 0.0624[a]<br>(0.0029) | 0.0634[a]<br>(0.003) | 0.0636[a]<br>(0.0030) | 0.0631[a]<br>(0.003) | 0.0634[a]<br>(0.0031) | 0.0635[a]<br>(0.003) | 0.0638[a]<br>(0.0032) |
| **Panel B: Dependent Variable: Rate of Real Cost Reduction (ΔTECH2)** | | | | | | | | | | |
| External Dependence X TURNOVER | -0.0000<br>(0.0005) | | | | -0.0004<br>(0.0005) | -0.0017<br>(0.0005) | | | -0.0004<br>(0.0005) | -0.0001<br>(0.0005) |
| External Dependence X MKTCAP | | 0.0004<br>(0.0005) | | | | | -0.0001<br>(0.0005) | -0.0000<br>(0.0040) | -0.0001<br>(0.0005) | -0.0001<br>(0.0055) |
| External Dependence X BANK | | | 0.0029[a]<br>(0.0006) | | 0.0034[a]<br>(0.0006) | | 0.0034[a]<br>(0.0007) | | 0.0035[a]<br>(0.0007) | |
| External Dependence X PRIVATE | | | | 0.0016[b]<br>(0.0006) | | 0.0016[b]<br>(0.0007) | | 0.0017[b]<br>(0.0008 | | 0.0016[b]<br>(0.0080) |
| Industry's Share in Manufacturing | 0.0404[a]<br>(0.0022) | 0.0401[a]<br>(0.0023) | 0.0039[a]<br>(0.0022) | 0.0389[a]<br>(0.0022) | 0.0400[a]<br>(0.0023) | 0.0402<br>(0.0022) | 0.0398[a]<br>(0.0023) | 0.0400[a]<br>(0.0023) | 0.0401[a]<br>(0.0024) | 0.0040[a]<br>(0.0023) |

[a] Significant at 1%; [b] Significant at 5%; [c] Significant at 10%

## Table 6: Robustness Tests – Property Rights Protection and Technological Progress

The parameter estimates are maximum likelihood estimates of four-way error component models containing random country, industry and time effects. The dependent variables are the rate of technological change (in Panel A), computed based on estimate of the production frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995; and the rate of real cost reduction (in Panel B), computed as the annual rate of real cost reduction, computed based on estimate of the stochastic cost frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995. Turnover Ratio is the value of total shares of stocks traded divided by market capitalization. Stock Market Capitalization is the ratio of the total market value of publicly traded equity to GDP. Domestic Credit is the sum of assets held by the monetary authority and depository institutions excluding inter-bank transfer divided by GDP. Industry Share in Manufacturing is calculated by dividing the real output of the industry in the country by the total real output of the manufacturing sector of the country. External Dependence is a measure of the external financial needs of young firms in the industry from Rajan and Zingales (1998). Intangibles is the ratio of intangible assets to total assets per industry from Claessens and Laeven (2003). Propfree is a broad index of property rights from the Index of Economic Freedom, the Heritage Foundation. Int301 is an index of protection of intellectual property rights from the Office of the U.S. Trade Representative. Patent is an index of protection of patent rights in 1980 form Grinarte and Park (1997). WEF is an index of property rights protection from the World Economic Forum. IntWEF is an index of intellectual property rights protection from the World Economic Forum. PropICRG is a broad index of property rights protection based on indices on the quality of bureaucracy, corruption, rule of law, risk of expropriation and risk of repudiation of contracts by the government. Coefficients of the intercept are not reported. The coefficients of the random country, industry and year effects are not reported. Asymptotic standard errors are given in parenthesis.

| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Dependent Variable: Rate of Technological Change (ΔTECH1)** | | | | | | | | | | | | |
| BANK | 0.0027[a] (0.0008) | 0.0026[a] (0.0008) | 0.0028[a] (0.0008 | 0.0028[a] (0.0008 | 0.0028[a] (0.0008 | 0.0027[a] (0.0008 | | | | | | |
| Propfree | 0.0006 (0.0018) | | | | | | | | | | | |
| Int301 | | -0.0004 (0.0016) | | | | | | | | | | |
| Patent | | | -0.0019 (0.0015) | | | | | | | | | |
| Wef | | | | -0.0018 (0.0019) | | | | | | | | |
| IntWef | | | | | -0.0014 (0.0019) | | | | | | | |
| PropIcrg | | | | | | -0.0002 (0.0013) | | | | | | |
| External Dependence X BANK | | | | | | | 0.0061[a] (0.0013) | 0.0062[a] (0.0013) | 0.0066[a] (0.0013) | 0.0064[a] (0.0013) | 0.0063[a] (0.0013) | 0.0064[a] (0.0013) |
| Propfree X Intangibles | | | | | | | 0.0036[a] (0.0006) | | | | | |
| Int301 X Intangibles | | | | | | | | 0.0043[a] (0.0083) | | | | |
| Patent X Intangibles | | | | | | | | | 0.0054 (0.0006) | | | |
| Wef X Intangibles | | | | | | | | | | 0.0017[a] (0.0006) | | |
| IntWef X Intangibles | | | | | | | | | | | 0.0018[a] (0.0004) | |
| PropIcrg X Intangibles | | | | | | | | | | | | 0.0006[b] (0.0003) |
| Industry's Share in Manufacturing | 0.0636[a] (0.003) | 0.0694[a] (0.003) | 0.0636[a] (0.003) | 0.0633[a] (0.003) | 0.0633[a] (0.0031) | 0.0636[a] (0.003) | 0.0662[a] (0.003) | 0.0706[a] (0.0034) | 0.0652[a] (0.003) | 0.0663[a] (0.003) | 0.0669[a] (0.003) | 0.0659[a] (0.003) |
| **Panel B: Dependent Variable: Rate of Real Cost Reduction (ΔTECH2)** | | | | | | | | | | | | |
| BANK | 0.0014[a] (0.0005) | 0.0014[a] (0.0005) | 0.0015[a] (0.0005) | 0.0015[a] (0.0005) | 0.0015[a] (0.0005) | 0.0014[a] (0.0005) | | | | | | |
| Propfree | 0.0005 (0.0013) | | | | | | | | | | | |
| Int301 | | -0.0004 (0.0011) | | | | | | | | | | |
| Patent | | | -0.0011 (0.0010) | | | | | | | | | |
| WEF | | | | -0.0007 (0.0013) | | | | | | | | |
| IntWef | | | | | -0.0005 (0.0013) | | | | | | | |
| PropIcrg | | | | | | 0.0003 (0.0009) | | | | | | |
| External Dependence X BANK | | | | | | | 0.0039[a] (0.0009) | 0.0039[a] (0.0009) | 0.0042 (0.0009) | 0.0041[a] (0.0009) | 0.0039[a] (0.0009) | 0.0041[a] (0.0009) |
| Propfree X Intangibles | | | | | | | 0.0026[a] (0.0005) | | | | | |
| Int301 X Intangibles | | | | | | | | 0.0029[a] (0.0006) | | | | |
| Patent X Intangibles | | | | | | | | | 0.0002 (0.0004) | | | |
| Wef X Intangibles | | | | | | | | | | 0.0011[a] (0.0004) | | |
| IntWef X Intangibles | | | | | | | | | | | 0.0012[a] (0.0003) | |
| PropIcrg X Intangibles | | | | | | | | | | | | 0.0004[b] (0.0002) |
| Industry's Share in Manufacturing | 0.0039[a] (0.0022) | 0.0440[a] (0.0023) | 0.0392[a] (0.0022) | 0.0393[a] (0.0023) | 0.0393[a] (0.0023) | 0.0393[a] (0.0022) | 0.0433[a] (0.0025) | 0.0472[a] (0.0025) | 0.0425 (0.0025) | 0.0434[a] (0.0025) | 0.0438[a] (0.0025) | 0.0431[a] (0.0025) |

## Table 7: Robustness Tests – Omitted Variables

The parameter estimates are maximum likelihood estimates of four-way error component models containing random country, industry and time effects. Specifications VI, VII and VIII use instrumental variables methodology. The instruments are: degree of investor protection afforded by the country's laws from La Porta et al (1998) in Specification VI; the colonial origin of the legal system (La Porta (1998) in Specification VII; and, the mortality rate of early settlers in European colonies from Acemoglu et al (2001) in Specification VIII. The dependent variables are the rate of technological change (in Panel A), computed based on estimate of the production frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995; and the rate of real cost reduction (in Panel B), computed as the annual rate of real cost reduction, computed based on estimate of the stochastic cost frontier, for each of the ten industries over thirty-eight countries for the period 1980-1995. Turnover Ratio is the value of total shares of stocks traded divided by market capitalization. Stock Market Capitalization is the ratio of the total market value of publicly traded equity to GDP. Domestic Credit is the sum of assets held by the monetary authority and depository institutions excluding inter-bank transfer divided by GDP. Industry Share in Manufacturing is calculated by dividing the real output of the industry in the country by the total real output of the manufacturing sector of the country. External Dependence is a measure of the external financial needs of young firms in the industry from Rajan and Zingales (1998). Human capital is the average for 1980 of the years of schooling attained by the population over 25 years of age from Barro and Lee (1993) . Per Capita GDP is the logarithm of GDP per capita in 1980. U.S. Growth is the real annual growth in sales of U.S. firms by industry averaged over the period 1980 through 1989 from Fisman and Love (2002). Accounting Quality is index of extent and quality of accounting disclosure from Rajan and Zingales (1998). IPO is number of Initial Public Offerings divided by population in millions from La Pota et al (1998). Coefficients of the intercept are not reported. The coefficients of the random country, industry and year effects are not reported. Asymptotic standard errors are given in parenthesis.

**Panel A: Dependent Variable: Rate of Technological Change (ΔTECH1)**

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| External Dependence X BANK | 0.0050[a] (0.0008 | 0.0057 [a] (0.0022) | 0.0033 [a] (0.0009) | 0.0025 [a] (0.0001) | 0.0047[a] (0.0008) | 0.0053 [a] (0.0012) | 0.0062 [a] (0.0012) | 0.0049 [b] (0.0026) |
| External Dependence X Human Capital | -0.0000 (0.0001) | | | | | | | |
| U.S. Growth X BANK | | -0.0256 (0.0287) | | | | | | |
| External Dependence X Per Capita GDP | | | 0.0007 [b] (0.0003) | | | | | |
| External Dependence X Accounting Quality | | | | 0.0052 (0.0036) | | | | |
| External Dependence X IPO | | | | | -0.0000 (0.0002) | | | |
| Industry's Share in Manufacturing | 0.0613 [a] (0.0030) | 0.0621 [a] (0.0030) | 0.0613 [a] (0.0030) | 0.0066 [a] (0.004) | 0.0643[a] (0.0032) | 0.0636 [a] (0.003) | 0.0632 [a] (0.0029) | 0.0622 [a] (0.0029) |

**Panel B: Dependent Variable: Rate of Real Cost Reduction (ΔTECH2)**

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| External Dependence X BANK | 0.0033[a] (0.0006) | 0.0049[a] (0.0016) | 0.0024[a] (0.0006) | 0.0019[b] (0.0008) | 0.0030[a] (0.0006) | 0.0036[a] (0.0009) | 0.0042[a] (0.0008) | 0.0038[a] (0.0019) |
| External Dependence X Human Capital | -0.0000 (0.0001) | | | | | | | |
| U.S. Growth X Bank | | -0.0328 (0.0212) | | | | | | |
| External Dependence X Per Capita GDP | | | 0.0004[b] (0.0002) | | | | | |
| External Dependence X Accounting Quality | | | | 0.0033 (0.0027) | | | | |
| External Dependence X IPO | | | | | -0.0000 (0.0002) | | | |
| Industry's Share in Manufacturing | 0.0383[a] (0.0022) | 0.0388[a] (0.0022) | 0.0382[a] (0.0022) | 0.0416[a] (0.0028) | 0.0408[a] (0.0024) | 0.0404[a] (0.0022) | 0.0400[a] (0.0022) | 0.0031[a] (0.0034) |

[a] Significant at 1%; [b] Significant at 5%; [c] Significant at 10%

## Appendix 1: Estimation of Rates of Technological Change and Real Cost Reduction

### 1.1 Empirical measures of Technological Change

I assume that there exists an unobservable function, a stochastic production frontier, representing the maximum attainable output level for a given combination of inputs. I represent these ***best-practice*** production technologies by a translog production function of the form[6],

$$\ln y_{ci}(t) = \beta_0 + \sum_j \beta_j \ln x_{ci}{}^j(t) + \beta_t t + \tfrac{1}{2}(\sum_j \sum_k \beta_{jk} \ln x_{ci}{}^j(t) \ln x_{ci}{}^k(t)$$
$$+ \beta_{tt} t^2) + \sum_j \beta_{jt} \ln x_{ci}{}^j(t) t + \mu_{ci}(t) + \varepsilon_{ci}(t)$$

*where,*

$$\varepsilon_{ci}(t) = \alpha_c + \eta_i + \nu_{ci}(t) \qquad (1.1A)$$

$x_{ci}^j(t)$ and $x_{ci}^k(t)$ are production inputs j and k used in industry i of country c during period t. The production inputs are capital (K) and labor (L). We use the variable t, an index of time, to represent the level of technology. $\mu_{ci}(t)$ is a one-sided random variable and measures the degree of ***inefficiency*** of industry i of country c in period t. The specification is a random-effects model in which latent country and industry effects are specified as random variables. $\alpha_c$ and $\eta_i$ are the random unobservable country-specific and industry-specific effects respectively, and $\nu_{ci}(t)$ is the usual white noise. The distributional assumptions on the error components are:

$$\alpha_c \approx iidN(0, \sigma_\alpha{}^2)$$
$$\eta_i \approx iidN(0, \sigma_\eta{}^2)$$
$$\mu_{ci}(t) \approx iid - halfNormal(0, \sigma_\mu{}^2), and, \mu_{ci}(t) \le 0$$
$$\nu_{ci}(t) \approx iidN(0, \sigma_\nu{}^2)$$

I estimate the model by the method of maximum likelihood to

[6] Our choice of this particular functional form is dictated by its flexibility. There is also evidence that manufacturing production is non-homothetic and exhibits scale economies, both of which are accommodated in the translog form.

obtain unbiased and efficient estimates of the parameters. The predicted estimates of the technological progress are obtained from the parameter estimates of the production function as:

$$\nabla TECH1_{cit} = \frac{\partial \ln y_{ci}(t)}{\partial t} = \beta_t + \sum_j \beta_{jt} \ln x_{ci}{}^j(t) + \beta_{tt} t \qquad (1.1B)$$

## 1.2 Empirical measures of Rate of Real Cost Reduction

Under certain regularity conditions, the underlying production technology can be uniquely represented by a dual cost function. Employing this duality, I represent the underlying technology by a restricted translog cost function of the form:

$$\ln C_{ci}(t) = \beta_0 + \beta_k \ln K_{ci}(t) + \beta_y \ln Y_{ci}(t) + \beta_t t +$$
$$\tfrac{1}{2}\{\beta_{kk}(\ln k_{ci}(t))^2 + \beta_{yy}(\ln Y_{ci}(t))^2 + \beta_{tt} t^2\} + \beta_{ky} \ln K_{ci}(t) \ln Y_{ci}(t) +$$
$$\beta_{kt} \ln k_{ci}(t) t + \beta_{yt} \ln Y_{ci}(t) t + \theta_{ci}(t) + \varepsilon_{ci}(t) \qquad (1.2A)$$

*where*,

$\varepsilon_{ci}(t) = \alpha_c + \eta_i + \xi_{ci}(t)$ $\theta_{ci}(t)$ is a one-sided random variable denoting the degree of economic ***inefficiency***. $\alpha_c$ and $\eta_i$ are country specific and industry specific error components. $\xi_{ci}(t)$ is the usual disturbance term with mean zero and standard deviation $\sigma_\xi$. The error components and the disturbance term follow the distributional assumptions in eq. (1.1A) above. Ln C is the log of costs. ln Y is the log of output and ln K is the log of capital stock. Also note that, with imposition of homogeneity, the input price of labor becomes a numerier, effectively entering in the intercept term. The empirical measure of technological progress based on the cost function represents the rate of cost reduction per year and is given by:

$$\nabla TECH2_{ci}(t) = \beta_t + \beta_{kt} \ln K_{ct}(t) + \beta_{yt} \ln Y_{ci}(t) + \beta_{tt} t \qquad (1.2B)$$

# Appendix A: Definition and Sources of Variables

| Variable | Definition | Sources |
|---|---|---|
| *Dependent Variables*: | | |
| Rate of Technological Progress **(ΔTECH1)** | A measure of the change in real output attributable to technological innovation. It is measured as shift in the production frontier over time holding input factors and production efficiency constant, and represents increases in real output due to adoption of better technology. | Constructed based on production functions estimated using data from the UNIDO database. |
| Rate of Real Cost Reduction **(ΔTECH2)** | The rate of downward shift in the cost function over time, holding output, input prices and cost efficiencies constant. | Constructed based on cost functions estimated using data from the UNIDO database. |
| *Independent Variables*: | | |
| Stock Market Capitalization (MKTCAP) | Value of listed shares of stock outstanding divided by GDP | Emerging Markets Database |
| Stock market Turnover Ratio (TURNOVER) | Value of shares of stocks traded as a ratio of stock market capitalization | Emerging Markets Database |
| Domestic Credit (BANK) | Domestic bank credit to the private sector as a ratio of GDP. Domestic credit is the sum lines 32a through 32f (excluding 32e) in the International Financial Series of the IMF. | International Finance Series from the IMF |
| Credit to Private Sector (PRIVATE) | Banks' claims against the private sector as a ratio of GDP. Claims against the private sector are lines 32d in the International Financial Series (IFS). | International Finance Series from the IMF |
| External Dependence | A measure of the external financial needs of young firms in an industry that are less than ten years old since public listing. It is computed as the ratio of capital expenditures minus cash flows from operations divided by capital expenditures averaged over 1980 to 1989. | Rajan and Zingales (1998) |
| Accounting Quality | An index of the comprehensiveness and quality of accounting disclosure measured on a scale of 0 to 90 based on the inclusion or omission of 90 reportable items (originally from the Center for International Financial Analysis and Research) | Rajan and Zingales (1998) |
| IPO | Ratio of the number of initial public offerings of equity in a given country to its population (in millions) for 1995-96. | La Porta et al (1997) |
| *Control Variables*: | | |
| Human Capital | The average for 1980 of the years of schooling attained by the population over 25 years of age. | Barro and Lee (1993) |
| Per capita GDP | The logarithm of real per capita GDP in 1980 | World Development Indicators |
| Industry's share in Manufacturing value added (SHARE) | Fraction of an industry's real value added to the value added of the manufacturing sector | Calculated from data in the UNIDO database |
| PROPFREE | A rating of property rights protection (on a scale from 1 through 5), based on the degree of legal protection of private property and the likelihood of expropriation by the government. Median rating over 1995 through 1999. | Index of Economic Freedom, Heritage Foundation |
| INT301 | An index of intellectual property rights (scale 1 through 5), based on the 'special 301' placements of the Office of the U.S. Trade Representative (USTR). Special 301 requires the Office to identify those countries that deny adequate protection of intellectual property rights. Based on this rating, countries are categorized as Priority Foreign countries (i.e., countries with the least protection of intellectual rights), 306 monitoring, Priority Watch, Watch list and Not listed countries. | Claesssens and Laeven (2003) based on USTR |
| PATENT | Index of patent rights protection in 1980. | Ginarte and Park (1997) |
| WEF | An index of property right (scale 1 through 7) in 2001 from the World Economic Forum (WEF) | Claesssens and Laeven (2003) originally from WEF |
| IntWEF | An index of intellectual property rights protection (scale 1 through 7) in 2001 from the World Economic Forum (WEF) | Claesssens and Laeven (2003) originally from WEF |
| PROPICRG | A broad index of property rights protection based on indices on the quality of bureaucracy, corruption, rule of law, risk of expropriation and risk of repudiation of contracts by the government from the International Country Risk Guide (ICRG) | Claesssens and Laeven (2003) originally from ICRG |
| Intangibles | Ratio of intangible assets-to-net fixed assets of U.S. firms by industry sector over the period 1980 to 1989. Primary Source: COMPUSTAT. | Claessens and Laeven (2003 |
| U.S. industry Sales Growth | Real annual growth in sales of U.S. firms by industry averaged over the period 1980 through 1989. | Fisman and Love (2002 |
| Legal Origin | The origin of the legal tradition of the country. The origin could be English common law, French civil law, German civil law, and German civil law. | La Porta et al (1998) |
| Legal Protection | Indices of the legal protection afforded to shareholders and creditors in each country | La Porta et al (1998) |
| Settler Mortality | The log of the annualized deaths per thousand European settlers in European colonies | Acemoglu et al (2001) |

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