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Financial Systems, Innovation and Economic Performance

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FINANCIAL SYSTEMS, INNOVATION AND ECONOMIC PERFORMANCE

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Abstract:

There is growing evidence of international divergence in the performance of new industries. While the United States is at the forefront of the recent revolution in information technologies, European economists and policy makers are concerned that Europe is falling behind with negative implications for long-term economic performance. This paper investigates the role of financial systems as a crucial determinant of apparent differences in national abilities to promote innovative activities in specific sectors. Firstly, a short overview of the relevant finance and innovation literature is provided, and a synthetic view of the finance-innovation link is sketched. It is argued that national financial systems have an impact on the *structure of growth* through their differing abilities to promote innovation in sector-specific technology regimes. Secondly, I apply a simple econometric model to a data set consisting of 17 OECD countries and 20 manufacturing industries to identify empirical patterns. The evidence suggests that sectors characterized by high technological opportunity and a focus on product innovation perform relatively better in financial systems with large stock markets, competitive banking sectors and good accounting standards. In contrast, the performance of sectors geared towards innovation in processes benefits from a more bank-oriented financial system and concentrated ownership structures.

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1. Introduction

During the 1990s the United States economy has positioned itself at the forefront of recent revolutions in information technologies. According to some observers, the USA is the originating country of the "e-conomy," an economy characterized by the rapid development and diffusion of electronics-based information technologies (DeLong et al., 2000). In contrast, there is a growing concern among European economists and policy makers that Europe is falling behind in the development of these types of industries with negative implications for long-term economic performance (Fagerberg et al., 1999). In spite of these apparent differences in national abilities to support specific industries, economic theory lacks explanations for international diversity. Differences in institutional infrastructure across countries can reasonably be expected to affect national innovation capabilities. In one recent contribution, institutions are identified as "standard social technologies" that complement physical technologies (Nelson and Sampat, 2001). In this view, diverging success in the innovation performance of particular countries and/or sectors may result from varying degrees of compatibility between physical and social technologies. One likely reason for the financial system to constitute a crucial element of standard social technologies is that it funds innovative projects before they reach the stage of generating products that can be evaluated and selected through competition in product markets. American economist Hal Varian, for example, attributes United States success in new industries to the unique ability to "finance crazy ideas" (New York Times, December 14, 2000). Similarly, Schumpeter identifies finance and financial institutions as crucial determinants of the entrepreneurial ability to develop new "combinations."

What is required is an approach that incorporates differences in national financial institutions as they affect countries' abilities to promote innovative activities and thus economic performance. However, the New Growth Theory understands innovation merely as a function of capital, labor and knowledge inputs while the institutional environment is assumed to be universal across countries. While there is a growing literature on the relationship between finance and growth (Levine, 1997; Tsuru, 2000), finance is modeled to promote growth essentially through an efficient allocation of capital and no attempt is made to analyze how finance affects growth through its impact on innovation. Finally, the national system of innovation approach (Nelson, ed., 1993) though emphasizing differences in national institutional settings has little to say about how a country's financial system affects the speed and character of technical change.

Following a short overview of the relevant finance and innovation literature this paper will provide a synthetic view of the finance-innovation link. It will be argued that national financial systems have an impact on economic performance through their differing abilities to promote sector-specific types of innovative activity. Financial institutions evolve predominantly at the national level of the economy but innovation processes are firmly embedded in sectoral technology regimes. The institutional framework might therefore be compatible with the requirements of firms in some but not all industries. National financial institutions are thus hypothesized to affect the structure of economic development. It will be argued that national financial arrangements have an impact on sectoral innovation capabilities beyond the provision of funds. A large and liquid stock market, for example, contributes little net financing to industry, but instead constitutes a sophisticated device for flexibility in the allocation of ownership and control. This in turn might greatly enhance companies' abilities to pursue

innovative ventures characterized by rapid change in technology and management practices. In contrast, tight ownership structures characteristic of insider systems might be better at providing the long-term horizon and stakeholder commitment required for innovation processes distinguished by their organizational complexity and reliance on company-specific knowledge inputs.

In order to identify empirical patterns in the relationship between financial system and innovation, I apply a simple econometric model to a data set consisting of 17 OECD countries and 20 manufacturing industries. Specifically, this study considers the role of complementarities between sectoral technology regimes and national institutional frameworks in promoting industry performance. It contributes to the literature by reformulating previous attempts to find empirical links between financial systems and sectoral performance through specifically focusing on innovation activities. It also allows for the exploration of financial system effects on performance through channels other than financial allocation. The findings suggest that sectors characterized by high technological opportunity and a focus on product innovation perform *relatively* better in financial systems with large stock markets, competitive banking sectors and good accounting standards. In contrast, the performance of sectors geared towards process innovation benefits from insider systems characterized by bank orientation and concentrated ownership structures.

2. Theory: Linking financial systems and innovation

The literature on the economics of innovation has made great progress in providing a comprehensive analysis of the process of innovation and the conditions required for its success.

A host of theoretical and empirical contributions have described innovation as the result of a complex organizational process of knowledge accumulation (Freeman and Soete, 1997; Tushman and Rosenkopf, 1992). Firstly, innovation is inherently uncertain because hurdles have to be constantly overcome along the way that cannot be known *ex ante*. For example, uncertainty arises out of the irreversibility of invested resources while the level and timing of future returns is unknown. Similarly, there is little information about the amount of resources needed to successfully complete a project and the risks of failure. The ability to experiment in trial-and-error processes is therefore an important element of a successful system of innovation. Hence, the financial system must be setup as "to allow for the possibility of rather numerous gambles on unexplored opportunities, about which little is known *ex ante*, but which can reasonably expected to be, on average, failures" (Dosi, 1990).

Recent contributions to the financial systems literature are also compatible with the uncertainty dimension of innovation. In general, a number of imperfections such as asymmetric information or incomplete contracts are identified, which open up possibilities for different financial systems incorporating markets and other institutions. This body of literature has convincingly shown that financial systems including ownership structures and corporate governance systems differ markedly across countries (Allen and Gale, 2000). With respect to the difference between bank-based *versus* market-based financial systems, they argue that stock markets are superior to banks in promoting sectors characterized by high technology and management risk. Innovative industries are characterized by sparse information and high levels of uncertainty compared to established sectors operating with known technologies. In this situation, "rational" disagreement about what the best projects are with respect to technology and/or management strategy is likely

to be present. Market-based systems populated by a multitude of investors are good at handling the resulting "diversity of opinion" and consequently, these sectors can grow faster by raising the number of innovative projects financed. By keeping a larger number of projects afloat, liquid stock markets thus raise the chances of the best (*ex post*) projects to survive.

In Huang and Xu's (2000) model the focus is on the character of the banking system. Multi-bank systems prefer to end projects that need additional financing due to conflicts over information sharing. Such a system enforces a hard-budget constraint. In a sector with high uncertainty about future earnings and therefore a high number of bad projects (*ex post*) this commitment to terminate is valuable because it motivates investors to supply funds. In contrast, in activities that are characterized by low uncertainty and imitative R&D projects, concentrated banking systems are likely to have collected more project-specific information with which to make *ex ante* investment decisions. Petersen and Rajan (1994) also investigate the effects of banking sector concentration on innovative, entrepreneurial firms but arrive at opposite conclusions. They provide a model and empirical evidence for the United States that a highly concentrated banking sector allows for the inter-temporal sharing of surplus between firm and creditor. Hence, in their model, concentrated banking sectors should enhance the growth of new sectors because they guarantee low-cost funding in the early stages of a firm's development.

The new finance view is an advance over traditional approaches because it assigns a role for both markets and institutions and can therefore account for the persistence and success of different national systems. Furthermore, it is able to link this more realistic view of financial structure to economic activities that are characterized by uncertainty going beyond the assumption of perfect

foresight in traditional economic theory. One shortcoming of this literature is the implicit idea that finance is allocated to specific projects, but in practice the majority of funds are given to companies, which in turn allocate resources to specific projects or divisions internally. The management literature therefore distinguishes between external and internal capital markets in understanding different institutional arrangements across countries (Porter, 1992). Furthermore, the exclusive focus on the different mechanisms to allocate financial resources for investment might be misleading because empirically the financing of investment does not differ significantly across national systems (Mayer, 1988). In fact, the major share of investment finance in developed economies is generated by own funds rather than raised externally (Corbett and Jenkinson, 1996). Similarly, Carpenter and Lazonick (2001) find that, even in such a rapidly developing sector as the optical network industry, investment is rarely financed by funds raised on the stock market.[i] Finally and most importantly, the process of innovation itself remains largely a black box unaffected by the institutional framework. Innovation seems to result from individual bursts of creativity, which are only subsequently evaluated and financed by the financial system but not affected by it.

In contrast, the innovation literature has developed a more realistic analysis of the process of innovation. Rather than being conducted by individuals acting in isolation most new technologies are developed and applied by complex organizations involving different groups of people (Tushman and Rosenkopf, 1992; Storper, 1996). Hence, innovation is best described as a complex learning process, which is cumulative and collective. Understanding this complex process requires a detailed knowledge of the business firm because it is the organization undertaking the majority of innovations (Chandler, 1990). The way individuals or departments

within a firm interact determines the way knowledge is generated, transformed and diffused. A number of tacit and changing organizational capabilities cannot be assigned to individual contributors but are the result of collective procedures within the firm. The focus here is on the process of learning and the behavior guiding participation in innovation rather than on allocating scarce resources to a set of projects differentiated by their level of uncertainty.

Mayer's (1996) work on the financial systems and corporate governance literature best highlights the links between financial system and organizational processes within the firm. He focuses on differences in ownership structures across countries, which are likely to provide incentives and disincentives for stakeholders to participate and commit in complex production processes. His model could thus be extended to include the organizational view of innovation, because he implicitly assumes that the character of the financial system influences the incentives of participants in work processes taking place within the firm. For example, production activities that require a high company-specific level of irreversible investment by stakeholders, like workers or specialized suppliers, benefit from concentrated ownership patterns in insider-dominated financial systems because these encourage and reward long-term commitment. Similarly, stakeholder commitment is also likely to be beneficial in collective learning processes dependent on the accumulation of company-specific knowledge. Without this commitment the efforts of groups of individuals jointly working on innovation projects can be disrupted. However, in activities where rapid technological change necessarily imposes costs on stakeholders, mutual commitments would slow down the necessary process of organizational change. Hence, these activities are likely to benefit from liquid, dispersed ownership in markets for corporate control found in outsider systems (see also Porter, 1992).

In addition to stakeholder commitment, financial systems are likely to affect patterns of information allocation among organizational participants within the firm (Aoki, 1998; Aoki and Dosi, 1992; Porter, 1992). Porter (1992) notes that American companies have increasingly moved toward a form of decentralization involving highly autonomous business units and limited information flows. Decision making by top managers is thus constrained to simple financial indicators that are easily gathered, but more detailed information on production and technological basis are isolated within the individual unit. He attributes this organizational setup to the demands of stock markets and institutional investors in the United States for easily identifiable financial returns and finance-based investment evaluations. In contrast, in the insider-oriented systems of Japan and Germany, decisions are driven by the goal to secure and advance the company's long-term competitive position in the market. Information related to overall performance flows freely between units and financial criteria are less important for decision-making.

Furthermore, large stock markets represent a flexible re-organization tool through facilitating corporate ownership changes and mergers, enabling companies in new industries to quickly adjust to new market conditions or technological developments.[ii] In this view, the stock market allocates ownership and control over technologies rather than investment funds. In addition, stock markets might help to provide crucial incentives for investors or employees in new companies to supply resources. Many employees of Internet startups, for example, accepted low current salaries in return for company stock options because of the potentially large payoffs from a successful IPO during the 1990s stock market boom.[iii] The potential magnitude of returns

through issuing stock is also a crucial motivation for the provision of venture capital. This might help explain why market-oriented countries also feature high levels of venture capital (Black and Gilson, 1998). These examples depict the financial sector as an integral part of a nation's system of innovation and not just a "detached" project evaluator and selector. Rather than focus solely on the role of banks *versus* markets or the nature of the banking system, this view also emphasizes the systemic, complementary nature of the institutional framework including the role of corporate structure and governance.

In addition to uncertainty and organizational complexity, innovation has also been found to develop along specific trajectories or technology regimes (Nelson and Winter, 1982; Winter, 1984; Dosi, 1982; Pavitt, 1984). In an early formulation, Nelson and Winter (1982) distinguish between a science-based and a cumulative technology regime. The former is characterized by intense, largely external, R&D activity resulting in a fairly broad and universal knowledge base. The latter's knowledge base, in contrast, is rather narrow and develops along a cumulative trajectory within the firm. The character of the knowledge base has been used to analyze differences in sectoral patterns of innovation and industrial competition. The science-based regime is associated with a creative destruction or entrepreneurial pattern characterized by the entry of new firms. In contrast, cumulativeness in the knowledge base is related to a sectoral regime of creative accumulation that favors the accumulation of knowledge within established firms that have innovated before. Similarly, Breschi, Malerba and Orsenigo (2000) propose that the way innovative activities are organized can be explained as the outcome of different learning regimes implied by the nature of technology in a specific sector of the economy. Specifically, a technology regime is defined by the combination of technological opportunities, the

appropriability of innovations, the cumulativeness of knowledge and the character of the knowledge base. The empirical evidence across countries shows that the organizational process of innovation is largely determined by technology-related rather than by country-related characteristics.

While the notion of technology regimes has been used frequently in empirical studies of industry structure in the industrial organization literature, there is little focus on how national institutional environments might affect the innovation performance of firms operating within specific technology regimes. Related to the previous theoretical discussion, one might expect that science-based, entrepreneurial regimes benefit from market-based financial systems which provide venture capital and the ability to attract talent with lucrative stock options. Furthermore, differences in financial systems could promote or constrain avenues of organizational learning. Dosi (1990), for example, argues that bank-oriented systems encourage cumulative firm learning within established paradigms. Process innovation, which requires tacit and company-specific knowledge, falls into this category. In contrast, market-based systems are likely to be superior at allowing highly uncertain experiments on new technological paradigms characterized by pervasive innovative opportunities. Such an environment is likely to be found in emerging sectors dominated by rapid advances in product innovation.

In conclusion, different financial and corporate governance systems can be hypothesized to affect innovation by offering varying degrees of financial and organizational support to different learning regimes that are inherent in the nature of sectoral technology. In addition to the allocation of funds the "coherence of physical and social technologies", to use Nelson and

Sampat's (2001) terminology, is a major determinant of companies' organizational ability to innovate and compete and thus affects the long-run rate of growth and export competitiveness of individual sectors.

3. Methodology

In the literature we find a limited number of attempts to provide empirical evidence on the relationship between financial systems, innovation and performance. For example, Allen (1993) notes that a number of new industries such as railways, automobiles, aircraft, consumer durables, computer, and biotechnology were developed in the stock market-based systems of the United Kingdom and the United States. This lends casual empirical support to some of the above-mentioned models in the new finance literature. But this simplistic correlation does neither take into account the considerable historical changes in financial structures around the world nor does it pay attention to the evolution of the nature of innovation from relatively simple textile manufacturing to complex science-based biotechnology.

Another attempt is Guerrieri and Tylecote's (1997) cross-country investigation, which is based on the assumption that in order to succeed in innovation a particular sector requires a good match of the sector's organizational requirements with nation-wide institutional characteristics. The financial system is identified as a crucial component of the national institutional infrastructure. However, the authors only divide their country sample into bank-based and market-based system of finance and subsequently analyze whether a particular country has a revealed comparative advantage in those activities that are likely to benefit from its institutional infrastructure. While

similar in spirit to this paper their results might be driven by a number of other country-specific factors that their empirical method used is not able to exclude.

Recently, Carlin and Mayer (1999) provided a systematic empirical test of the relationship between financial system characteristics and sectoral growth patterns for 14 OECD countries, extending an empirical methodology first introduced by Rajan and Zingales (1998). While not investigating innovation per se, they find that country financial structures affect sectoral patterns of R&D investment. In contrast, Beck and Levine (2001) applying a similar methodology to a larger sample of countries conclude that financial system characteristics have no impact on growth in sectors characterized by varying shares of R&D investment. Their findings indicate that rather than financial structure, it is the overall level of development of the financial system—markets and intermediaries—which is positively associated with growth in R&D intensive activities. One reason for the apparently contradictory nature of these results is that while Carlin and Mayer utilize R&D investment shares as the dependent variable, Beck and Levine take U.S. data to compute sectoral R&D characteristics as part of the explanatory variable set. In addition, both empirical methodologies focus solely on the allocative properties of financial system. This study avoids this potential problem by using measures of sectoral technology regimes instead of R&D investment shares to characterize the nature of innovative activity in an industry.

In summary, while the theoretical literature on innovation and finance identifies a number of different channels through which the financial system influences sector-specific innovation thereby promoting growth, there is little systematic and often contradictory evidence to evaluate

the different analytical models proposed. This paper provides a systematic empirical investigation for a broad number of industrialized economies. It attempts to answer the question of what types of financial systems are better suited in promoting what types of technical change at the sector level of the economy. Specifically, the paper develops an econometric model that will allow us to identify empirical regularities on how countries' financial systems (FS) interact with sectoral technology regimes (TR) in determining their prospects for growth and competitiveness (P). The analysis will apply the following simple econometric specification to a sample of 20 manufacturing sectors in 17 OECD countries (Rajan and Zingales, 1998):

$$(1) \qquad P_{i,j} = \alpha_{i,j} + \beta_{i,j} (FS_i * TR_j) + \varepsilon_{i,j} .$$

Specifically, I use two dependent performance variables (P): The demeaned average annual growth rate of value added and an index of revealed comparative advantage. The former measures growth in industry i in country j controlling for the average growth of industry i in all OECD countries in the sample and the average growth of total manufacturing value added in country j. Similarly, export performance is represented by the export share in sector i in country j (controlling for the average export share of industry i in all OECD countries in the sample) and the average export share of manufacturing in country j.

The financial structure variable (FS) quantifies the diversity in the size and character of national financial systems. This includes indicators for the size of stock markets or banks, accounting standards and ownership concentration. All of these measures are demeaned by their respective OECD averages. Lastly, technology characteristics measure the type of innovation regime in the

20 manufacturing sectors included in the analysis (demeaned by the manufacturing average). To find patterns of the interaction of national financial systems and industry characteristics for the promotion of growth and competitiveness, it is crucial to identify industry characteristics (assumed to be constant across countries) separately from the countries in which they are located. This condition will be discussed in detail in section 4(c).

In order to focus solely on the interaction of industry and country characteristics in driving economic performance, other determinants of sector performance need to be held constant. I control for fixed industry and country effects by "demeaning" the dependent and independent variables (instead of introducing country and industry dummies). While this procedure does not completely eliminate the potential omitted variable bias, it allows me to have more confidence in the results. Furthermore, the regressions using growth as the dependent variable also include the sector's output share in total manufacturing at the beginning of the period to account for the convergence effect (Carlin and Mayer, 1999). The underlying hypothesis is therefore that the long-run economic performance of the sector is determined by the ability to generate continuous technical change (Nelson, 1998). In turn, this ability is a function of the coherence of the national financial institutions (standard social technologies) and the technology regime in a sector (physical technologies). Estimated β-coefficients give us an indication of the patterns of interactions between financial structure measures and innovation characteristics in stimulating growth and competitiveness.

While this methodology can be used to relate industry performance to the compatibility of financial institutional structure and industry technology regime, the results do not lend

themselves to make statements about the overall performance of different countries. The analysis provides an evaluation of whether the compatibility of country structure and industry characteristics is associated with the performance of particular sectors in particular countries *relative* to the average performance in those industries and countries. In other words, this paper attempts to contribute to an explanation of the industrial composition of exports and growth rather than their aggregate levels.

4. Data

Three types of data are needed to apply the previously developed model:

(a) Performance measures:

The data set includes sectoral growth rates of value added from the OECD STAN database for 20 manufacturing sectors at the three to four-digit ISIC level. The second dependent variable measures the international competitiveness of a sector using an index of revealed comparative advantage (RCA) also computed from the OECD STAN database for the same 20 manufacturing sectors. Details on the data set are provided in the appendix.

(b) Financial structure:

Financial structure indicators are available for 17 OECD countries taken from several sources (see appendix for details). Four variables measure the degree to which a country is market based or bank based. First, the ratio of assets of deposit money bank over GDP is used as a proxy for the role and influence of the banking sector (average for 1970-1997 in Beck et al., 2000). Second, stock market capitalization, i.e. the combined value of listed shares, over total national

output (GDP) averaged for the period 1975-1997 provides an indicator of the role of stock markets (Beck et al., 2000). Third, the relative dominance of markets vs. banks is represented by a structure index derived by computing the ratio of the two size measures mentioned above (Stock market capitalization/Bank assets). The higher the value of the index the greater the degree of market orientation.[iv] Fourth, the availability of company information can also be understood as an indicator of the role of financial markets in a national financial system. The wide availability of company financial data allows market participants to make informed decision and is, therefore, a crucial prerequisite for functioning stock markets.[v] It might also serve as a proxy for the relative power of financial actors vis-à-vis company managers.[vi] Following Rajan and Zingales (1998) I apply an index of accounting standards from a survey conducted by the Center of International Financial Analysis and Research in 1990.

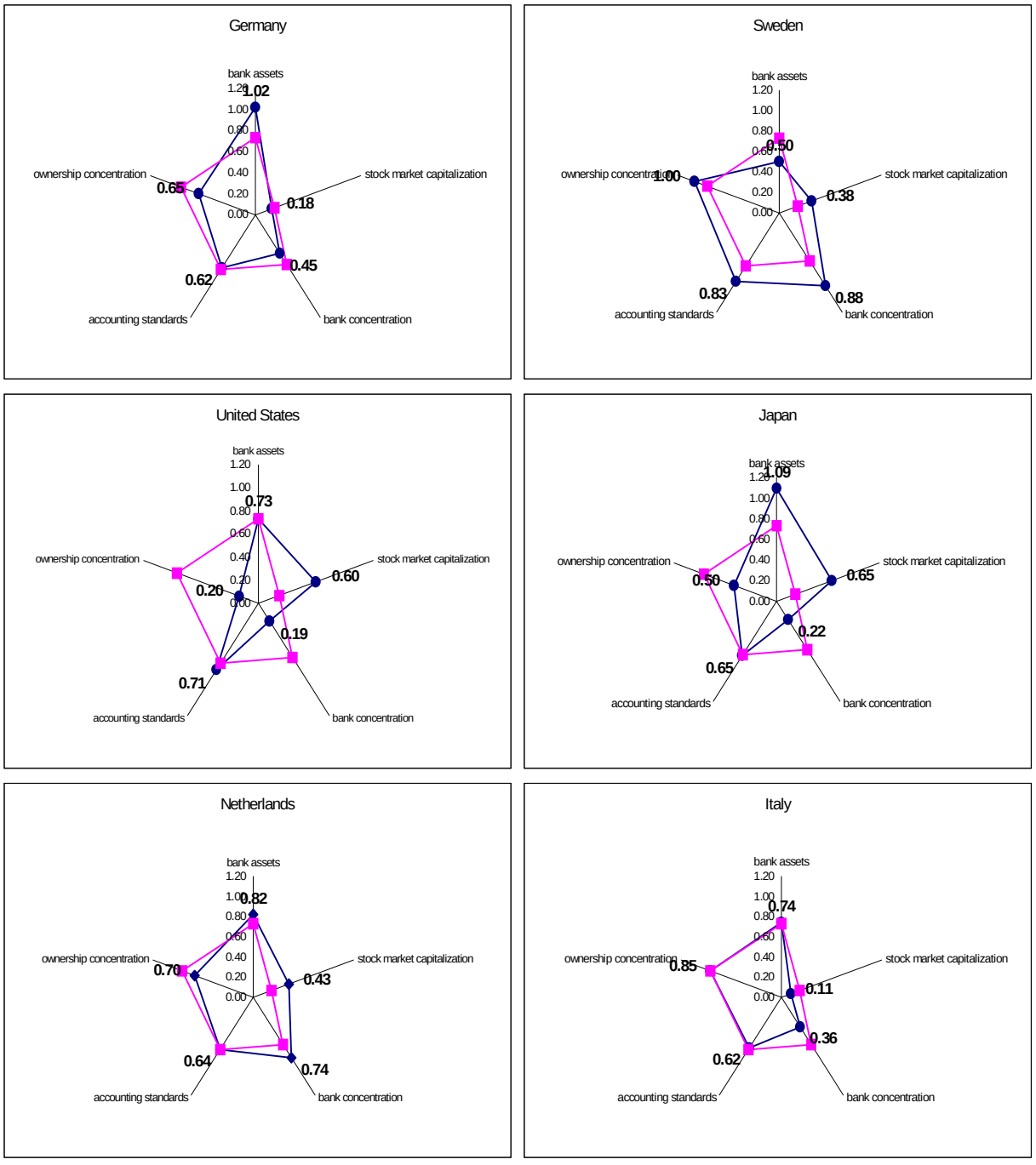
The ratio of the three largest banks' assets to total banking sector assets averaged for the period 1990-1997 (Levine et al., 2000) is used to account for the degree of competition among banks. This indicator allows us to distinguish single-bank vs. multi-bank systems. A further dimension emphazized in theoretical models is the nature of the corporate system. In this empirical analysis the concentration of ownership serves as a measure of stability vs. flexibility in ownership patterns. This indicator is computed as one minus the percentage of widely held of the largest 20 publicly traded companies in 1995 (La Porta et al., 1998). Note that all country structure variables used in the econometric estimations are normalized relative to the OECD average.

A problem might arise because data for some of the indicators is only available for the latter half of the period under investigation. Consistent data on accounting standards, for example, were

collected only since the early 1990s. However, accounting standards have been found to be rather stable over time. Rajan and Zingales (1998) compare available data for the early 1980s with 1990s survey results and find little difference, in particular when it comes to the quality of accounting standards relative to other countries. Similarly, the measures for bank and ownership concentration are also only available for the early 1990s, but it can be reasonably assumed that these characteristics are relatively stable over the period under investigation.

Figure 1 provides a graphical representation of a number of country profiles. The country profiles not only show that financial infrastructures differ markedly across countries, they also reveal that these national differences go beyond the simple bank-based/market-based dichotomy, which still dominates the literature. While Germany represents the typical bank-based system compared to the market-based structure in the United States, countries like Sweden and the Netherlands are not so easily classified. Sweden, for example, combines characteristics of a market-based system (high accounting standards and stock market capitalization) with high levels of bank and product market concentration usually associated with bank-based or insider systems. Japan, which is traditionally grouped with the bank-based countries, features a large stock market and levels of bank and ownership concentration more characteristic of a market-oriented system.

Figure 1: Country profiles of financial systems (relative to OECD median country)



Source: see appendix

Finally, one strand of the finance and growth literature maintains that it is the development of the financial sector *per se* that stimulates growth rather than its structure (Levine, 2000). The relationship between borrower and lender is characterized by a host of imperfections, which can be alleviated by sophisticated financial intermediaries as well as liquid stock markets. According to this view, the differences between Germany and the United States are of minor significance because both have a relatively high level of overall financial development; i.e. the combined value of stock market capitalization and banks assets as a share of GDP is roughly the same (120-130 percent of GDP). In contrast, a country like Italy has a relatively weak financial system as the total value of stock capitalization and bank assets only adds up to 85 percent of GDP. To control for this potential financial development effect, I compute an index consisting of the sum of bank assets and stock market capitalization as a ratio of GDP.

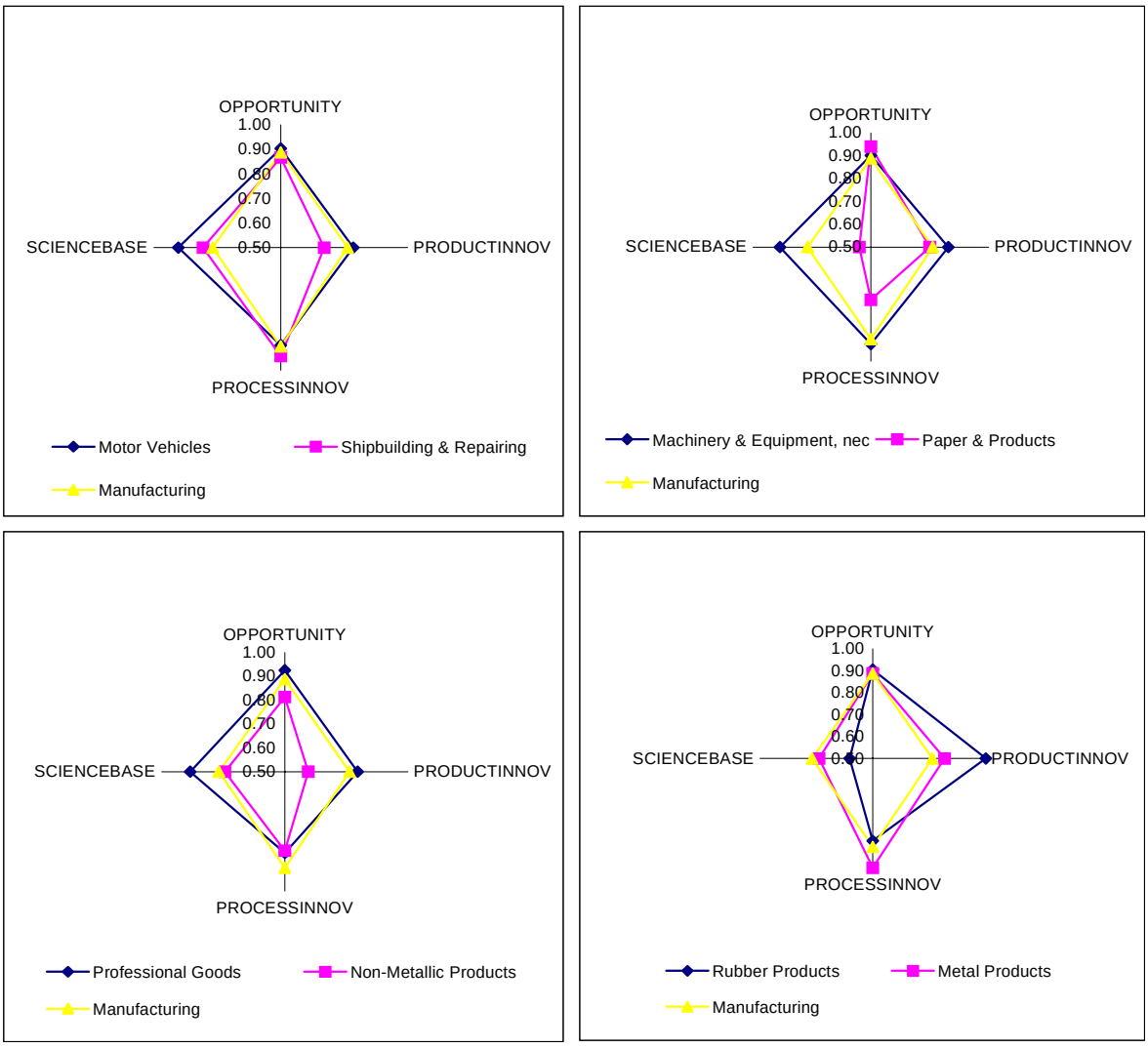
(c) Technology characteristics:

The construction of a set of sectoral measures of technology characteristics is crucial to the applicability of the empirical methodology suggested in this paper. In particular, in order for the interactive terms in equation (1) to measure the compatibility of financial structure and sectoral innovation requirements, the indicators for the nature of sectoral technology have to be independent of the national institutional environment. Empirical studies utilizing the technology regime framework found that the organization of innovative activities differs markedly across sectors, but is relatively stable across countries, which indicates that the differences are related to the inherent nature of technology but not country-specific factors. I therefore follow Breschi, Malerba and Orsenigo (2000) who use the PACE data to construct measures of the sectoral technology regime including technological opportunity and cumulativeness of technology.

Similarly, I construct four technology characteristics indicators for (i) technological opportunity, (ii) cumulativeness of product innovation, (iii) cumulativeness of process innovation, and (iv) degree to which a sector is based on scientific inputs. All four indicators are normalized relative to the total manufacturing average when used in the econometric tests presented below. The following provides a brief description of these four concepts (cf. the appendix for a more detailed explanation of how they were constructed).

First, technological opportunity reflects the intensity of innovative activity in a sector for a given level of resources invested. It is an indicator of the frequency and newness of potential technological innovations. Hence, in sectors with high opportunities it is legitimate to assume a high degree of diversity of opinion about what the best projects are. Following the model by Allen and Gale (2000) this indicator will allow us to investigate the informational requirements of sectoral environments. Second, the cumulativeness of technology refers to the fact that today's innovations are built upon the knowledge created by previous streams of innovations. High levels of cumulativeness are features of sectoral environments characterized by strong continuities in innovative activities. To measure cumulativeness I distinguish between product and process innovations. On the one hand, product innovation is associated with high levels of uncertainty and the accumulation of sector-specific rather than company-specific knowledge. On the other hand, the knowledge generated and accumulated through process innovation is likely to be of a more tacit, company-specific nature. Fourth, sectoral technology regimes are assumed to be different in terms of their dependence on scientific knowledge inputs. Innovative projects in science-based sectors can be assumed to be highly complex and have longer gestation periods. They can be hypothesized to thrive in environments with highly developed financial infrastructures, but the relation with the character of the financial system is less clear.

Figure 2: Sector profiles of technology regimes



Source: See appendix

Figure 2 depicts 8 manufacturing sectors based on these four dimensions and compares them with the manufacturing average. The upper left hand graph exhibits a relatively high-tech sector, motor vehicles, with a more low-tech sector, shipbuilding. Motor vehicles scores higher in all categories except process innovation. It seems reasonable to assume motor vehicle

production to be characterized by higher levels of opportunity, a greater bias towards product innovation and science-based inputs compared to shipbuilding. Comparing the professional goods sector with non-metallic products (lower left graph) generates a similar high-tech/ low-tech distinction. The lower right graph shows that rubber products and metal products are not distinguished so much by intensity of innovative activity as by the difference between product and process innovation. Table 1 summarizes some of the theoretical hypotheses that can be derived from combining the four measures of technological characteristic with the previously described indicators of financial structure.

5. Estimation results

I first report the estimation results relating the dependent variable growth or revealed comparative advantage to a single independent variable capturing the interaction between financial structure and technology characteristic. Table 2 shows the regression coefficients in matrix form divided into two panels: (a) growth regressions and (b) export regressions. First, there are more significant coefficients on the interactive terms when growth is the dependent variable compared to the export equation in panel (b). In particular, the intensity of product innovation in a sector interacts with a number of financial structure variables in determining growth of value added. As hypothesized by some of the theoretical models presented in table 1, all three stock market indicators interact positively with the measure of product innovation. In contrast, the level of bank concentration as well as ownership concentration has a negative and significant effect on growth in sectors characterized by higher levels of cumulativeness in new product development. Developed stock markets also have positive effects on relative growth

Table 1: Financial systems and technology regimes--Hypotheses

TECHNOLOGY FINANCE STRUCTURE	Opportunity	Intensity of product innovation	Intensity of process innovation	Degree of science base
BANKS:				
Bank assets				
Bank concentration		(--) Huang/Xu (2000) multi-bank systems better at enforcing hard-budget constraints in sectors with high number of bad projects (ex post)		
STOCK MARKETS:				
Stock market capitalization	(+) Allen/Gale (2000) stock markets better at dealing with diversity of opinion	(+) Allen/Gale (2000) stock markets better at dealing with diversity of opinion		
Accounting standards	(+) Allen/Gale (2000) stock markets better at dealing with diversity of opinion	(+) Allen/Gale (2000) stock markets better at dealing with diversity of opinion	(--) Porter (1992) disclosure requirements can lead to underproduction of company-specific knowledge—dominance of financial indicators	
Market orientation (Stock market cap./ bank assets)	(+) Porter (1992) market-oriented systems can quickly reallocate resources in rapidly changing environments			
CORPORATE SYSTEM:				
Ownership concentration Insider/outsider system	(--) Mayer (1996) outsider systems better at reorganization even with costs for some stakeholders		(+) Mayer (1996) insider systems provide incentives for long-term commitment of stakeholders	
DEVELOPMENT:				
Financial development (bank assets + stock market cap.)	(+) Levine (1997) Banks and markets provide complementary services to overcome market imperfections—structure does not matter	(+) Levine (1997) Banks and markets provide complementary services to overcome market imperfections—structure does not matter	(+) Levine (1997) Banks and markets provide complementary services to overcome market imperfections—structure does not matter	(+) Levine (1997) Banks and markets provide complementary services to overcome market imperfections—structure does not matter

Notes: (--), (+) indicate hypothesized sign on β-coefficients

performance in high opportunity and science-based sectors although the size of the coefficient and significance levels are smaller compared to the regressions using product innovation as technology characteristic. There appears to be no interaction between financial system and growth in process innovation-oriented sectors as stipulated by the innovation literature and Mayer (1996).

In general, export competitiveness seems to be less affected by complementarities between technology characteristic and financial institutions. As in the growth regressions accounting standards again interact positively with technological opportunity in promoting export success. In contrast, the product innovation variable has no significant interactions with measures of corporate and financial structure. As hypothesized by Porter (1992) the negative and significant coefficient on the interactive variable of accounting standards and process innovation indicates that information availability is detrimental to the relative export performance of process-oriented sectors. The last column shows a number of significant interactions of our institutional measures with science-based sectors. Bank and ownership concentration are associated negatively with export performance in sectors with high science inputs. The positive coefficients on bank assets and stock capitalization in combination with a positive and significant coefficient on financial development indicate that development of the financial sector might be more important than its structure in supporting science-based production activities.

The findings of the multivariate growth regressions are presented in table 3. It reports results for estimation results when different time periods and variable specifications are used.[vii] The coefficients measuring the role of the banking sector's interaction with technology characteristics

Table 2: Financial structure, sectoral innovation and performance—Simple regression results

(a) dependent variable is sectoral growth rate for the period 1970-1997

		SECTORAL INNOVATION CHARACTERISTICS		
FINANCIAL STRUCTURE	opportunity	product innovation	process innovation	science based
Banks				
bank assets	-0.005 (-0.77)	0.002 (0.13)	-0.03 (-1.54)	0.002 (0.71)
bank concentration	-0.005 (-0.85)	**-0.28** (-2.47)**	0.003 (0.2)	0.002 (0.94)
Stock market				
stock market capitalization	0.008 (1.38)	**0.032*** (2.74)**	0.009 (0.52)	0.003 (1.15)
accounting standards	**0.021* (1.85)**	**0.07*** (2.97)**	0.024 (0.71)	**0.008* (1.7)**
Financial structure				
size index	**0.007* (1.75)**	**0.021*** (2.73)**	0.015 (1.23)	0.001 (0.79)
Corporate structure				
ownership concentration	-0.003 (-0.58)	**-0.17* (1.9)**	-0.008 (-0.57)	-0.0007 (-0.43)
Financial development				
size index	0.002 (0.42)	**0.02** (1.95)**	-0.008 (-0.67)	0.002 (1.29)

regression includes constant term and initial sector share (not reported)

(b) dependent variable is Index of Revealed Comparative Advantage 1975-1997

		SECTORAL INNOVATION CHARACTERISTICS		
FINANCIAL STRUCTURE	opportunity	product innovation	process innovation	science based
Banks				
bank assets	0.001 (0.074)	0.034 (1.28)	0.013 (0.31)	**0.013** (2.49)**
bank concentration	0.007 (0.549)	-0.039 (-1.6)	-0.05 (-1.23)	**-0.016*** (-3.48)**
Stock market				
stock market capitalization	0.0095 (0.72)	0.02 (0.75)	-0.031 (-0.79)	**0.01** (2.1)**
accounting standards	**0.05** (1.95)**	-0.02 (-0.44)	**-0.186** (-2.48)**	-0.00 (-0.001)
Financial structure				
size index	0.008 (0.90)	0.006 (0.36)	-0.032 (-1.20)	0.0036 (1.06)
Corporate structure				
ownership concentration	-0.0021 (-0.121)	-0.023 (-1.17)	0.01 (0.35)	**-0.009** (-2.42)**
Financial development				
size index	0.005 (0.55)	0.024 (1.38)	-0.009 (-0.33)	**0.011*** (3.17)**

regression includes constant term (not reported)
financial structure variables are averages for 1970s-1997
(*) indicates 10%-significance level
(**) indicates 5%-significance level
(***) indicates 1%-significance level
17 OECD countries, 20 manufacturing sectors

are presented in the top section of the table. There appears to be a strong negative effect of higher bank concentration on growth in sectors with emphasis on product innovation. This result is robust across different time periods and alternative specifications. Interestingly, there is a positive and significant sign on the interactive term (process innovation*bank concentration) for the period of the 1970s.

The following section in the table looks at the role of the stock market using accounting standards, market orientation index and stock market capitalization as financial systems variables. Similar to the results of the bivariate correlations, accounting standards as a measure of market orientation interact significantly with three of the four technology variables. Specifically, high levels of accounting standards are positively associated with growth in product innovation and science-based sectors. The coefficients in the high opportunity sectors though always positive are only significant in the period of the 1980s. However, the interaction of information availability and process innovation correlates negatively and significantly with growth of value added. These results are robust across different time periods as well as when a measure of overall financial development is included (columns 4 and 5). The structure index measuring the degree of market orientation of the financial system is used as an alternative stock market variable in two specifications (columns 6 and 7). Here the results indicate a positive effect of more market orientation in promoting growth in sectors based on cumulativeness in product innovations. In sum, our results indicate that the size and influence of the stock market has a positive effect on the relative performance of sectors characterized by high opportunity, product innovation and scientific base. In contrast, sectors in which technical change relies on process innovation seem to fare better in more bank-oriented financial systems.

Table 3: Financial structure, sectoral innovation characteristics and growth—Multivariate regressions

growth (period)	(1970-97)	(1980-90)	(1970-80)	(1970-97)	(1970-80)	(1970-97)	(1970-97)	(1970-97)
Initial output share	**-0.174**	**-0.132**	**-0.253**	**-0.179**	**-0.257**	**-0.171**	**-0.168**	**-0.167**
	-(3.86)	**-(2.11)**	**-(3.42)**	**-(3.97)**	**-(3.48)**	**-(3.78)**	**-(3.71)**	**-(3.66)**
Banking sector	Bank concentration							Bank assets
* opportunity	-0.004	-0.001	**-0.029**	-0.004	-0.025	-0.005		-0.004
	-(0.43)	-(0.09)	**-(1.91)**	-(0.39)	-(1.53)	-(0.48)		-(0.50)
* product innovation	**-0.070**	**-0.057**	**-0.083**	**-0.061**	**-0.091**	**-0.049**		0.017
	-(3.63)	**-(2.18)**	**-(2.61)**	**-(3.02)**	**-(2.73)**	**-(2.37)**		(1.12)
* process innovation	0.042	0.020	**0.103**	0.023	**0.085**	0.006		**-0.040**
	(1.59)	(0.56)	**(2.40)**	(0.85)	**(1.90)**	(0.21)		**-(1.95)**
* science base	-0.003	0.001	**-0.009**	0.000	-0.006	0.003		0.003
	-(0.83)	(0.29)	**-(1.75)**	(0.10)	-(1.01)	(0.85)		(1.31)
Stock market	Accounting standards					Structure index		Capitalization
* opportunity	0.020	**0.038**	0.028	0.020	0.027	0.011	0.009	0.013
	(1.15)	**(1.64)**	(1.01)	(1.15)	(0.96)	(1.31)	(1.25)	(0.98)
* product innovation	**0.144**	**0.115**	**0.179**	**0.140**	**0.181**	**0.048**	**0.026**	**0.061**
	(4.06)	**(2.40)**	**(3.09)**	**(3.99)**	**(3.14)**	**(2.83)**	**(1.80)**	**(2.28)**
* process innovation	**-0.082**	**-0.107**	**-0.140**	**-0.076**	**-0.135**	-0.010	-0.007	-0.053
	-(1.72)	**-(1.66)**	**-(1.79)**	**-(1.63)**	**-(1.74)**	-(0.42)	-(0.36)	-(1.46)
* science base	**0.016**	**0.016**	**0.020**	**0.015**	**0.019**	0.003	**0.005**	**0.012**
	(2.66)	**(1.93)**	**(2.07)**	**(2.53)**	**(1.98)**	(1.03)	**(1.91)**	**(2.62)**
Corporate structure	Ownership concentration							
* opportunity	0.006	0.007	0.016	0.006	0.022	0.013	0.010	0.009
	(0.78)	(0.66)	(1.26)	(0.69)	(1.53)	(1.08)	(0.97)	(0.90)
* product innovation	**0.031**	0.009	**0.063**	**0.041**	**0.050**	**0.057**	0.025	0.020
	(1.92)	(0.39)	**(2.36)**	**(2.25)**	**(1.69)**	**(2.31)**	(1.20)	(0.98)
* process innovation	-0.027	-0.027	**-0.064**	**-0.050**	**-0.087**	-0.041	-0.038	-0.037
	-(1.23)	-(0.89)	**-(1.77)**	**-(2.02)**	**-(2.14)**	-(1.22)	-(1.33)	-(1.32)
* science base	0.002	0.001	0.004	**0.005**	0.007	0.004	**0.007**	**0.006**
	(0.64)	(0.27)	(0.78)	**(1.72)**	(1.50)	(1.06)	**(1.91)**	**(1.79)**
Financial development								
* opportunity				0.006	0.011	0.001	0.002	
				(0.02)	(0.92)	(0.16)	(0.27)	
* product innovation				0.041	-0.021	0.023	**0.033**	
				(1.23)	-(0.87)	(1.59)	**(2.28)**	
* process innovation				**-0.050**	-0.040	**-0.043**	**-0.044**	
				-(2.06)	-(1.24)	**-(2.17)**	**-(2.30)**	
* science base				**0.005**	**0.007**	**0.007**	**0.006**	
				(2.57)	**(1.81)**	**(2.66)**	**(2.54)**	

T-statistics in parentheses
Coeffcients with at least 10% significance are highlighted

Thirdly, I use ownership concentration to identify possible interactions between corporate structure and technology regimes. The results are somewhat unexpected and contradictory. While the interactive variable of ownership concentration and product innovation orientation was significantly negatively correlated with growth in the bivariate regressions, the signs are now positive and significant. This result is fairly robust when using different time periods and specifications. The results further contradict theoretical stipulations of a positive interaction between process innovation and tight ownership structures. All of the eight coefficients are negative and three of them are significant at the 10 percent level.

Finally, I included a measure of financial development to investigate whether the results are affected by the level of overall financial development as stipulated by Levine (1997), that were confirmed empirically in some later studies (Beck and Levine, 2001). My earlier results are unaffected when including the development effect. However, the overall level of financial sophistication interacts positively with growth in science-based industries. It seems that in these sectors the structure of the financial system matters less than its level of development.

The regression estimates using export competitiveness as the dependent variable show fewer significant coefficients on the interactive terms (see Table 4). This confirms the results from the bivariate regressions reported above. With respect to the role of the banking sector, there is a robust significant negative correlation of bank concentration in science-based sectors. The coefficient on bank assets interacting with science base is, however, positive and significant. Among the stock market variables it is only accounting standards similar to the bivariate case, which interacts negatively and significantly with process-innovative technology regimes in promoting exports. There are no significant correlations for the interaction of ownership

Table 4: Financial structure, sectoral innovation characteristics and export performance—Multivariate regressions

Dependent variable	Revealed comparative advantage (1975-1997)				
Banking sector	Bank concentration				Bank assets
* opportunity	-0.010	-0.003	0.017		-0.001
	-(0.47)	-(0.14)	(0.77)		-(0.05)
* product innovation	-0.049	-0.039	-0.057		0.053
	-(1.15)	-(0.88)	-(1.27)		(1.61)
* process innovation	0.026	0.003	-0.048		-0.024
	(0.46)	(0.05)	-(0.78)		-(0.53)
* science base	**-0.020**	**-0.016**	**-0.016**		**0.015**
	-(2.79)	**-(2.09)**	**-(2.04)**		**(2.56)**
Stock market	Accounting standards		Structure index		Capitalization
* opportunity	0.107	0.106	0.021	**0.029**	0.044
	(2.87)	(2.83)	(1.15)	**(1.89)**	(1.54)
* product innovation	-0.063	-0.065	-0.005	-0.031	-0.028
	-(0.82)	-(0.85)	-(0.13)	-(1.01)	-(0.48)
* process innovation	**-0.245**	**-0.240**	-0.040	-0.062	-0.086
	-(2.35)	**-(2.30)**	-(0.78)	-(1.45)	-(1.09)
* science base	0.014	0.013	0.007	-0.001	0.008
	(1.11)	(1.04)	(1.02)	-(0.24)	(0.82)
Corporate structure	Ownership concentration				
* opportunity	0.021	0.030	0.024	0.035	0.028
	(1.22)	(1.55)	(0.90)	(1.58)	(1.27)
* product innovation	-0.038	-0.026	-0.013	-0.051	-0.059
	-(1.06)	-(0.64)	-(0.23)	-(1.11)	-(1.31)
* process innovation	-0.008	-0.040	-0.017	-0.048	-0.016
	-(0.17)	-(0.73)	-(0.22)	-(0.77)	-(0.27)
* science base	-0.001	0.004	0.008	-0.003	-0.005
	-(0.19)	(0.59)	(0.82)	-(0.43)	-(0.64)
Financial development					
* opportunity		0.016	0.018	0.015	
		(1.00)	(1.18)	(1.01)	
* product innovation		0.021	0.020	0.030	
		(0.66)	(0.61)	(0.95)	
* process innovation		-0.054	-0.060	-0.052	
		-(1.26)	-(1.38)	-(1.22)	
* science base		**0.009**	**0.009**	**0.013**	
		(1.67)	**(1.70)**	**(2.41)**	

T-statistics in parentheses
Coeffcients with at least 10% significance are highlighted

Table 5: Summary of estimation results

		Opportunity		Product innovation		Process innovation		Science base	
		growth	exports	growth	exports	growth	exports	growth	exports
Bank assets	B								+
	M								
Bank concentration	B			--					--
	M			--					--
Stock market capitalization	B			+					+
	M			+					
Accounting standards	B	+	+	+			--	+	
	M			+			--	+	
Market based	B	+		+					
	M			+					
Ownership concentration	B			--					--
	M			+					
Financial development	B			+					+
	M							+	+

Notes: B = bivariate regression results; M = multivariate regression results

concentration with any of the four technology regime measures. Finally, financial development is positively associated with export success in science-based industries in all three specifications that include this variable. This appears to indicate that financial structure, other than bank concentration, plays a minor role in understanding innovation and export performance. Rather, it is the ability of both banks and stock markets to provide information and funds that is required in science-based sectors.

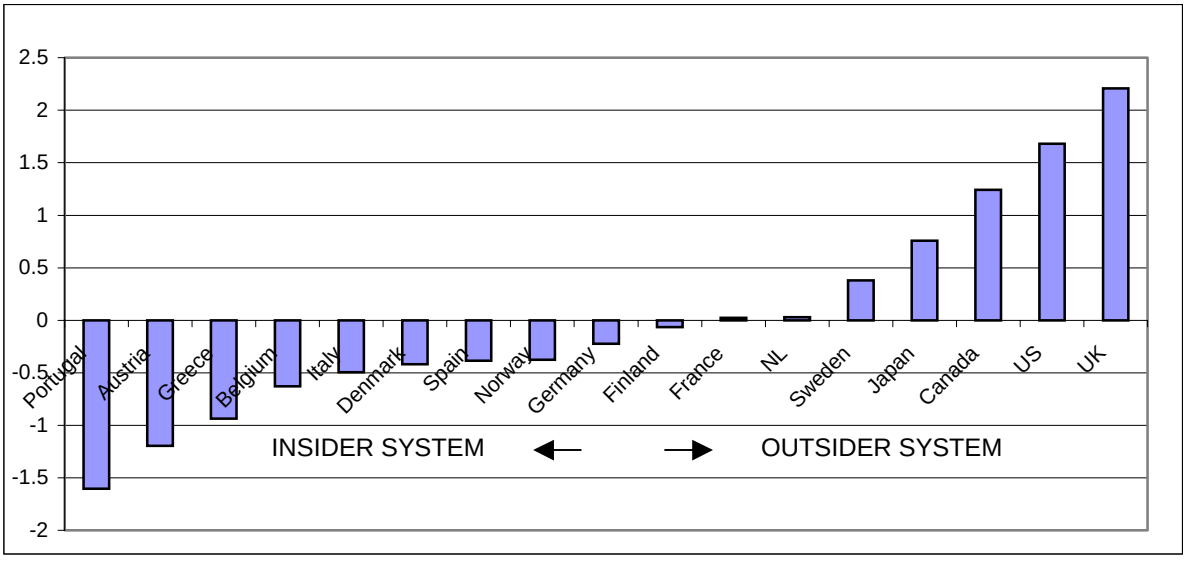
Table 5 summarizes the evidence for both the multivariate and bivariate growth and export regressions. As theorized by a number of scholars large and well-functioning stock markets complement innovative behavior in sectors with high opportunities and a focus on product innovation. The complementarity between stock market orientation and the two technology

regime indicators works mainly through promoting growth. Furthermore, good accounting standards have a positive effect on growth in science-based sectors. In contrast, stock markets especially good accounting information appears to have a negative effect on countries' export performance in sectors geared towards process innovation. Bank concentration has a negative effect on growth when interacting with product innovation as the technology regime variable. Similarly, limited competition in the banking sector plays a detrimental role in science-based sectors through lowering export competitiveness. There are no robust results to report in terms of the role of ownership concentration. On the other hand, financial development in interaction with science-based technology regimes has a positive influence on both exports and growth.

The analysis so far has focused on individual variables to measure the character of the financial system. But one single variable such as e.g. ownership concentration or bank assets cannot fully capture the systemic nature of national financial infrastructures. I therefore further derive a composite index incorporating four financial structure variables (bank concentration, the financial structure index, accounting standards and ownership concentration) by using principle components analysis. Outsider systems are characterized by lower bank and ownership concentration as well as better accounting standards and greater stock market orientation relative to insider systems. Figure 3 shows the values of the first principal component for the 17 OECD countries.

Then I re-estimated the growth and export regressions using the insider/outsider indicator (first principal component) as my structure variable interacting with the four technology regime indicators. The results are largely consistent with my previous findings (Table 6). Outsider

Figure 3: Insider and outsider systems



systems (large stock markets, good accounting standards, low bank and ownership concentration) are positively correlated with growth in product-oriented and science-based sectors. There is a positive association of insider systems with export competitiveness in process-oriented sectors. Outsider systems have a positive effect on growth and export success of science-based industries, but overall development is still important.

6. Conclusions

The theoretical discussion and the empirical regularities provided in this paper suggest that financial systems are an important factor in explaining innovation across sectors and countries. Rather than having an impact on aggregate growth levels through investment funding, national financial systems were found to play a role in giving various degrees of financial and

Table 6: Insider and outsider systems

	Growth (1970-97)		RCA (1975-97)	
initial output share	**-0.175**	**-0.178**		
	-(3.87)	**-(3.90)**		
Insider/outsider system				
* opportunity	0.001	0.001	0.004	0.005
	(0.41)	(0.66)	(1.16)	(1.28)
* product innovation	**0.009**	**0.006**	0.008	-0.002
	(3.03)	**(1.71)**	(1.21)	-(0.22)
* process innovation	-0.002	0.003	**-0.019**	**-0.017**
	-(0.51)	(0.65)	**-(2.19)**	**-(1.59)**
* science base	**0.001**	0.001	**0.003**	0.001
	(1.97)	(0.79)	**(2.65)**	(0.40)
Financial development				
* opportunity		-0.003		-0.006
		-(0.55)		-(0.43)
* product innovation		0.014		**0.054**
		(1.20)		**(2.04)**
* process innovation		**-0.029**		-0.012
		-(1.78)		-(0.34)
* science base		0.003		**0.013**
		(1.32)		**(2.97)**

T-statistics in parentheses
Coeffcients with at least 10% significance are highlighted

organizational support to sector-specific technological learning regimes. In other words, the results of this study indicate that complementarities between financial infrastructures and complex organizational innovation processes best described at the sectoral level of the economy can help to explain observable differences in national industrial structures. Specifically, market-dominated outsider systems are relatively better at promoting industrial innovation activities characterized by high technological opportunity and a focus on product innovation. Insider systems in which market allocation of funds and ownership is limited are compatible with

innovation regimes characterized by higher levels of cumulativeness of company-specific knowledge.

The undeniable fact that the United States has been especially successful in promoting sectors associated with the information revolution is therefore at least partly attributable to its market-based financial and corporate governance system. However, the widespread concern among European economists and policy makers that lackluster innovation performance in ICT is associated with a growth slowdown might be premature. First, innovative learning takes place in all sectors of the economy not just in high technology sectors. In fact, though growing in size sectors like ICT or biotechnology contribute only a small percentage to total output. Second, European institutions might be especially successful at promoting innovative activities in industries operating more established technologies. Performance in today's high-technology sectors might therefore improve as the underlying innovation process changes its character and becomes more mature.

DATA APPENDIX

A. Performance data (20 manufacturing sectors, 17 OECD countries):

(1) Growth of value added (constant prices, OECD STAN database)

$$g^*_{i,j} = g_{i,j} - g_{i,OECD} - g_{man,j} + g_{man,OECD}$$

Dependent variable is growth in industry i in country j controlling for the average growth of industry i in all OECD countries in the sample and the average growth of manufacturing in country j.

(2) Index of revealed comparative advantage (OECD STAN database)

$$RCA_{i,j} = (X_{i,j} / X_{man,j}) / (X_{i,OECD} / X_{man,OECD})$$

Dependent variable is export share in sector i in country j controlling for the average export share of industry i in all OECD countries in the sample and the average export share of manufacturing in country j.

B. Financial structure indicators:

(1) Size of banking sector: Deposit money bank assets/GDP (average for 1970-1997 in Levine et al., 2000)

(2) Character of banking sector: Bank concentration measured as the ratio of the three largest banks' assets to total banking sector assets averaged for the period 1990-1997 (Levine et al., 2000)

(3) Size of stock market: Stock market capitalization (value of listed shares)/GDP averaged for the period 1975-1997 (Levine et al., 2000)

(4) Information availability: Accounting standards on a scale from 0 to 90 reported in Rajan and Zingales (1998) from a survey conducted by the Center of International Financial Analysis and Research in 1990.

(5) Financial structure index: Stock market capitalization/Bank assets—market based or bank based, degree of market orientation

(6) Ownership concentration: 1 minus the percentage of widely held of the largest 20 publicly traded corporations in 1995 (La Porta et al., 1998)—character of corporate system, insider vs. outsider system.

(7) Financial development index: (Stock market capitalization + bank assets) / GDP—degree of overall financial sophistication

Table A.1: Financial system indicators

	Bank assets	Bank concentration	Stock market capitalization	Accounting standards	Financial structure	Ownership concentration	Financial development	Insider/ Outsider
Austria	0.97	0.72	0.07	0.54	0.07	0.95	1.04	-1.20
Belgium	0.65	0.65	0.24	0.61	0.37	1.00	0.89	-0.63
Canada	0.49	0.58	0.46	0.74	0.93	0.50	0.95	1.24
Denmark	0.50	0.74	0.22	0.62	0.44	0.90	0.72	-0.42
Finland	0.59	0.88	0.23	0.77	0.39	0.85	0.81	-0.06
France	0.77	0.41	0.20	0.69	0.25	0.70	0.97	0.02
Germany	1.02	0.45	0.18	0.62	0.18	0.65	1.20	-0.22
Greece	0.39	0.77	0.10	0.55	0.27	0.95	0.49	-0.94
Italy	0.74	0.36	0.11	0.62	0.15	0.85	0.86	-0.49
Japan	1.09	0.22	0.65	0.65	0.59	0.50	1.74	0.76
Netherlands	0.82	0.74	0.43	0.64	0.52	0.70	1.25	0.03
Norway	0.57	0.84	0.18	0.74	0.31	0.95	0.74	-0.37
Portugal	0.79	0.46	0.07	0.36	0.09	1.00	0.86	-1.60
Spain	0.84	0.47	0.20	0.64	0.24	0.85	1.04	-0.39
Sweden	0.50	0.88	0.38	0.83	0.76	1.00	0.88	0.38
United Kingdom	0.66	0.56	0.75	0.78	1.13	0.10	1.41	2.21
United States	0.73	0.19	0.60	0.71	0.82	0.20	1.33	1.68
Average	0.71	0.58	0.30	0.65	0.44	0.74	1.01	N/A

C. Industry characteristics:

The industry structure variables are based on results from the PACE (Policies, Appropriability and Competitiveness for European Enterprises) survey of R&D managers in the 500 largest enterprises in Europe (UK, Germany, Italy, Benelux, Spain, Denmark, France) conducted in 1993-94. I matched individual responses to the 20 manufacturing sectors for which performance data were available from the OECD STAN database. I then computed sectoral averages based on responses (five-point Likert-scale ratings) to the following questions. Table A.2 presents normalized average values of sectoral technology regime indicators.

(1) Technological opportunity:

> PACE question: "How important to the innovative activities of your unit is technical knowledge obtained from the following sources: 1. Affiliated firms; 2. Joint or cooperative ventures; 3. Independent suppliers; 4. Independent clients or customers; 5. Public research institutes or universities." Added scores (min. 5 - max. 25).

(2) Cumulativeness product innovation:

PACE question: "How important are frequent technical product improvements in making your unit's innovations difficult or commercially unprofitable to imitate?" Simple score (min. 1 - max. 5).

(3) Cumulativeness process innovation:

PACE question: "How important are frequent technical process improvements in making your unit's innovations difficult or commercially unprofitable to imitate?" Simple score (min. 1 - max. 5).

(4) Science base:

PACE question: "How important to the progress of your unit's technological base was publicly funded research, in any country, over the past ten years in: 1. Computing Science; 2. Materials Science; 3. Medical and Health Sciences; 4. Chemical Engineering; 5. Electrical Engineering; 6. Mechanical Engineering." Added score (min. 6 - max. 30).

Table A.2: Technology regime indicators (normalized values)

ISIC (Rev. 2	Sector description	Opportunity	Product innovation	Process innovation	Science base
3110	Food	0.89	0.79	1.00	0.78
3130	Beverages	0.88	0.73	0.88	0.66
3140	Tobacco	0.80	0.61	0.77	1.00
3210	Textiles	0.86	0.79	0.94	0.74
3410	Paper & Products	0.94	0.75	0.73	0.55
3510	Industrial Chemicals	0.85	0.83	0.98	0.78
3520	Chemical Products	0.90	0.79	0.92	0.74
3540	Petroleum & Coal	0.90	0.77	0.91	0.79
3550	Rubber Products	0.91	1.00	0.88	0.60
3560	Plastic Products	1.00	0.83	0.99	0.70
3620	Glass & Products	0.83	0.72	0.91	0.67
3690	Non-Metallic Produc	0.81	0.60	0.83	0.74
3710	Iron & Steel	0.94	0.71	0.98	0.87
3720	Non-Ferrous Metals	0.87	0.66	0.92	0.75
3810	Metal Products	0.89	0.82	1.00	0.74
3820	Machinery & Equipm	0.90	0.83	0.92	0.89
3830	Electrical Apparatus	0.88	0.79	0.82	0.77
3841	Shipbuilding	0.87	0.67	0.94	0.81
3843	Motor Vehicles	0.90	0.79	0.90	0.90
3850	Professional Goods	0.92	0.79	0.84	0.88
Manufacturing average		0.89	0.76	0.90	0.77
Manufacturing median		0.89	0.79	0.92	0.76

[i] Additional evidence is provided in a panel study of small firms in high tech industries in the United States. Himmelberg and Petersen (1994) find that the flow of internal finance is the principal determinant of the rate at which small high-tech firms acquire technology through R&D.

[ii] In their study of the optical network industry, Carpenter and Lazonick (2001), for example, show that stock was the major "acquisition" currency in the late 1990s. According to their data, Cisco, Nortel and Alcatel, the leading companies in that sector, acquired a number of mostly small start-up companies between 1998-2000 and paid for them with company stock.

[iii] The magnitude of these stock options is by no means trivial. British economist Andrew Smithers (cited in Krugman, New York Times, February 1, 2002) estimates that Cisco System's 1998 profit of US $ 1.35 billion would have turned into a $ 4.9 billion loss had the company counted the market value of stock options issued that year as a cost in its balance sheet.

[iv] I also used activity measures for banks (total private credit/GDP) and stock markets (total stocks traded/GDP). These activity indicators are highly correlated with the size indicators used in this study and therefore generated similar results in the regressions, but are not reported here.

[v] The use of accounting standards in empirical studies differs. Rajan and Zingales (1998) and Beck and Levine (2000) use accounting standards as a measure of overall financial development while Carlin and Mayer (1999) utilize accounting data as an indicator of the stock market orientation of financial systems. This study will follow the latter interpretation because widely available company information promotes the role of stock markets.

[vi] A dispute between German automaker Porsche and the German stock exchange is a good example of the potentially contentious role of accounting information. The stock exchange

recently stopped including Porsche in a particular segment of the DAX (Deutscher AktienindeX) because of its continued refusal to publish quarterly (instead of semi-annual) earnings reports. Porsche's CEO Friedekind defended his company's position by arguing that publishing company information in such frequency would divert attention to short-run performance measures rather than to the long-run structural health of the company. The fact that Porsche could maintain this position is an indicator of the continued weakness of the shareholder value movement in Germany.

[vii] In addition to estimating different specifications and time periods all regressions reported in this paper were also run including the raw variables that are used to compute the interactive variables. In all cases the coefficients on the raw variables were insignificant. Since the coefficients on the interactive variables were only marginally affected when compared to estimates excluding the raw variables only the latter are reported here.

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