Innovation, Information and Financial Architecture

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INNOVATION, INFORMATION and FINANCIAL ARCHITECTURE

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Abstract

Does a financial system architecture anchored on banks better than one centered on markets in fostering technological innovations as engine of growth? In a panel of industrial sectors across a large cross section of countries, I find that while market-based systems have a general positive effect on innovations in all economic sectors, bank-based systems foster more rapid technological progress in more information-intensive industrial sectors, suggesting a heterogeneous impact of financial architecture. Thus, the relative performance of bank-based systems vis-à-vis market-based systems depends on the industrial structure of the economy.

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I. Introduction

The relative merits of financial intermediaries vis-a-vis financial markets as providers of capital has been a recurring theme in corporate finance. A macro-economic version of this issue is whether the financial architecture of an economy – i.e., the degree to which its financial system is bank-oriented or market-based – has any impact on economic performance in the real sector. Does financial architecture matter for long-term growth, and in particular, in fostering innovations and technology. The debate, which goes as far back as Schumpeter (1912) and Bagehot (1873), commenced with reference to Germany and the United Kingdom in the late ninteen century, and later expanded to include the U.S. as a prototype market-based system and Japan as a representation of bank-based economy[1]. It has become more fervent in recent times because financial system configuration is at the core of market reform policies in transition and emerging economies that are in route to capitalism from decades of totaliterian repression. This paper explores empirically the relation between technological innovation and financial architecture, focusing on differences between markets and banks in processing information.

The role of financial architecture in fostering innovation and technology is theoretically controversial. The bank-based and the market-based views primarily emphasize the merits of banks or financial markets in mitigating informational imperfections. Markets and banks perform vital functions in an economy, including capital formation, risk sharing, information production and monitoring. The case for bank-based or market-oriented systems is usually made by focusing on the relative effectiveness with which banks or markets execute these common functions. In particular, a key attribute of financial markets - a feature that distinguishes them from banks - is that prices formed in financial markets provide valuable information to real decisions of firms. This is what is called the 'information feedback' function of markets. There are two important properties of this information feedback function – namely, that prices aggregate diverse informed opinions about the firm's investment opportunities, and that information is revealed to third parties relatively easily. With banks, instead of investors producing

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[1] Allen and Gale (1995), Boot and Thakor (1997), and Allen and Gale (2000) provide excellent reviews of the literature on the merits of bank-based versus market-based systems.

information through trading and conveying it via prices, loan officers generate information while evaluating projects for loan financing. To contrast, while such information generation is different from the price mechanism, bank-generated information is also relatively safe from leakage. These fundamental differences in the manner in which information is processed by banks vis-a-vis financial markets have critical implications for the relative performance of bank-based versus market-based financial systems, particularly in fostering innovations and technology.

The market-based view holds that markets have attributes in processing information that intermediaries do not have that are advantageous in fostering innovative technologies. In the first place, financial markets facilitate the identification of profitable innovative investment opportunities through their information-feedback function (see, e.g., Boot and Thakor (1997)). Moreover, market-based systems facilitate innovation by allowing financing when diversity of opinion prevails (see Allen (1993); Allen and Gale (1999)). The argument is that assessment of new technologies is difficult either because little information is available about their potential returns or because the information itself is difficult to judge without some expertise, indicating that there is often substantial diversity of opinion. Bank-based financing requires delegation of the decision regarding financing to a relatively small number of decision makers. When there is no disagreement, this delegation is effective and entails cost savings. It is, however, problematic if diversity of opinion persists, because some of the providers of funds would disagree with the decisions of the delegated monitor. Bank-based finance, therefore would under-fund new technologies. Financial markets, on the other hand, permit individuals to agree to disagree, and therefore allow coalition of investors with similar views to join together to finance projects. Hence, markets are effective in financing new industries and technologies where relevant data is completely lacking[2].

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[2] Other arguments in favor of market-based systems are also offered. For example, as creditors, banks are risk averse or conservative, and have bias against financing innovation (Weinstein and Yafeh (1998), and Morck and Nakamura (1999)). Also, powerful banks reduce the firms' incentive to undertake innovative, projects by extracting informational rents (Hellwig (1991), and Rajan (1992)). In addition, capital markets, by allowing the financing of long-term projects by savers with short-term liquidity needs, enable the adoption of innovative but long-gestation technologies (Hicks (1969); Bencivenga, Smith and Starr (1995); and Saint-Paul (1992)).

On the other hand, the bank-based view emphasizes the relative disadvantages of markets in processing information particularly relevant for firms' incentive to innovate. First, financial markets could lead to underinvestment in information acquisition in the first place, with a negative impact on identification of innovative projects. The argument is that efficient markets reduce the incentives of investors to generate information about firms because others could free-ride on ones' costly information (Grossman (1976); Stiglitz (1985)). In contrast, banks dissipate less information to the public, providing incentives to generate information (Boot, Greenbaum, and Thakor (1993)). Second, and more importantly, financing innovations through markets may risk the revelation of proprietary technological information to the firms' competitors, providing greater incentives to finance innovation via banks (Bhattachcharya and Chiesa (1995); Yosha (1995))[3]. The idea is that firms with valuable innovations may value confidentiality. Information disclosed in multilateral financing (i.e., markets) will eventually be available to third parties including the firms' competitors. By contrast, bilateral (i.e., bank) financing results in less leakage. In equilibrium, high quality firms with valuable innovations prefer bilateral (i.e., bank) financing to multilateral (i.e., market) financing (Yosha (1995)). Conversely, the architecture of the financial system affects the incentives of firms to innovate. The importance of confidentiality to innovative firms means that firms with observationally more sensitive information – those with the most to lose from leakage of their private information – fare better in bank-based financial systems[4].

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[3] A related notion is that of Dewatripont and Maskin (1995) who argue that bank-based financing is vulnerable to renegotiation problems, and that market-based finance might be superior because it maintains commitments not to renegotiate. This is so because of the free-rider problem and the high transaction costs involved in negotiating with a large number of bondholders. But others have shown that renegotiation is not necessarily bad; it is welfare-enhancing (see, e.g., Allen and Gale (2000)).

[4] Other arguments for bank-based systems are also offered. First, bank-based systems are more effective in funding new and innovative activities that require staged financing (Stulz (2000)) because banks can credibly commit to making additional funding as the project develops. Second, banks more effectively finance industrial expansion in underdeveloped economies (Gerschenkron (1962), Boyd and Smith (1996, 1998), since powerful banks can induce firms to reveal information better than markets in such economies (Rajan and Zingales (1999a)). Third, bank-based systems encourage innovation by facilitating the financing of long-term projects through reducing liquidity risk (Greenwood and Jovanovic (1990); and Bencivenga and Smith (1991)). Some also argue that banks are better for corporate governance. Efficient markets may hamper the effectiveness of takeovers as a corporate governance tool by providing incentives to atomistic investors to hold up (Grossman and Hart (1980)), and that liquid markets reduces the incentives of dispersed shareholders to monitor inside managers (Bhide (1993)).

As the arguments on both side of this historic debate are compelling, in this paper, I take an agnostic position on the issue to explore the consistency of each side of the debate with available data. Using industry-level panel across a large cross-section of countries, I examine the importance of financial architecture to fostering innovation and growth based on differences in information processing. I begin by evaluating the total, average effect of financial architecture on innovation. That is, I test whether, by and large, industries realize faster or slower rates of technological progress if they are supported by market or bank-based systems. Given the opposing theoretical views, the answer to this question is not obvious. The evidence supports that market-based systems have, on average, a positive impact on innovation.

Going beyond the analysis of this average effect, I then ask whether firms or industries that differ in their *information intensiveness* fare relatively better or worse in market or bank based systems. Again, given the opposing theoretical views, one would expect informationally-intensive sectors to realize faster rates of technological progress in either bank-based or market-based systems. Exploiting industry-specific information about the asset composition of firms as a measure of the degree of information intensity, I thus ask if financial architecture has a heterogeneous impact across industrial sectors as suggested by the theory. I find that financial architecture, indeed, has a heterogeneous effect on innovation, whereby specific firms or industries appear to benefit from market-based systems while others from bank-based systems.

The empirical test I carry is as follows: Firms with greater intangible assets in their asset composition are considered to be more informationally intensive. In the literature, the extent of intangible assets in firm's asset composition – the intangible intensity – has been utilized variously as a measure of the informational sensitivity of the firm's activities and as an indicator of the firm's vulnerability to problems of informational asymmetry. Industries with high intangibles in their asset mix are commonly knowledge-intensive sectors with nonstandard, relatively complex activities and outcomes that are less amenable to independent measurement. These are also sectors with soft assets that stand to lose more from information leakage. Furthermore, Claessens and Laeven (2003) shows that there is a systematic pattern in intangible intensity across industrial sectors that can be attributed to technological and market conditions. One would, therefore, expect to find stronger evidence of either effect of financial architecture by focusing the analysis on sectors that vary in intangible intensity. I examine the effects of market or bank orientation of the financial system on the realization of innovation by asking whether industrial sectors that typically use many intangible assets realize relatively faster rate of innovation in bank-based compared to market-based systems. The results show robust evidence that such industries realize relatively faster rates of innovation in countries with more bank-oriented financial systems.

To sharpen the empirical tests, I also consider industrial differences on more innovation-related measures of information intensiveness, such as R&D activities, and patent use intensities. In particular, I examine if industrial sectors that typically spend higher proportion of their revenues on R& D activities, or sectors that use relatively more patents realize faster rates of innovation in bank-based or market based financial systems. The use of such measures confirms the main finding that informationally intensive industries realize faster innovation in countries with bank-oriented financial systems.

These results are robust to a number of checks, including alternative measures of the focal variables of interest, alternative explanations of the results, omitted variables bias, and simultaneity bias. 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.

The two results – that market based systems foster innovation on average and that bank-based systems foster innovation in informationally-intensive sectors– are not in contradiction. Rather, taken together, they confirm the basic predictions of the market-based and bank-based views. Market-oriented financial systems foster innovation by enabling the identification and financing of new technologies, and industries in general where diversity of opinion persists (e.g., Allen (1993), Boot and Thakor (1997)). On the other hand, the impact of financial architecture is not homogeneous across economic activities. Bank-based systems promote innovation especially in informationally sensitive economic sectors. This could be so for many reasons, including the fact that these are firms that have more to lose from information leakage related to impending innovation, closely consistent with the key predictions of the bank-based views of Yosha (1995) and Bhattachcharya and Chiesa (1995) that emphasize the advantages of banks in handling proprietary information.

The paper contributes to the emerging empirical literature on the financial architecture-growth nexus[5]. Levine (2002) examines the impact of financial architecture on per capita GDP growth and total factor productivity growth, and Beck and Levine (2002) explore whether the output growth of industries that differ in their dependence on external finance depends on financial architecture. Both Levine (2002) and Beck and Levine (2002) find overall financial development and not financial system architecture as important for growth. Demirguc-Kunt and Maksimovic (2002) reports that whether the financial system is bank or market oriented has little effect on firm growth. Tadesse (2002), on the contrary, finds that across financially underdeveloped countries, industry growth is faster in bank-based systems than in market-based systems and vise versa across financially developed countries. Countries dominated by small firms grow faster in bank-based systems and those with large firms in market based systems. Thus, financial architecture, in and of itself, is relevant for growth. Hence, as Allen (2000), summarizing the literature, notes the empirical evidence on the merits of bank based versus market-based systems is mixed. In the context of this controversy, the paper examines and provides evidence on the role of appropriate financial architecture for spurring technological innovation as an engine of growth.

The paper extends the literature by analyzing and documenting an information-based channel through which financial architecture could affect economic performance. Earlier studies focus on differences in financial architectures in terms of capital provision (e.g., Levine (2002) and Beck and Levine (2002)), finding no difference, and others emphasize differences in the compatibility of financial system design to countries' legal and contractual environments (e.g., Tadesse (2002)). Beck and Levine

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[5] The debate on the relative merits of bank-based versus market based financial systems is historical, and the literature goes back much further. For example, Goldsmith (1969) provide a comparison of the financial systems of Germany and the U.K., and Gerschenkron (1962) reports on the importance of the bank, Credit Mobilier, for the industrialization of France and that of the Great Banks for the development of Germany. Mayer (1990) reports how the Japanese banking system contributed to its post-war development, and Cohen (1967) documents on the role of such banks as Banca Commerciale Italiana for Italy. On the other hand, Bagehot (1873) and Hicks (1969) emphasize the role of the mature securities markets in Great Britain as a precursor of the Industrial Revolution.

(2002), for example, examine whether industries that are heavy users of external capital grow faster in bank or market based systems, underlining the differences in the two systems in mobilizing capital for externally dependent firms. Instead, recognizing that financial systems provide both capital mobilization and governance services in the form of information processing and monitoring, the paper complements existing research by arguing that the differential effectiveness of bank-based versus market-based systems may arise from the relative comparative advantages of the two systems in processing information. With such a view, I draw a particular channel through which financial system design could influence economic performance – i.e., via its effect on firms' conduct in adopting new technologies. Hence, instead of searching for a general association between financial architecture and performance as in, e.g., Levine (2002), the paper examines a particular channel by focusing on the technological response of industries with diverse asset structures to variations in financial architecture. In so doing, it provides the first evidence on the effect of financial architecture on the attainable technological progress of industries that vary in their asset composition, reflecting their informational environments.

The balance of the paper is organized as follows. Section II introduces the empirical methodology and the data. Section III reports the main results. Section IV provides robustness tests, and Section V concludes.

II. Methodology and Data

A. Empirical Model Specification

To explore the relations among financial architecture, information, and technological innovations, I use the setup of Rajan and Zingales (1998, RZ hereafter)[6]. RZ introduced an innovative methodology to explore the relation between financial development and economic growth in a cross-industry cross-country setting. They argue that, if financial development matters, firms with greater 'natural' demand for external finance should grow faster in financially developed countries. To test this, they need a measure of the 'natural' demand for external finance. RZ construct a measure of the dependence of

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[6] Other studies that use the RZ methodology include, among others Ceterolli and Gambera (2001) to study the impact of banking industry structure, and Fisman and Love (2002) to examine the role of trade credit.

industries on external finance based on the degree of external financing by U.S. firms. They argue that the relative sophistication and efficiency of capital markets in the U.S. allows U.S. firms to raise external capital to their *desired* level. Hence, there should be technological and economic reasons why some industrial sectors depend more on external finance than others in the U.S., and that these differences across industrial sectors should prevail in other countries as well. This does not imply that two industrial sectors in two countries will have identical degree of external dependence; rather the rank order of industries by their degree of external dependence should be similar across industries. They, therefore, use the external dependence of U.S. industries as a proxy for technology-driven 'natural' degree of external dependence in other countries as well, and show that industries that are more dependent on external finance grow faster in financially developed countries.

The RZ framework has been utilized in Claessens and Laevens (2003) to examine the role of property rights in spurring economic growth. They postulate that strong property rights protection should be more important to firms with high intangibles in their asset mix, since soft assets are more vulnerable to expropriation including outright theft. They argue, following RZ (1998) that 'the well-protected property rights in the U.S. should allow U.S. firms to achieve the desired…asset structures for their respective industrial sectors' (Claessens and Laeven (2003), p. 2406). They then use this 'desired extent of asset mix' by U.S. industries as the optimal asset mix of an industry anywhere in the world. They find that intangible-intensive industries –i.e., industries with greater intangible usage in their asset composition – indeed, grow faster in countries with stronger property rights.

In this study, I argue that industrial sectors that differ in their asset composition in terms of their intangible intensity should fare relatively better or worse in countries with different financial architectures. I argue that the differential asset-mix in the U.S. industries also reflects the differences in the complexity and sensitivities of information, reflecting the nature of the underlying technologies and economic activities. I, thus, use the intangible intensity of industrial sectors as a proxy for the informational intensiveness of the sectors' economic activities that is driven by technological and market conditions. The bank-based and market-based views provide opposing predictions about the impact on the innovative activities of such sectors. Intangible intensive activities are relatively knowledge based, soft, hard-to-monitor, and generally more complex activities. The market-based view that financial markets allow financing of innovations in situations where diversity of opinion is substantial suggests that more complex activities fare better in market based economies. On the other hand, the bank-based views of, among others, Yoshi (1995) and Bhattacheria and Chiesa (1995) predict that such industries should prosper in bank-based economies because of the high value of confidentiality. Claessens and Laeven (2003) shows that the degree of intangible intensity in firms' asset mixes vary across industrial sectors. Hence, evidence that industries with greater intangible-intensity realize faster rates of innovation in market-based or bank-based systems provide a direct test of the market or bank based view of the role of financial system configuration to innovation.

What is needed, ideally, is a ranking of industrial activities by the degree of complexity and sensitivity of information – the informational environment of the industry – reflective of the nature of innovation-related economic activities. I use the measure of intangible intensity as a proxy for the information intensiveness of the industry for a number of reasons. First, intangible assets represent activities with inherently uncertain, long-term payoffs, such as assets representing R & D efforts, and those related to brand names. High intangible activities are generally knowledge-based, hard-to-monitor, and less amenable to valuation agreements, an attribute of the information environment we wish to measure. Second, as a result, firms with substantial intangibles are also considered to have more informational asymmetry (see, e.g., Barth, et al. (2001)). They have soft, hard-to-monitor assets also means that intangibles are relatively prone to information leakage. Finally, the asset mix of the industry is reflective of the nature of the underlying economic activities. Since the values of intangible assets (versus tangible properties) are relatively more firm-specific, a measure based on intangible intensity would be reflective of the firms' internal information environment.   Other potential measures could be measures of the difficulty of performance measurement by outsiders, such as the degree of analyst forecast consensus, and more direct measures of innovation-related activities, such as R&D costs and the use of patents. The problem with using analyst' forecast consensus is, however, that it primarily reflects the noise in the reporting environment, rather than the nature of the firms' activities. In addition, lack of consensus may simply reflect firm specific risk (volatility) than the level of information (Clarke and Shastri (2001)). Nonetheless, the ranking of industries by intangible intensity closely mirrors the ranking based on financial analysts' difficulty in earnings forecast. As a robustness check, I also perform the analysis using forecast consensus for U.S. industries. Additionally, sharper measures of the information environment surrounding the industrial innovation-related activities might be more direct measures of innovation, such as the degree to which the industry invests on R & D activities and the degree to which it rely on acquisition and protection of patents. In our context, the use of these measures introduces significant endogeneity problem, as these same measures are also commonly used as measures of technological innovation. Nonetheless, I also report the results using R&D activities, and industrial patent use for robustness.

I use manufacturing[7] industrial sectors as units of observation, and examine if industries that vary in their use of intangibles in their asset mix fare better or worse in bank or market based systems. In the basic empirical model, following RZ, I regress a measure of industrial rate of innovation on a variable that interacts a measure of the industry's intangible intensity and the financial architecture of the country, controlling for non-observable country, industry, and time related sources of industrial innovation[8]. The specification of the basic empirical model is as follows:

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[7] As RZ note, this is done "… in order to reduce the dependence on country-specific factors, like natural resources…" (Rajan and Zingales (1998, p. 567).

[8] To address the main research question, we need variations in the independent variables, such as financial architecture. One approach is to examine how the technological performance of industries changes as a country moves from one form of financial architecture to another over time. However, this is less feasible because the financial architecture of a country does not show much variation over time. The movement of countries from relatively bank-based to market-based systems and vise versa is gradual. Another approach is to observe the technological responses of *similar* industries across countries as a function of financial architecture (which has cross-country variation). This is the approach taken in this paper, and is in line with the literature on financial architecture (e.g., Levine (2002), Beck and Levine (2002)), finance and growth (e.g., Rajan and Zingales (1998) as well as the extensive empirical literature on economic growth.

$$\begin{aligned} TECH_{ict} &= \alpha + \Gamma_1 IndustryDummy_i + \Gamma_2 CountryDummy_c + \Gamma_3 YearDummy_t \\ &+ \gamma_4 IntagibleIntensity_i * FinancialArchitecture_c \\ &+ \gamma_5 IndustryShareofValueAdded_{ict} + \varepsilon_{ict} \end{aligned} \tag{1}$$

where TECH is a measure of the rate of technological innovation (to be fully explained below). A subscript i indicates that the variable refers to the ith industry. Similarly, a subscript c indicates a variable referring to the cth country, and a subscript t, the tth year. Uppercase coefficients indicate vectors. The industry and year dummies control for industry-specific and period-specific sources of variation in technical innovation. The industry's share in value added, measured as the total value added of industry i in the country as a ratio of total value added of the country's manufacturing sector, measures the relative importance of the industry in the country. The country controls include regressors customarily used in cross-country growth regressions.

Financial architecture is an index of the relative importance of financial markets to banks. The focal coefficient of interest is γ_4. A $\gamma_{4>0}$ indicates that industries that utilize greater intangibles in their asset composition, as a proxy for information intensity, innovate faster in market based financial systems. A $\gamma_{4<0}$, on the other hand, would be consistent with the bank-based view. In addition, to isolate the total effect of financial architecture, the country controls will include the variable 'Financial Architecture' separately. Again the sign of the coefficient of this variable is a priori ambiguous.

One of the advantages of this specification is that it overcomes the identification problems encountered in the standard cross-country regressions by interacting a country characteristics (financial architecture) with an industry characteristics (intangible intensity). The approach is less subject to criticism of omitted variable bias. Strengthening these advantages, I will estimate the versions of the model with explicit country controls as random-effects specification. This has an advantage of (i) accounting for intra-industry and intra-country correlations and (ii) enabling identification of the effects of country-factors, such as financial architecture more accurately.

B. Data

B.1 Data on Technological Innovation

To measure the dependent variable, the rate of technological innovation, I estimate structured production functions and identify technological progress as that portion of observed output growth attributable to changes in the underlying production function as a representation of the technology. In so doing, I follow a long tradition in the growth economics literature going back to Solow (1957). Specifically, an aggregate index of improvement in an economic unit, extensively used in the literature, is the growth rate in output ($\dot{y}$). I first isolate the contributions of input factors (such as labor and capital) to output growth ($\dot{y}$) from the contributions of Total Factor Productivity (TFP) based on inter-country production frontiers. I further model the TFP component of growth to be arising from either industry-specific efficiency improvements or technological innovations. The effect of technological progress is measured as the shift in the production frontier over time holding input quantities at the same level.

Structurally, I assume that there exists an unobservable production frontier that 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,

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

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

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

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. (3) with respect to time, we have

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

Eq. (4) decomposes output growth into a combined effects of factor accumulation and scale economies (the first term), the shift in the production technology (g_t), and efficiency changes during period t. Empirically, I represent eq. (3) by a translog stochastic production frontier (see Appendix 2). I then generate the values of the realized rates of technological change (i.e., g_t) based on the parameter estimates of the frontier. The empirical proxy thus obtained is **ΔTECH1**, and it operationalizes g_t. **Δ**TECH1 represents increases in output yield due to shifts in the best-practice technology, g[.]. As explained in Appendix 2 below, in computing **Δ**TECH1, the production frontier is estimated for a panel of industries across the sample countries, with country and industry effects appropriately controlled through a random effects specification. Controlling for such country effects ensures that **Δ**TECH1does not pick up differences in production technologies owing to country peculiarities. The parameter estimates from which the measures of technological change are constructed do not reflect country-specific sources of variations in production technologies so that the resultant measures would be comparable across countries.

Alternatively, for checking the robustness of the main results, I derive the corresponding measures of the rate of technical innovation based on a stochastic *cost* frontier (see section IV (A) below).

The data for estimating the inter-country stochastic production and cost functions is obtained from the United Nations Industrial Statistics database. The database, which contains industry-level data on production and cost characteristics, has been extensively used in the finance-growth literature (see, e.g., Rajan and Zingales (1998), and Tadesse (2004)).

Table 1 provides a summary of the variables for the sample countries. There is a wide variation in economic performance across countries (see Panel A). Realized rates of technological change range from –1/2 percent per annum in Sri Lanka to 3.6 percent in Japan. Ranking countries by their average realized rates of technical innovations we observe as in Figure 1 that technological progress is much faster in developed countries than in developing economies. This may be a reflection of developed countries' larger wherewithal to spur technological innovations, and as such it provides additional credence that our measure captures the cross-country differences in production technologies consistent with economic intuition. In contrast, overall productivity does not appear to be significantly different between developed and developing countries (not reported). Realized productivity growth in the U.S. (3.1% per annum) compares well with that of the Philippines (3.3%).

There is also an enormous variation across industries (see Panel B of Table 1), with the highest rate of technical progress registered in Industrial Chemicals industry (2.6%) which includes pharmaceutical and biotech firms and the lowest in the Apparel industry (0.8 %). As would be expected, traditional industries exhibit slower rates of technical progress than their younger counterparts. External validation of the veracity of our measures of technological change is extremely difficult because of the lack of other comprehensive and consistent measures of innovation at the industry level. However, the technological profile of the industries emerging from our measures appears to be consistent with indicators of technological activities from other sources. For example, Allen (1996) provides data on the ratio of scientific and engineering employment to total employment for selected industries in the U.S. for 1979 through 1989. This ratio is the lowest at 0.2 percent for the Apparel industry and the highest for chemicals industry at 10.9 percent, with primary metals at a modest 3.3 percent. Patent use by U.S. industries in the 1980 through 1983 from Lach (1995) ranks the Apparel industry near the bottom while such industries as drugs, industrial chemicals and machineries are among the top. The ratio of company R & D funds to net sales over 1984-90 as reported by the National Science Foundation (1993) is the lowest for textile and apparel at 0.44 percent and is one of the highest for drugs and medicines at 8.7 percent.

B.2 Financial Architecture

There is no uniformly accepted empirical definition of whether a given country's financial system is market-based or bank-based. Previous studies use stylized facts based on a handful of countries such as Germany as representative of a bank-based system and the U.S. as the prototype of a market-based system. I use a variety of financial architecture indicators which are based on aggregate cross-country data recently compiled at the World Bank. The data set described in Demirguc-Kunt and Levine (2001) as well as Beck, Demirguc-Kunt, and Levine (2000) contains measures of the relative size, activity, and efficiency of the banking and the financial market sub-sectors of the financial system for a broad cross-section of countries over the period 1980 to 1995. I use a continuous variable, ***ARCHITECTURE***, as a measure of financial architecture.

ARCHITECTURE is an index of the degree of stock market orientation of a financial system and is based on three indices that measure the relative importance of the stock market compared to the banking sector in an economy. The three indices are measures of the relative size, activity and efficiency of the stock market in a given country vis-à-vis those of the banking sector. The variable ARCHITECTURE reflects the principal component of these three variables: architecture-size, architecture-activity and architecture-efficiency. Higher values of ARCHITECTURE indicate a more market-oriented financial system.

> Architecture-Size measures the relative size of stock markets to that of banks in the financial system. The size of the domestic stock markets is measured by the market capitalization of domestic stocks relative to the GDP of the country. The size of the banking sector is measured by the bank credit ratio defined as the claims of the banking sector against the private real sector as a percentage of GDP. This excludes claims of non-bank intermediaries, and credits to the public sector. Architecture-Size combines the two size measures as a ratio of the capitalization ratio to bank credit ratio. Larger values indicate more market orientation in terms of relative size.
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> Architecture-Activity measures the activity of stock markets relative to that of banks. It is denoted by the ratio of total value of stocks traded to bank credit ratio. Total value traded as a share of GDP measures stock market activity relative to economic activity; bank credit ratio (defined above) indicates the importance of banks in the economic activities of the private sector.
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> Architecture-Efficiency measures the relative efficiency of a country's stock markets vis a vis that of its banks. Efficiency of stock markets is measured by the total value traded ratio, which is defined to be the share of total value of shares traded to GDP. Efficiency of banking is measured by bank overhead ratio, defined to be the ratio of banking overhead costs to banking assets. Architecture-

Efficiency is the product of total value traded ratio and overhead ratio. Demirguc-Kunt, and Levine (2001) also present measures using turnover ratio (instead of value traded) and find no different rankings.

I take the principal component of the three series (capitalization to bank credit ratio, value traded to bank credit ratio, and the product of value traded and overhead ratios) and compute the composite measure ***ARCHITECTURE***. As a robustness test, I also use the construction of the variable as a means-removed simple average of the series. In addition, I will use the three components – Architecture-size, Architecture Activity, and Architecture-Efficiency separately as a measure of the market-orientation of the financial system.

ARCHITECTURE provides a measure of the comparative role of banks and markets in the economy. The underlying measures which reflect the degree of bank development and stock market liquidity are shown to have effects on economic performance (see, Levine (1997) for review). High score on Architecture is associated with stronger investor protection and high accounting standards (Demirguc-Kunt and Levine (2001)), indicating that the measure of financial architecture reflects the legal and regulatory differences across countries. The alternative measures are also closely related with each other. The main ARCHITECTURE measure is strongly correlated with the Architecture-Size (coefficient, 0.954), Architecture-Activity (coefficient, 0.952) and Architecture-Efficiency (coefficient, 0.639). It is also highly correlated with the measure of market orientation independently constructed by Demirguc-Kunt and Levine (2001) as a means-removed average simple average of the three series (correlation, 0.636), and the architecture measure by Beck and Levine (2002) as a principal component of the series (correlation, 0.744). The Architecture variable makes the intuitively attractive classification of the U.K., the U.S. (not in the sample because of its use as a benchmark), Canada and Singapore as more market-based systems, and Germany, Austria and Portugal as more bank-based. ARCHITECTURE also identifies Japan as in between because Japan has a large, active market. This ordering is similar to what is found in the literature (e.g., Beck and Levine (2002)).

B.3 Data on Industry Characteristics

I use the degree of intangible asset usage in an industry's asset composition – intangible-intensity – as an industry-attribute relevant for the degree of impact of the financial system on the industry's technological innovation. Claessens and Laeven (2003) construct a measure of the intangible intensity for manufacturing industries based on the intangible intensity of industries in the U.S. They argue, following Rajan and Zingales (1998), that 'the well-protected property rights in the U.S. should allow U.S. firms to achieve the desired…asset structures for their respective industrial sectors' (Claessens and Laeven (2003), p.2406). This desired extent of asset mix could then be used to identify the optimal asset mix of an industry anywhere in the world. Intangible intensity is computed as the ratio of intangible assets to net fixed assets. Intangibles are measured as the net value of intangible assets (COMPUSTAT item 33) and include blueprints or building designs, patents, copyrights, trademarks, franchises, organizational costs, client lists, computer software patent costs, licenses, and goodwill. I use the intangible-intensity measures for U.S. industries from Claessens and Laeven (2003) as measures of the desired asset composition unique to the corresponding industries in other countries. One advantage of this procedure is that it minimizes potential endogenity problem because we would exclude the U.S. industries from the analysis. Additionally, to construct the measures of intangible intensity, we use accounting data for U.S. industries from financial statements based on U.S. accounting standards. As a result, we eliminate the potential measurement error that could arise due to different accounting treatment of assets because of differences in accounting standards and procedures across countries.

Alternatively, for robustness, I use two other industry variables to characterize the information intensity of the sector. The first is the degree to which an industry invests in R & D activities, and is measured as the ratio of R&D costs as a proportion of revenue. The second one is the extent of patent use by U.S. industries from Lach (1995). In addition, I use the average analyst earnings forecast consensus in the U.S. by industry.

C. Sample Selection

The sample is a panel of ten manufacturing industries across thirty-four countries over the period 1980 to 1995. The sample period coincides with the period for which the index of financial architecture is available, hence limiting the study period. Panel C of Table 1 summarizes the characteristics of the sample. I have complete data for thirty-five countries; however, following RZ, I use the U.S. as a benchmark to identify the intangible intensiveness of the industries, and exclude it from the analysis.

III. Results

Table 2 presents the main empirical results. I begin with evaluating the impact of financial architecture to the average industry, irrespective of the latter's asset composition. To do so, I relax the specification of the basic model in eq. (1) by replacing the country dummies with explicit country-specific variables, including financial architecture. In column (1) of Table 2, financial architecture is the only country-level variable and the interaction term (meant to capture the particular channel that is the focal of this study) is excluded. I would like to evaluate the pure general effects of financial architecture. The results indicate that the average industry realizes faster rate of technological progress in more market-based financial systems. This is consistent with the market-based views that markets have comparative advantages over banks in identifying and funding innovations (Allen and Gale (1999); Boot and Thakor (1997)).

This specification, however, is subject to omitted variables bias as it does not account for variables that have been shown to be important for economic growth and, by implication, for innovations. Examples of such variable that have been used in the growth literature include the level of per capita GDP, human capital, property rights, and measures of financial development (Romer (1990), Barro (1991), Claessens and Laeven (2003), and Levine and Zervos (1998)). Levine and Zervos (1998) find that stock market liquidity and overall bank development positively impacts long-run growth. I use the stock market liquidity measured as the stock market turnover ratio, and bank development measured by domestic credit to the private sector to GDP ratio (following Levine and Zervos (1998), and Cetorelli and

Gambera (2001)) to control for effects of financial development, and expect the variables to have positive effects. The importance of property rights protection for growth is increasingly recognized (see, e.g., Claessens and Laeven (2003)). Stern et al. (2000) show that the strength of a country's protection of intellectual property rights affects its innovative capacity. I use a broad index of property rights from the International Country Risk Guide (ICRG) to measure property rights protection, and expect it to be positively related to technological change. The level of human capital is measured as the average of the number of years of schooling attained by the population over 25 years of age in 1980 (Barro and Lee (1993)) and is expected to have a positive effect on growth and innovation. Per Capita GDP is included to capture innovation-enhancing other institutional differences across countries. Developed countries have the resource wherewithal to keep them on the technological edge, suggesting a positive association between level of development and technical progress.

In this extended model, financial architecture enters again with a large statistically significant positive coefficient, indicating that the market-orientation of the financial system has a general positive impact on technological progress. The average industry realizes faster rate of innovation in more market-based systems. This result lends support to the prior that market-based systems foster technological innovations. The other country controls have the expected relations with technological progress. As would be expected, technological progress is faster in countries with better protection of property rights. Consistent with previous studies (e.g., Levine and Zervos (1998)), financial development as measured by stock market liquidity and bank development has significant positive impact. Human capital has a statistically insignificant but negative coefficient. This is comparable to Rajan and Zingales (1998)'s finding of similar effect on industry growth. As expected, industries in developed countries realize faster technical progress, as those industries that are more important in the country as measured by share of industry's value added to total manufacturing value added.

I now turn to the focal relation of interest, namely, the differential effects of financial architecture across industries that vary in their asset composition. To examine this particular channel, column (3) of Table 2 includes the interaction between intangible intensity and financial architecture. Intangible intensity measures the informational intensiveness of the economic activities of the industry. In addition, to control for the economy-wide effect of financial architecture, I include the variable separately as the only country-level control. To minimize the potential problem of omitted variables in this specification, column (3) also includes other country controls common in standard growth regressions. The model contains industry and period dummies as well. The result indicates that informationally intensive industries realize relatively faster technological progress in relatively bank-oriented countries. The interaction term is negative and statistically significant at one percent level. On the other hand, the general effect of financial architecture remains the same: the average industry realizes faster rate of innovation in more market-based systems. The two effects of financial architecture are robust to the inclusion of the various control variables, all with coefficient estimates consistent with priors. In the industries with higher intangible intensity, the benefits of bank-based systems appear to outweigh that of market-based systems. For least intensive industries, the net benefit of market-based systems is positive, implying that the general effects of market-based systems outweigh the heterogeneous industry-specific effects for these industries.

The two major findings – that market-based systems promote technological innovation in general and bank-based systems promote innovation in industries with greater intangible-intensity– may appear in conflict. In fact, the combined results are consistent with the theoretical priors. It suggests that market-based systems have a positive effect on innovation that, on average, affects all sectors indiscriminately. It could be that market-oriented financial systems enable the identification and financing of new technologies where diversity of opinion persists, of which all sectors in the economy benefits (Allen (1993) Allen and Gale (1999)). On the other hand, introducing differences in industries in knowledge intensiveness, we find an industry-specific positive effect of bank-oriented (and negative effect of market-oriented) financial system. This is consistent with the theoretical prior that banks have a comparative advantage in economizing transactional and informational costs in funding innovations, which could be more important in sectors which are informationally intensive. As such, the finding is consistent with the bank-based views that rely on the advantages of banks in areas of information processing (e.g., Bhattachcharya and Chiesa (1995); Yosha (1995)).

In column (4), I estimate the regression that includes indicator variables for all countries and for all industries, effectively controlling for all country-related, industry-related and period-related sources of variation in the dependent variable. The coefficient estimate of the interaction terms is robustly negative and significant at one percent level. It does not appear that one country or industry is responsible for the results. The explanatory power of the regression goes up significantly suggesting the importance of omitted inter-country and inter-industry differences in explaining variations in the rates of innovation. This is the basic empirical model I use in the rest of the paper.

IV. Statistical Robustness Tests

To ensure accurate inference and avoid mechanical explanations for the main results so far, I provide a series of robustness tests in this section, for which I focus on the basic empirical model specification. All the pertinent robustness tests have also been conducted on the first-order effects of financial architecture, which is shown to be very robust.

A. Alternative Measures of Rate of Technological Innovations

In the foregoing, I used, as a dependent variable, a measure of technological innovation derived from the underlying production function as a representation of the technology as represented by g[.]. There is another way to construct measures of technological change. Duality theory suggests that under certain regularity conditions[9], if producers pursue cost minimizing objective, the production function can be uniquely represented by a cost function, and therefore one can infer the rate of technological progress from the cost function. Letting h (.) be the best practice variable cost frontier, the minimum possible variable cost for period t, given input price of w, the level of fixed input I, and output y is given by

$$C_{ci}^{F}(t) = h(w_{ci}(t), I_{ci}(t), y_{ci}(t), t) \tag{5}$$

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[9] 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.

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

$$C_{ci}(t) = C_{ci}^{F}(t)e^{\theta_{ci}(t)} = h(w_{ci}(t), I_{ci}(t), y_{ci}(t), t)e^{\theta_{ci}(t)} \qquad (6)$$

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. (6) with respect to t, and noting that improvements in terms of cost mean cost diminution, we obtain:

$$-\frac{\dot{C}_{ci}(t)}{C_{ci}(t)} = -\left\{ h_w \frac{\dot{w}_{ci}(t)}{w_{ci}(t)} + h_I \frac{\dot{I}_{ci}(t)}{I_{ci}(t)} + h_y \frac{\dot{y}_{ci}(t)}{y_{ci}(t)} + h_t + \dot{\theta}_{ci}(t) \right\} \qquad (7)$$

Eq. (7) 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. (6) 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.

Column (1) through (3) of Table 3 presents the main results using this alternative measurement of the dependent variable. It clearly indicates that the main results are robust. Financial architecture has a positive first-order effect (columns (1) and (2)) and a negative industry-specific second-order effect (column (2) and (3)). Both effects are statistically highly significant and of the same order of magnitude as those in Table 2.

B. *Alternative Measurement of Financial Architecture*

The measure of the market-orientation of the financial system, ARCHITECTURE, is constructed as the first principal component of three separate indices that measure the relative importance of markets versus banks in terms of their relative size, extent of activity and their relative efficiency. The variable provides an intuitive classification of countries into bank and market based systems. The rank ordering is also consistent with previous research (e.g., Demirguc-Kunt and Levine (2001), Beck and Levine (2002)).

To check for the robustness of the results to measurement issues related to this independent variable, I use alternative measures in column (4) through (10) of Table 3. Column (4) uses a measure of financial architecture constructed as a means-removed simple average of the measures of size, activity and efficiency, and is taken from Demirguc-Kunt and Levine (2001). The result is robust to measuring financial architecture using this variable. Beck and Levine (2002) uses three different measures to characterize financial architecture: a principal component aggregation of the architecture-size and architecture-activity indices, the degree of state ownership of banks, and the degree of regulatory restrictions of banks. They argue that bank-based systems are also characterized by state ownership and regulatory restrictions. Columns (5) through (7) use the indices of Beck and Levine (2002). The results are very robust. The interaction terms with financial architecture (column (5)), indicating more market-orientation, is negative and significant, while the interactions with more state ownership (column (6)) and more restriction (column (7)), indicating more bank-orientation, are positive and statistically significant.

Columns (8) through (10) use the component measures of Architecture-size, Architecture-activity and Architecture-efficiency separately instead of the aggregate index. The result is again robust; the interaction term carries a negative coefficient that is both statistically significant and of the same order of magnitude.

C. Alternative Measures of Industrial Information Intensity?

As a measure of informational intensity by industry, I use the intangible intensity typical of industrial sectors in the U.S. The use of this variable as well as employing the U.S. as the benchmark country may raise a number of concerns. To begin, the U.S. financial system is a prototype market-based system, and, it may be argued that the use of the U.S. as a benchmark may bias the results in favor of market- based financial architecture. Furthermore, the measures of intangible intensity for U.S. industries reflect accounting standards and procedures in the U.S. To check for the robustness of the results to these concerns, I use Germany and Japan, two typical bank-based systems, as the benchmark countries. I compute the mean intangible intensity (intangible assets to tangible assets ratio) for each of the ten industries of the sample in Germany and Japan respectively. The data is obtained from the WorldScope database, and the average intangible intensity for the respective industry was calculated over the period 1980 through 1995. In column (1) of Table 4, I use the intangible intensities of German industries instead of the U.S. industries. Accordingly, because Germany is serving as a benchmark country, it is dropped from the sample and the U.S. is included. The results in column (1) indicate that changing the benchmark country does not alter the main results. The intangible intensity-financial architecture is significantly negative. In column (2), I use the intangible intensity measures of Japanese industries instead. The sample is adjusted to exclude Japan, the benchmark country, but include Germany and the U.S. Again, the results are robust. Industries high on intangible intensity realize faster rates of technical innovation in more bank-oriented financial systems, regardless of which benchmark country is used. In addition, this finding provides evidence that the results hold despite differences in accounting standards that may affect the measurement of intangible intensity.

Intangible intensity is used as a measure of information intensiveness peculiar to the technological environment of the industry. Alternately, it may be suggested that more direct measures of technological activities, such as the extent of R&D activities or that of patent acquisitions might be appropriate. The main problem of using such measures is that measures of R & D activities and their outcome, the extent of patenting, are commonly used as measures of technological innovation (see, e.g., Bartel and Sicherman (1999)), and hence their use as explanatory variables introduces endogeniety. Nonetheless, in columns (3) through (6), we check if the results are robust if we measure information intensiveness differently. In column (3) through (5), I use the extent of R & D activities by industries – R&D intensity. The variable is constructed as the ratio of R & D costs as a percentage of revenue based on financial statement data in the WorldScope database. I calculate the average R & D intensity for each firm in the industry over the sample period of 1980 through 1995. The industry R & D intensity is the median of the firm mean averages. The regressions use the R & D intensities of the U.S., German and

Japanese industries respectively in columns (3) through (5). In each case, I drop the benchmark country from the sample. This would minimize the endoginiety problem discussed above. The results confirm the robustness of the main findings. Industries high in informational intensities appear to realize faster technological innovations in more bank-oriented countries.

In column (6) of Table 4, I use the extent of patent use in the industry as an alternate measure of information intensity relevant to technology in the industry. Patent data are generally collected by technology field, and have not been available by industry. I use the number of patents used by manufacturing industries in the U.S. in the 1980s analyzed in Lach (1995). The variable is the number of patents used during 1980 through 1983, the last year for which data is available, as a fraction of that used in the 1970s. The use of patents as a proxy for information intensity suffers from endogeniety bias in that the variable is also a measure of the extent of innovation. However, in the regression, I drop the U.S., the benchmark country, from the sample and use the U.S. industries' extent of patenting as a proxy for information intensity in industries in other countries, which mitigates some of the endogeniety problem. Column (6), again, confirms the main findings of the study. Industries with higher information-intensity realize relatively faster technical innovation in bank-based economies. The interaction term between patent intensity and financial architecture is robustly negative.

Another way of measuring information intensity might be to assess the difficulty outsiders, such as financial analysts, encounter in assessing firm performance. For example, the extent of consensus in financial analysts' forecast of a firm's earnings could signal about the complexity of the firm's activities, and hence the difficulty with which its outcome can be assessed. Analyst forecast consensus has also been used extensively in the literature as a measure of informational asymmetry (see, e.g., Clarke and Shastri (2001)). The problem in using such a variable as a measure of information-intensiveness for an industry is that lack of analyst forecast consensus may reflect more the external informational environment or the noise outside the firm. For example, low consensus may be attributable to lack of investors' interest and low analyst following. Hence, analyst forecast consensus is, at best, a noisy proxy of information-intensity attributable to the technology of the firm. With these caveats, I use, in column

(7) of Table 4, a measure of analyst forecast consensus for U.S. industries. Forecast consensus is measured as the coefficient of variation of annual earnings forecast from the mean annual forecast based on data from IBES. I calculate the average forecast consensus for each firm in the industry over the sample period of 1980 through 1995. The industry forecast consensus is the median of the firm averages. I dropped the benchmark country, the U.S., from the sample. The results in column (7) confirm the basic findings that informationally-intensive industries, measured this way, fare better in relatively bank-based systems.

D. 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); Cleassens 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 be argued that, therefore, the financial architecture measure is simply a proxy for the degree of property rights protection in the country and so the effects documented could be simply effects of better property rights instead of financial architecture. We can check for this possibility by explicitly including measures of property rights protection. I use six different measures of the degree to which countries protect property rights from various sources. These are (1) a broad index of property rights from the International Country Risk Guide (PROPERTY RIGHTS ICRG), (2) a rating of protection of property rights from the index of economic freedom (PROPERTY FREEDOM), (3) a rating of protection of intellectual property rights based on the "special 301" placements of the U.S. Trade representative (INTELLECTUAL PROPERTY), (4) a patent rights index by Ginart and Park (1997) (PATENT RIGHTS), (5) an index of the general legal protection of private property from the World Economic Forum (WEF), and (6) an index of intellectual property rights from the World Economic Forum (INTELLECTUAL WEF). A detailed definition of the variables is provided in Appendix 1. These variables have been used in previous research. For example, Claessens and Laeven (2003) find that property rights protection affects growth through shaping firms' asset allocation.

Table 5 shows that the main results are robust to inclusion of these alternative measures of property rights. In columns (1) through (6), I include an interaction of each of the property rights variable with intangible intensity in the model containing the interaction of intangible intensity with financial architecture. The intangible intensity-financial architecture interaction is consistently negative and the coefficients statistically significant at one-percent level. As would be expected and consistent with Claessens and Laeven (2003), industries with higher use of intangibles realize relatively faster rates of technological progress in countries with better property rights protection[10].

E. Could the results be driven by omitted variables?

It may be argued that differences in other country specific comparative advantages (i.e., other than financial architecture) or industry-specific characteristics (i.e., other than intangible intensity) may be dictating the observed relations on industrial technological progress. However, these results cannot be explained unless the dependence of the industry on that comparative advantage is correlated with intangible intensity, and that financial architecture is a proxy of this unobserved comparative advantage. I minimize the possibility of this type of omitted variable bias by focusing on only manufacturing industries thereby reducing, for example, the influence of availability of natural resources.

In addition, I can directly test if financial architecture or intangible intensity stands for something else. For example, it could be argued that the results are simply a reflection of the well-known effects of financial development (e.g., Rajan and Zingales (1998)). To check if this is the case, I include the interactions of intangible intensity with measures of financial *development* in the basic specification with the intangible intensity-financial architecture interaction. A proxy for financial development used in many studies (e.g., Cetorelli and Gambera (2001); Rajan and Zingales (1998)) is bank development, measured as the ratio of domestic credit to the private sector to GDP. Rajan and Zingales (1998) also uses an aggregate measure of financial development reflecting both the stock market and the banking

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[10] To be exact, Cleassons and Laeven (2003) include an intangible intensity-property rights interaction in a model that contains the interaction between external dependence and financial development and find both interactions to be positive where the dependent variable is growth. I replicate their results using my data as well.

sector. I construct an aggregate measure of financial development as a principal component of stock market capitalization, stock market turnover and bank development. Column (1) and (2) of Table 6 presents the results. I highlight that the main result that industries with greater intangible intensity realize relatively faster technological progress in bank-oriented systems remains robust, controlling for the fact that such industries also fare well with financial development.

It could be argued that knowledge intensive economic sectors are dependent on human capital as well. If financial architecture is correlated with human capital, the observed effect might be a proxy for the interaction of the industry dependence on human capital and the availability of trained labor force in the country. To test for this possibility, I include in column (3) the interaction of intangible intensity and human capital in the basic model that contains the intangible intensity-financial architecture interaction. Consistent with expectations, the coefficient of the human capital-intangible intensity interaction significantly positive, but I highlight the fact that the interaction between intangible intensity and financial architecture remains significantly negative and of same order of magnitude.

It might also be argued that industries' use of intangibles may reflect industry growth opportunities. This concern is analogous to Fisman and Love (2002b) critique of Rajan and Zingales (1998) that external financial dependence may reflect the relative growth opportunities of industries. Using U.S. industries' sales growth as measures of sectoral growth opportunities, they find that the interaction of this measure with financial development is robustly positive while the Rajan and Zingales (1998)' interaction between external dependence and financial development disappears.

If the argument is valid in our case, for a given financial architecture, it may not be informationally-intensive industries that realize faster technical progress instead those with better growth opportunities. If industrial growth opportunities are systematically correlated with financial architecture, the reported relations between technical progress and the interaction term will be spurious. To check for this possibility, column (4) of Table 6 includes an interaction of a measure of industry growth opportunity and financial architecture in the basic model that contains the focal interaction variable. I use the average growth rate in sales of U.S. industries from Fisman and Love (2002b) as a measure of industrial investment opportunities. The coefficient of the interaction between financial architecture and intangible intensity is robustly negative, suggesting that intangible intensity may not be a proxy for growth opportunities. The result replicates the positive effect of growth opportunities reported in Fisman and Love (2002b).

Similarly, it could be that the effect of financial architecture via intangible intensity documented here might be a reflection of the effects of external financial dependence. To the extent that firms rely on external finance to fund growth opportunities, it may be argued that the asset structure of industries may reflect their degree of external dependence. Beck and Levine (2002) find that the growth of externally dependent industries is unaffected by financial architecture. Column (5) shows that the results are robust to such a concern. It includes an interaction of financial architecture with a measure of external finance dependence for U.S. industries from Rajan and Zingales (1998) in the basic regression that contains the intangible intensity-financial architecture interaction. The coefficient of the intangible intensity interaction is strongly negative. Consistent with previous research, financial architecture does not explain performance across industries that differ in degree of external financial dependence.

Another concern could be that financial architecture might be a proxy for the general countrywide 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 differences in the comparative advantages of financial architectures in funding industries' innovation. To check for this, I add in column (6) the interaction of the log of per capita with intangible intensity in the basic model that includes the interaction of financial architecture and intangible intensity. The coefficient of the financial architecture interaction remains significantly negative. Consistent with Rajan and Zingales (1998), the interaction with income is positive.

F. Reverse Causality?

The results from the basic regression so far do not explicitly control for the potential for endogeneity. In examining the association between technological innovation and financial architecture, I measure the latter using proxies that I assume to be exogenous and predetermined. It might be argued that the configuration of the financial system adapts to the technological characteristics of the country, and hence, financial architecture 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 architecture could lead to differential degree of technological progress among firms that differ in their asset composition. As an advantage over the traditional cross-country methodology, a finding of within-country between-industry difference in technological progress based on their degree intangible intensity is, in the words of RZ, "the smoking gun" in the debate about causality. Second, by design, I use the U.S. industries' intangible intensity to explain technological progress of industries in other countries, thereby reducing a potential endogeneity problem if I include the U.S. in the sample. Third, I explicitly account for potential omitted variables, such as property rights.

To address any remaining reverse causality concerns, however, I estimate the basic model using instrumental variables methodology. The ideal instruments are variables that might affect financial architecture but less likely to be affected by it. To select the appropriate instruments, I use theory and recent empirical works. First, some identify the legal environment of countries as the critical factor that shapes its institutions. La Porta et al. (1998) 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. Rajan and Zingales (1998) and Levine and Zervos (1998), among many others, use these variables as instruments for financial development. I include these variables as a potential set of instruments. The second set is the geographic or environmental endowments of countries. The endowment theory of economic development contends that the geographical/environmental endowment of countries has left an indelible mark on long-lasting institution (e.g., Acemoglu et al. (2001)). Institutions in many countries' were shaped by their experiences during European colonization. Early colonists encountered varying climates around the world. Acemoglu et al. (2001), argue that current institutions reflect the willingness of colonial powers to settle. In colonies with inhospitable climates (mostly the tropics), the colonial powers avoided settlement, preferring to establish ‘extractive’ institutions; whereas, in colonies with hospitable climates (mostly the temperate), they established settler institutions that support private property and restrain the power of the State. Natural endowments, therefore, may influence a broad array of institutions. I use the latitudinal distance of countries from the equator as a proxy for endowments.

Columns (7) of Table 6 present the instrumental variables (IV) results. The first stage regressions reject the null hypothesis that they do not explain any of the cross-country variation in financial architecture. Column (7) confirms the major finding from Table 2 and 3 that financial architecture has a heterogonous impact on industrial technological progress. Specifically, the coefficients of the interaction term between intangible intensity and financial architecture is strongly negative. The exogenous components of financial architecture predetermined by the extent of legal protection afforded to investors and the geographic /climate endowments of countries have a statistically significant impact on technological progress. Hence, the relations between technological innovation and financial architecture identified in this study are less likely to be explained by endogeneity.

V. Concluding Remarks

Recent empirical research in finance and growth has established that financial development has a positive impact on economic growth. The consensus on the finance-growth link has ignited a renewed interest in the historic debate of whether a nation’s financial architecture – i.e. the degree to which the financial system is market or bank oriented -- matters to its long-run economic growth, and in particular, in fostering innovations and technology. The theoretical debate on both sides of the issue is strong, and the available evidence is both anecdotal and mixed.

Based on data on a broad cross-section of countries with industry panel, the study attempts to shade light on this historic debate, focusing on arguments on the relative merits banks versus financial markets in processing information. The findings suggest a significant impact of financial architecture on industrial innovative activities. It reports evidence that market-based financial systems have a first-order positive effect on technological progress. This is consistent with the theoretical predictions that markets have a comparative advantage of identifying and funding new technologies where diversity of opinion matters. On the other hand, the study also finds evidence that financial architecture has a heterogeneous effect across industries. In particular, knowledge-intensive industries, with soft, hard-to-monitor complex activities fare better in bank based financial systems. This finding is consistent with theoretical models that emphasize the comparative advantages of banks in resolving transactional and informational imperfections, and models that emphasize the value of confidentiality and relationships.

The implications of the paper are numerous. First, the findings indicate that financial architecture matters for long-term growth, and that the choice of an appropriate financial architecture is a source of value in and of itself. In particular, the appropriate financial architecture is a function of the industrial structure of the country. Second, from a public policy perspective, at least in terms of the effects on innovations and technology, there does not appear to be a Pareto dominant policy regarding the optimal financial architecture. Market-based systems do not dominate bank-based systems and vice versa in all times. Third, given the financial architecture of the country, individual industries could attain different rates of innovation. That is to say the financial architecture of a country has heterogeneous impacts on the technological progress and productivity of industries. Hence, financial architecture plays an important role in shaping the industrial structure of the country. Finally, and in sum, financial architecture partially dictates the pace of countries' technological progress.

APPENDIX 1

Definition and Sources of Variables

Variable	Definition	Sources
Dependent Variables:		
Rate of Technological Progress	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. Alternatively, it is measured as the rate of real cost reduction computed as the rate of downward shift in the cost function over time, holding output and cost efficiencies constant.	Constructed based on production and cost functions estimated using data form the UNIDO database.
Independent Variables:		
Financial Architecture	An index of the degree of stock market orientation of a financial system, and is a aggregate of three indices of the market orientation based on (i) the relative size of stock market to that of banks, (ii) the relative intensity of activity in stock markets vis a vis the banking sector, and (iii) the relative efficiency of stock markets vis a vis the banking sector. The size, activity and efficiency indices are aggregated as principal component.	Constructed based on data in Beck et al (2000)
Intangible Intensity	Ratio of intangible assets-to-net fixed assets of U.S. firms by industry sector over the period 1980 to 1989. Primary Source: COMPUSTAT. Intangibles is COMPUSTAT item 33 and represents the net value of intangible assets. Intangibles in COMPUSTAT includes blueprints or building designs, patents, copyrights, trademarks, franchises, organizational costs, client lists, computer software patent costs, licenses, and goodwill. Net fixed assets is COMPUSTAT item 8 and represents net property, plant and equipment.	Claessens and Laeven (2003)
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 share in Manufacturing value added	Fraction of an industry's real value added to the value added of the manufacturing sector	Calculated from data in the UNIDO database
Stock Market Capitalization	Value of listed shares of stock outstanding divided by GDP	Emerging Markets Database
Stock market Turnover	Value of shares of stocks trades as a ratio of stock market capitalization	Emerging Markets Database
Bank Development	Domestic credit to the private sector as a ratio of GDP	International Finance Series from the IMF
Property Freedom	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
Intellectual Property	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.	USTR
Patent Rights	Index of patent rights protection in 1980.	Ginarte and Park (1997)
Property Rights (WEF)	An index of property right (scale 1 through 7) in 2001 from the World Economic Forum (WEF)	World Economic Forum
Intellectual Property (WEF)	An index of intellectual property rights protection (scale 1 through 7) in 2001 from the World Economic Forum (WEF)	World Economic Forum
Property Rights (ICRG)	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)	ICRG
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 (2002b)
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.	LLSV (1998)
Legal Protection	Indices of the legal protection afforded to shareholders and creditors in each country	LLSV (1998)
Distance from the Equator	The distance of the country from the equator, scaled between 0 and 1	LLSV (1999)

APPENDIX 2

Estimation of Rates of Technological Change

A2.1 Empirical measures of Technological Change Based on Stochastic Production Function

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[11],

(A2.1.1)
$$\ln y_{ci}(t) = \beta_0 + \sum_j \beta_j \ln x_{ci}{}^j(t) + \beta_t t + \tfrac{1}{2}\Big(\sum_j \sum_k \beta_{jk} \ln x_{ci}{}^j(t) \ln x_{ci}{}^k(t) + \beta_{tt} t^2\Big) + \sum_j \beta_{jt} \ln x_{ci}{}^j(t) t + \mu_{ci}(t) + \varepsilon_{ci}(t)$$

where,

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

$x_{ci}{}^j(t)$ 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. α_c and η_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:

(A2.1.2)
$$\begin{aligned} &\alpha_c \approx iidN(0,\sigma_\alpha{}^2) \\ &\eta_i \approx iidN(0,\sigma_\eta{}^2) \\ &\mu_{ci}(t) \approx iid - halfNormal(0,\sigma_\mu{}^2), and, \mu_{ci}(t) \le 0 \\ &\nu_{ci}(t) \approx iidN(0,\sigma_\nu{}^2) \end{aligned}$$

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[11] 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.

I estimate the model by the method of maximum likelihood to 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:

(A2.1.3)

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

A2.2 Empirical measures of Technological Change Based on Stochastic Cost Function

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:

(A2.2.1)

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

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***. α_c and η_i are country specific and industry specific error components. $\xi_{ci}(t)$ is the usual disturbance term with mean zero and standard deviation σ_ξ. The error components and the disturbance term follow the distributional assumptions in eq. (A2.1.2) 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 numeraire, 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:

(A2.2.2)

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

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TABLE 1
Technological Innovation and Financial Architecture: Averages over the period 1980-1995.

Panel A: Averages by Countries

	Technological Progress (based on Stochastic Production Frontier) $(\nabla TECH1)$	*Technological Progress (based on Stochastic Cost Frontier)* $(\nabla TECH2)$	*Industry Share in Manufacturing* *(SHARE)*	*Financial Architecture* *(ARCHITECTURE)*	*Log(Per Capita GDP)*
Australia	0.023	0.030	0.043	0.938	9.704
Austria	0.023	0.027	0.038	-1.552	9.856
Belgium	0.027	0.031	0.032	0.205	9.791
Canada	0.024	0.029	0.029	0.951	9.899
Chile	0.012	0.022	0.026	0.198	6.086
Colombia	0.014	0.024	0.061	-0.314	7.711
Denmark	0.020	0.026	0.050	-0.037	7.096
Egypt	0.015	0.026	0.061	-1.104	10.085
Finland	0.020	0.024	0.042	-0.593	10.081
Germany	0.033	0.035	0.045	-0.173	9.963
Greece	0.017	0.023	0.054	-0.512	8.968
India	0.015	0.028	0.051	-2.604	5.780
Indonesia	0.007	0.021	0.040	-2.350	6.315
Israel	0.014	0.022	0.037	0.465	9.287
Italy	0.028	0.032	0.051	-0.486	9.757
Japan	0.036	0.036	0.046	0.676	9.966
Jordan	0.022	0.023	0.123	0.554	7.008
Korea	0.022	0.027	0.055	0.491	8.527
Malaysia	0.016	0.023	0.043	1.287	7.730
Mexico	0.016	0.023	0.055	0.768	7.975
Netherlands	0.025	0.028	0.057	0.454	9.786
New Zealand	0.015	0.023	0.068	0.651	9.444
Norway	0.021	0.027	0.043	-0.207	10.179
Pakistan	0.006	0.019	0.043	-0.260	5.794
Peru	0.019	0.026	0.051	0.433	7.524
Philippines	0.010	0.022	0.058	0.355	6.566
Portugal	0.022	0.028	0.048	-2.439	8.690
Singapore	0.013	0.021	0.037	1.295	9.422
Spain	0.025	0.029	0.045	-0.353	6.496
Sri Lanka	-0.005	0.014	0.079	-0.290	9.344
Sweden	0.021	0.028	0.040	0.759	10.123
Turkey	0.018	0.025	0.046	0.711	7.880
U. K.	0.030	0.033	0.044	1.112	6.984
Venezuela	0.024	0.029	0.047	-0.434	9.949

Panel B: Averages by Industries

	$(\nabla TECH1)$	$(\nabla TECH2)$	(SHARE)	(ARCHITECTURE)	Log(Per Capita GDP)
Food Products (ISIC 311)	0.022	0.029	0.116		
Beverages (ISIC 313)	0.023	0.028	0.041		
Tobacco (ISIC 314)	0.019	0.024	0.028		
Textiles (ISIC 321)	0.021	0.028	0.056		
Wearing Apparel (ISIC 322)	0.008	0.010	0.029		
Industrial Chemicals(ISIC351)	0.026	0.030	0.050		
Rubber Products (ISIC355)	0.017	0.024	0.015		
Plastic Products (ISIC 356)	0.014	0.023	0.021		
Iron and Steel (ISIC 371)	0.026	0.031	0.041		
Machinery, except Electrical (ISIC 382)	0.016	0.024	0.067		

Panel C: All Observations

	$(\nabla TECH1)$	$(\nabla TECH2)$	(SHARE)	(ARCHITECTURE)	Log(Per Capita GDP)
No. of observations	2679	2679	2626	34	34
Mean	0.019	0.026	0.044	-0.154	8.627
Standard Dev.	0.012	0.007	0.041	1.051	1.380
Minimum	-0.019	0.003	0.002	-2.604	5.780
Maximum	0.056	0.053	0.326	1.295	10.179

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-four countries over the period 1980 to 1995. Technological Progress (ΔTECH1) measures the shift in the production frontier over time, and represents increases in real output due to adoption of better technology. The alternative measure of technological progress (ΔTECH2) 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. Financial architecture is a continuous variable that measures the degree of market orientation of a financial system and is a principal component of the size, activity, efficiency dimensions of financial architecture.). Per Capita GDP is the logarithm of real GDP per capita in 1980.

TABLE 2

The Average and Differential Impacts of Financial Architecture on the rate of Technological Innovation of Industries that vary in Intangible Intensity

	1	2	3	4
Share of Industry value added to Manufacturing	0.054***	0.064***	0.064***	0.067***
	(0.005)	(0.005)	(0.005)	(0.004)
Intangible Intensity * Financial Architecture			-0.0036***	-0.0041***
			(0.0011	(0.0008)
Financial Architecture	0.0014***	0.0006***	0.0018***	
	(0.00018)	(0.0002)	(0.0004)	
Property Rights		0.0013***	0.0014***	
		(0.0002)	(0.0002)	
Stock Market Liquidity		0.0037***	0.0041***	
		(0.0006)	(0.0007)	
Bank Development		0.0052***	0.0050***	
		(0.0006)	(0.0007)	
Human Capital		-0.0000	0.0000	
		(0.0001)	(0.0001)	
Per Capita GDP		2.99E-7	2.4E-7***	
		(6.0E-8)	(7.2E-8)	
R^2	0.2745	0.5397	0.5151	0.7588
N	2624	2392	1728	1882
Countries	34	34	34	34

The dependent variable in all regression is the rate of technological progress for each industrial sector in each country. Share of industry value added to Manufacturing is calculated by dividing the real value added of the industry in the country by the total real value added of the manufacturing sector of the country. Financial architecture is a continuous variable that measures the degree of market orientation of a financial system and is a principal component of the size, activity, efficiency dimensions of financial architecture. Intangible Intensity is the ratio of intangible assets to net fixed assets to net fixed assets of U.S industries. Stock market capitalization is market value of listed stocks outstanding divided by GDP. Stock market liquidity is total value of stocks traded divided by stock market capitalization. Bank development is domestic credit to the private sector divided by GDP. Property Rights 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 from the International Country Risk Guide (ICRG). 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. Other regressors included, but not reported are country dummies, industry dummies and year dummies. Heteroskedasticity-consistent standard errors are reported in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

TABLE 3

The Average and Marginal Impacts of Alternative Measures of Financial Architecture on the Rate of Technological Innovation of Industries that vary in Intangible Intensity

	1	2	3	4	5	6	7	8	9	10
Share of Industry Value Added to Manufacturing	0.038^{***} (0.0034)	0.044^{***} (0.0035)	0.047^{***} (0.0035)	0.067^{***} (0.0036)	0.066^{***} (0.0036)	0.066^{***} (0.0036)	0.065 (0.0036)	0.068^{***} (0.004)	0.067^{***} (0.003)	0.066^{***} (0.003)
Intangible Intensity*Financial Architecture		-0.0016^{**} (0.0008)	-0.0026^{***} (0.0008)	-0.0047^{***} (0.0011)	-0.0057^{***} (0.0009)	0.00006^{**} (0.00003)	-0.0013^{***} (0.0003)	-0.0050^{***} (0.0008)	-0.0023^{***} (0.0006)	-0.0014^{*} (0.0008)
Financial Architecture	0.0002^{*} (0.0001)	0.0008^{**} (0.0003)	0.0007^{**} (0.0003)							
Property Rights (ICRG)			0.0009^{***} (0.0001)							
Stock Market Liquidity			0.0028^{***} (0.0004)							
Bank Development			0.0025^{***} (0.0005)							
Human Capital			0.0000 (0.0000)							
Per capita GDP			2.3E-8 (5.0E-8)							
R^2	0.3257	0.3252	0.4687	0.7577	0.7495	0.7452	0.7467	0.7604	0.7571	0.7554
N	2485	1882	1728	1882	1831	1831	1831	1882	1882	1882
Countries	34	34	34	34	34	34	34	34	34	34

The dependent variable in all regression is the rate of technological progress for each industrial sector in each country. The rates of technological progress used in columns (1) through (3) are derived from estimation of stochastic cost functions. Columns (5) through (7) use measures of financial architecture from Beck and Levine (2002). Columns (8) through (10) use the components of the aggregate index of financial architecture. Share of industry value added to Manufacturing is calculated by dividing the real value added of the industry in the country by the total real value added of the manufacturing sector of the country. Financial architecture is a continuous variable that measures the degree of market orientation of a financial system and is a principal component of the size, activity, efficiency dimensions of financial architecture. Intangible Intensity is the ratio of intangible assets to net fixed assets to net fixed assets of U.S industries. Stock market capitalization is market value of listed stocks outstanding divided by GDP. Stock market Liquidity is total value of stocks traded divided by stock market capitalization. Bank development is domestic credit to the private sector divided by GDP. 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. Other regressors included, but not reported, are country , industry, and year dummies. Heteroskedasticity-consistent standard errors are reported in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

TABLE 4

The Differential Impacts of Financial Architecture on the Rate of Technological Innovation of Industries that vary in Various Measures of Informational Intensity

	1	2	3	4	5	6	7
Share of Industry Value Added to Manufacturing	0.066*** (0.003)	0.061*** (0.003)	0.064*** (0.003)	0.069*** (0.003)	0.0062*** (0.003)	-0.068*** (0.004)	0.069*** (0.003)
Intangible Intensity of German Industries * Financial Architecture	-0.0035*** (0.0008)						
Intangible Intensity of Japanese Industries*Financial Architecture		-0.0003** (0.0001)					
R&D Intensity of U.S Industries *Financial Architecture			-0.018*** (0.003)				
R&D Intensity of German Industries*Financial Architecture				-0.1440*** (0.020)			
R&D Intensity of Japanese Industries* Financial Architecture					-0.0590*** (0.018)		
Patent Intensity of U.S. Industries * Financial Architecture						-0.0025*** (0.0003)	
Analyst Consensus for U.S. Industries * Financial Architecture							-0.0423*** (0.007)
R^2	0.7905	0.7639	0.7687	0.7942	0.7644	0.7700	0.8069
N	2525	2664	2624	2525	2664	1882	2180
Countries	34	34	34	34	34	34	34

The dependent variable in all regression is the rate of technological progress for each industrial sector in each country. Share of industry value added to Manufacturing is calculated by dividing the real value added of the industry in the country by the total real value added of the manufacturing sector of the country. Financial architecture is a continuous variable that measures the degree of market orientation of a financial system and is a principal component of the size, activity, efficiency dimensions of financial architecture. Intangible Intensity is the ratio of intangible assets to net fixed assets to net fixed assets of Germany and Japanese industries. R & D intensity is the ratio of R & D costs to sales revenue for industrial sectors in the U.S., Germany, and Japan. Patent intensity in U.S. is the number of patents used in manufacturing industries in the U.S. obtained from Lach (1995). Analyst forecast consensus in U.S. is the coefficient of variation in analyst forecast of annual earnings for U.S. industries. Other regressors included, but not reported are country dummies, industry dummies and year dummies. Heteroskedasticity-consistent standard errors are reported in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

TABLE 5

The Marginal Impacts of Financial Architecture and Property Rights Protection on the Rate of Technological Innovation of Industries that vary in Intangible Intensity

	1	2	3	4	5	6
Share of Industry Value Added to Manufacturing	0.067^{***} (0.0036)	0.067^{***} (0.003)	0.072^{***} (0.004)	0.068^{***} (0.004)	0.068^{***} (0.0036)	0.0680^{***} (0.0036)
Intangible Intensity*Financial Architecture	-0.0042^{***} (0.0008)	-0.0050^{***} (0.0008	-0.0041^{***} (0.0008)	-0.0047^{***} (0.0008)	-0.0042^{***} (0.0009)	-0.0043^{***} (0.0008)
Intangible Intensity*Property Rights ICRG	0.0004 (0.0004)					
Intangible Intensity*Property Freedom		0.0036^{***} (0.0010)				
Intangible Intensity*Intellectual Property			0.0016 (0.0012)			
Intangible Intensity*Patent Rights				0.0022^{**} (0.0009)		
Intangible Intensity*WEF					0.0009 (0.0009)	
Intangible Intensity*Intellectual WEF						0.0014^{**} (0.0006)
R^2	0.7588	0.7603	0.7420	0.7596	0.7599	0.7603
N	1882	1882	1807	1882	1875	1875
Countries	34	34	34	34	34	34

The dependent variable in all regression is the rate of technological progress for each industrial sector in each country. Financial architecture is a continuous variable that measures the degree of market orientation of a financial system and is a principal component of the size, activity, efficiency dimensions of financial architecture. Intangible Intensity is the ratio of intangible assets to net fixed assets to net fixed assets of U.S industries. Share of industry value added to Manufacturing is calculated by dividing the real value added of the industry in the country by the total real value added of the manufacturing sector of the country. Property Rights (ICRG) 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 from the International Country Risk Guide (ICRG). Property Freedom is a broad index of property rights from the Index of Economic Freedom, the Heritage Foundation. Intellectual Property is an index of protection of intellectual property rights from the Office of the U.S. Trade Representative. Patent rights are 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. Intellectual WEF is an index of intellectual property rights protection from the World Economic Forum Other regressors included, but not reported, are country, industry, and year dummies. Heteroskedasticity-consistent standard errors are reported in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

TABLE 6

The Differential Impacts of Financial Architecture on the Rate of Technological Innovation of Industries that vary in Intangible Intensity

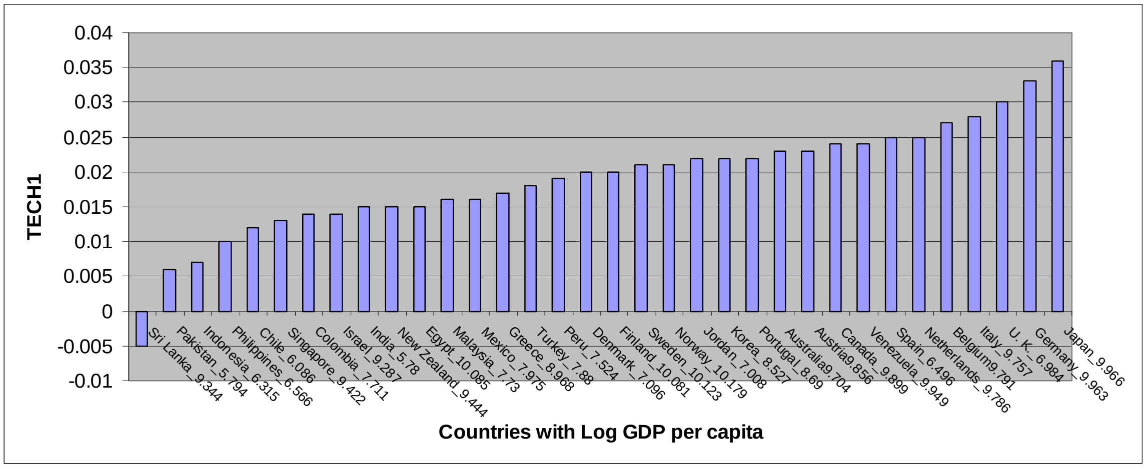
	1	2	3	4	5	6	7 (IV)
Share of Industry Value Added to Manufacturing	0.068*** (0.003)	0.067*** (0.003)	0.067*** (0.0035)	0.067*** (0.0036)	0.067*** (0.0036)	0.0068*** (0.0036)	-0.074*** (0.004)
Intangible Intensity * Financial Architecture	-0.0038*** (0.0008)	-0.0050*** (0.0011)	-0.0050*** (0.0008)	-0.0027*** (0.0008)	-0.0045*** (0.0008)	-0.0050*** (0.0008)	-0.0791*** (0.0147)
Intangible Intensity*Bank Development	0.0065*** (0.0019)						
Intangible Intensity*Financial Development		0.0014 (0.0011)					
Intangible Intensity*Human Capital			0.0010*** (0.0003)				
US Growth in Sales*Financial Architecture				-0.0589*** (0.0011)			
External Dependence*Financial Architecture					-0.0007 (0.0006)		
Intangible Intensity*Per Capita GDP						0.0027*** (0.0006)	
R^2	0.7604	0.7589	0.7598	0.7623	0.7663	0.7612	0.7477
N	1858	1882	1882	1882	1882	1882	1676
Countries	34	34	34	34	34	34	34

The dependent variable in all regression is the rate of technological progress for each industrial sector in each country. Share of industry value added to Manufacturing is calculated by dividing the real value added of the industry in the country by the total real value added of the manufacturing sector of the country. Financial architecture is a continuous variable that measures the degree of market orientation of a financial system and is a principal component of the size, activity, efficiency dimensions of financial architecture. Intangible Intensity is the ratio of intangible assets to net fixed assets to net fixed assets of U.S industries. 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. Other regressors included, but not reported are country dummies, industry dummies and year dummies. Heteroskedasticity-consistent standard errors are reported in parenthesis. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

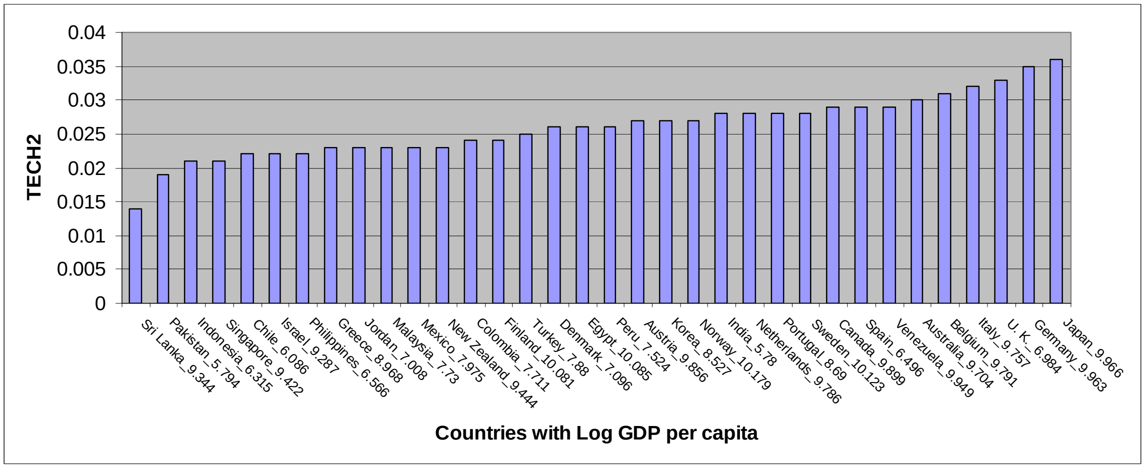
FIGURE 1

Rates of Technological Innovation across Countries

(a) *Technological Innovation based on Stochastic Production Frontier* ($\nabla TECH1$)



(b) *Technological Innovation based on Stochastic Cost Frontier* ($\nabla TECH2$)



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