Understanding the Drivers of National Innovative Capacity:

Implications for the Central European Economies

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A. Introduction

In the past decade, both academic scholars and policymakers have focused increasing attention on the central role that technological innovation plays in economic growth. There are at least two distinct reasons for this increased interest. First, though economists have long recognized the centrality of technological innovation in microeconomic and macroeconomic processes (Schumpeter, 1950; Solow, 1956; Ambramovitz, 1956), leading models and frameworks for understanding economic growth and national competitiveness did not directly incorporate the economic drivers of the innovation process until the late 1980s and early 1990s (Romer, 1990; Porter, 1990; Nelson, 1993). At the same time, the dramatic political changes wrought by the end of the Cold War and the globalization of economic activity have increased the salience of productivity growth as a principal goal of policymakers across the OECD. In turning their attention to the sources and consequences of technological innovation, both the academic and policy communities confront a striking empirical puzzle: while R&D activity is relatively dispersed around the world, "new-to-the-world" innovation tends to be concentrated in a few countries at a given point in time. For example, during the 1970s and the early 1980s, only Switzerland, a relatively small but very technology-intensive country, achieved a per capita "international" patenting rate comparable to the rate achieved by U.S. inventors. Motivated by the geographically concentrated nature of "new-to-the-world" innovation, researchers in the economics of technological change (as well as policymakers throughout the advanced economies) have attempted to understand what drives the differences among countries in terms of their R&D productivity.[1]

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[1] Indeed, the past decade has seen a dramatic rise in the number of comparative international studies of innovation and relative productivity From a policy perspective, there have been several influential "benchmarking" studies which have attempted to provide a more thorough account of international differences in industrial and R&D productivity (Dertouzos, et al (1989); Porter and Stern (1999b)). At the same time, scholars in the economics of technological change became interested in documenting the existence and characteris tics of national innovation "systems" (Nelson, 1993)., mostly drawing upon rich, qualitative and institutional evidence. Finally, there has been an upsurge in the use of quantitative methods, particularly those relying on the use of patent data (Evenson (1984), Dosi, Pavitt, and Soete (1990); Eaton and Kortum (1996; 1999); Porter and Stern (1999a); Stern, Porter, and Furman (1999)).

In this short paper, we first review our own prior research examining the sources of national R&D productivity differences[2] and then extend these prior analyses to consider the historical experience and contemporary challenges for Central Europe. We organize our analysis around a novel framework based on the concept of *national innovative capacity.* National innovative capacity is the ability of a country – as both a political and economic entity – to produce and commercialize a flow of innovative technology over the long term. Innovative capacity depends on an interrelated set of investments, policies, and resource commitments which underpin the production of new-to-the-world technologies. National innovative capacity is not simply the realized level of innovative output; rather, it is reflected in the presence of fundamental conditions, investments, and policies that determine the extent and success of innovative effort in a country (e.g., high levels of science and technology resources, policies which encourage innovative investment and activity, and innovation-oriented domestic industrial clusters).

In the next three sections of this paper, we review the national innovative capacity framework, summarize our empirical methodology for measuring the key concepts associated with this framework, and present the results of an empirical analysis of the determinants of national innovative capacity across the OECD over the past twenty-five years. Section V uses these results to offer some remarks about the challenges facing Central Europe with respect to the development and sustainability of national innovative capacity. Specifically, while the Central European countries of Germany and Switzerland have historically invested in factors that have contributed to a relatively high level of innovative capacity, Austria has been among the middle tier of OECD countries. Through the first half of the 1990s, however, each of these three countries has slowed the pace of the investment in innovative activities, particularly when compared with the investments of other OECD countries such as Japan and a cluster Northern European economies.

[2] Our prior work in this area has been conducted with Michael E. Porter of the Harvard Business School. See Stern,

B. Determinants of National Innovative Capacity

National innovative capacity is defined as an economy's potential, at a given point in time, for producing a stream of commercially relevant innovations.[3] This capacity depends in part on the technological sophistication and labor force in a given economy, but also reflects the investments and policies of the government and private sector which affect the incentives for and the productivity of a country's research and development activities. As well, national innovative capacity is distinct from both the purely scientific or technical achievements of an economy (in the spirit of Bush (1945)), which do not *necessarily* involve the economic application of new technology, and national industrial competitive advantage, which results from a myriad of factors in addition to the development and application of innovative technologies (Porter, 1990).

Our framework for organizing the determinants of national innovative capacity consists of elements from two broad categories: (1) a *common* pool of institutions, resource commitments, and policies that support innovation and (2) the *particular* innovation orientation of groups of interconnected industrial clusters.[4] Figure A illustrates our framework. The left-hand side represents the cross-cutting factors that support innovation throughout many if not all industries, referred to as the *common innovation infrastructure*. These include such elements as the current level of technological sophistication in the economy, the supply of technically oriented workers, the extent of investments in basic research and education, and policies that affect the incentives for innovation in any industry. The

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Porter, and Furman (1999), Stern and Porter (1999a) and Stern and Porter (1999b).

[3] We develop the national innovative capacity framework by drawing on three distinct areas of prior research: ideas-driven endogenous growth theory (Romer, 1990), cluster-based theory of national industrial competitive advantage (Porter, 1990), and the literature on national innovation systems (Nelson, 1993). Each of these perspectives identifies specific factors which may determine the aggregate flow of innovation produced in a given national environment. See Stern, Porter and Furman (1999) for a more complete exposition of this framework and its relationship to prior research in this area.

[4] We focus our attention at the country level; however, one could also conduct such an analysis at the regional level, particularly for countries with substantial institutional and economic heterogeneity across geographic regions (e.g., Italy).

diamonds on the right side signify the innovative environment in individual national industrial clusters.[5] Driven by the forces highlighted by Porter in his studies of national industrial competitive advantage (Porter (1990)), individual industrial clusters must compete and evolve on the basis of sustained innovation in order to contribute to a nation's innovative capacity. Finally, linkages between the common innovation infrastructure and the individual industrial clusters contribute to an economy's ability to mobilize resources associated with the infrastructure towards innovation opportunities in specific industrial sectors.

Common Innovation Infrastructure. Although the innovative performance of an economy ultimately rests with the behavior of individual firms and industrial clusters, some of the most critical investments that support innovative activity operate across all innovation-oriented sectors in an economy. We describe such elements as an economy's *common innovation infrastructure*. Figure B illustrates three specific categories associated with the common innovation infrastructure. First, as a country becomes more technologically sophisticated, the average cost of generating a specific amount of innovation may decline, as innovators are able to draw on a more varied set of approaches and potential solutions when pursuing R&D activities. As such, consistent with models of increasing returns in knowledge production (Rosenberg, 1976; Romer, 1990), our framework suggests that a country's R&D productivity will depend upon the stock of knowledge it may draw upon in the context of the innovation process (denoted A_t in Figure B). Second, the level of innovative activity realized by an economy will ultimately depend on the extent of available scientific and technical talent who may be dedicated to the production of new technologies (denoted $H_{A,t}$ in Figure B).[6] In addition to the size of a country's knowledge stock and talent pool, R&D productivity will also depend on national investments and policy choices, such as spending on higher education, intellectual property protection, and openness to

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[5] We focus on clusters (e.g., information technology) rather than individual industries (e.g., printers) because there are powerful spillovers and externalities that connect the competitiveness and rate of innovation of clusters as a whole (Porter, 1990). As well, previous research has suggested that the scope of industrial clusters is often quite local in nature, operating at the regional or even city level (see, e.g. Porter, 1998).

[6] This notation follows the seminal model of Romer (1990), which derives equilibrium growth based on the endogenous allocation of labor to the "ideas" sector of the economy (see Jones (1995; 1998) for a useful introduction and review and Porter and Stern (1999a) for further discussion of the empirical properties of the national "ideas" production function).

international competition, which will have a cross-cutting impact on innovativeness across economic sectors. (These factors are denoted together as X^{INF} in Figure B).[7]

Cluster-Specific Innovation Orientation. While the common innovation infrastructure determines the general pool of innovation-supporting resources available an economy, it is ultimately firms that introduce and commercialize innovations. In thinking about the overall innovative performance of an economy, then, one must examine the extent to which innovation is supported by the competitive environment in a country's industrial clusters.[8] To do this, we apply the framework introduced by Porter (1990), which highlights how four key elements of the microeconomic environment -- the presence of high-quality and specialized inputs; a context that encourages investment and intense local rivalry; pressure and insight gleaned from sophisticated local demand; and the presence of a cluster of related and supporting industries -- influence the rate of innovation in a country's industrial clusters (see Figure C).[9] By incorporating cluster-level dynamics into our national innovative capacity framework, this model is useful for integrating the results from research at multiple levels of analysis.

The Quality of Linkages. Finally, the relationship between industrial clusters and the common innovation infrastructure is reciprocal: conditional on the environment for innovation in any particular cluster, its innovative output will increase with the strength of the economy's common innovation infrastructure. As well, the strength of linkages *between* these two areas will determine the extent to which the potential for innovation supported by the common innovation infrastructure is translated into specific innovative outputs in a nation's industrial clusters. In the absence of strong linking mechanisms,

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[7] Across countries, the salience and specific manifestation of these additional factors may vary greatly. For example, in the United States, the dominant performers of basic research are members of the university system who compete with each other for federal funding, mostly through peer-reviewed grant processes. In contrast, basic research German is performed by a more diversified set of organizations, including a substantial share by several non-university-based research institutes, such as the Helmholtz research centers, the Max Planck institutes, and the "Blue List" institutes. While this heterogeneity is of independent research interest (see, for example, the careful comparative studies in Nelson (1993)), our focus here is on the ultimate consequences of such institutions in terms of observed R&D productivity.

[8] Following Porter (1990, 1998), these industrial clusters are the sources of the geographic and cross-industry spillovers which serve to shape and reinforce national industrial competitive advantage.

upstream scientific and technical activity may spill over to other countries more quickly than opportunities can be exploited by domestic industries.[10] For example, consider the case of the chemical industry in the second half of the 19th century. While the underlying technology creating this industry was the result of the discoveries of the British chemist Perkins, the sector quickly developed and became a major exporting industry for Germany, not Britain. At least in part, this migration of the fruits of scientific discovery to Germany was due to that country's stronger university-industry relationships and the greater availability of capital for technology-intensive ventures (Murmann, 1998; Arora, Landau, and Rosenberg, 1998).

With this framework in mind, we can now turn to the development of our empirical methodology for measuring the role played by specific elements associated with national innovative capacity in explaining observed differences in country-level R&D productivity.

C. Modeling National Innovative Capacity

We use the national innovative capacity framework to direct our empirical analysis of the determinants of R&D productivity across the OECD over the past twenty-five years. In effect, we estimate an production function for economically significant technological innovations, in a manner similar to the ideas production described by endogenous growth theory (Romer, 1990; Jones, 1995; Jones, 1998; Stern and Porter, 1999). We choose a specification in which innovations are produced as a function of the factors underlying national innovative capacity:

$$\dot{A}_{j,t} = \delta_{j,t}(X^{INF}_{j,t}, Y^{CLUST}_{j,t}, Z^{LINK}_{j,t}) H^{A\,\lambda}_{j,t} A^{\phi}_{j,t} \qquad (1)$$

where $\dot{A}_{j,t}$ represents the flow of new-to-the-world technologies from country *j* in year *t*, $H^{A}_{j,t}$ is the

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[9] The Porter "diamond" is most commonly applied to describe the dynamics of competition in national industrial clusters. In our framework, we emphasize the extent to which the environment in a country's industrial clusters encourages innovation as a specific outcome of the competitive process.

[10] While there have been some attempts to understand the role played by these linking mechanisms in shaping R&D productivity , most international comparative studies have confined themselves to carefully identifying and highlighting the mechanisms associated with institutions that play such roles in particular countries (e.g., the

total level of capital and labor resources devoted to the ideas sector of the economy, and $A_{j,t}$ is the total stock of knowledge held by an economy at a given point in time to drive future ideas production. In addition, X^{INF} refers to the level of cross-cutting resource commitments and policy choices which constitute the common innovation infrastructure, Y^{CLUS} refers to the particular environments for innovation in a country's industrial clusters, and Z^{LINK} captures the strength of linkages between the common infrastructure and the nation's industrial clusters.[11] Letting L X be defined as the natural logarithm of X, our main specification takes the following form:

$$L\dot{A}_{j,t} = \delta_{YEAR} Y_t + \delta_{COUNTRY} C_j + \delta_{INF} LX^{INF}_{j,t} + \delta_{CLUS} LY^{CLUS}_{j,t} + \delta_{LINK} LZ^{LINK}_{j,t} + \lambda LH^{A}_{j,t} + \phi LA_{j,t} + \varepsilon_{j,t} \quad (2)$$

We conduct our analysis on a panel dataset of OECD countries from 1973 to 1995 (See Table 1). Implementing (2) requires that we identify observable measures for new-to-the-world innovation and each of the concepts underlying national innovative capacity. While no measure of innovation at the national level is ideal, we organize our empirical analysis around the observed number of "international patents" (PATENTS), a useful indicator of the country-specific level of realized, visible "new-to-the-world" innovation at one point in time.[12] The average number of PATENTS produced by a country in a given year is 3986 (with a standard deviation of 8220). As can be seen in Figures D-1 and D-2, "per capita" patenting rates (PATENTS / MILLION POP) demonstrate substantial differences across countries. There is, however, a *convergence* in the realized level of patenting among the initial top tier countries (the United States and Switzerland) and countries in the middle and lower tiers. Most striking,

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Fraunhofer Institutes in Germany, MITI in Japan, and Cooperative Research and Development Associations (CRADAs) in the United States).

[11]Note that this specification assumes that the elements of national innovative capacity are complementary with one another in the sense that the marginal productivity associated with increasing one factor is increasing in the levels of each of the other factors.

[12]For the purposes of this paper, "international patents" are defined as those granted by the United States Patent & Trademark Office as well as by the home country of the inventor. Our use of international patents draws on an extensive body of prior work (building on the foundations developed in Griliches, 1984) which has established both the advantages (as well as the limitations) of using patent data relative to other measures of innovation (Evenson, 1984; Trajtenberg, 1990; Henderson and Cockburn, 1994, 1996; Eaton and Kortum, 1996; 1998). A more complete justification for the use of patents as a measure of national level innovative activity appears in Stern, Porter, and Furman (1999).

Japan and Germany "join" the top group in the 1980s, while a number of Northern European economies evidence relative increases in observed innovative output over time.

The principal empirical exercise conducted in the context of our prior work is to relate PATENTS to a set of variables which correspond to various elements of national innovative capacity. The specific measures we use, along with definitions and sources, are listed in Table 2; summary statistics are presented in Table 3. Essentially, we utilize a number of observed aggregate measures (such as FT S&E and R&D $) as well as indicators of national policies (IP and OPENNESS) to capture the strength of the common innovation infrastructure; we attempt to capture the innovation orientation of industrial clusters and the strength of linkages by *compositional* variables which capture the relative sources of R&D funding between the public and private sector (PRIVATE R&D FUNDING) and the degree to which R&D performance takes place in the university sector (UNIV R&D PERFORMANCE).

D. Empirical Findings

Using the framework and methodology described above, we have performed empirical analyses which allow us to dissect the drivers of national innovative capacity. Specifically, our analysis allows us to evaluate which factors matter most for driving differences in observed national R&D productivity. We can then use these results to evaluate historical trends in national innovative performance. The remainder of this section briefly reviews these empirical findings.

Table 4 reports the principal models that we have used to evaluate trends in national innovative capacity across the OECD.[13] In (4-1), we estimate a specification which is analogous to the formal model of the national ideas production function suggested by Romer (1990) and Jones (1995). In this, as

[13] There are a number of methodological considerations which we do not have space to discuss here (e.g., endogeneity), but which are treated more fully in Porter, Stern, and Furman (1999) and Porter and Stern (1999b). In these papers' more extensive analytic sections, we demonstrate the robustness of our results to a number of modifications, including (a) using the cumulative sum of patents as a measure of countries' knowledge stock; (b) employing alternative specifications, such as country fixed effects and time trends; and (c) including additional measures of the determinants of national innovative capacity.

in each of the specifications we model, L PATENTS is increasing in L GDP PER CAPITA and L FTE S&E. Equation (4-2) includes our complete set of measures, including elements associated with the common innovation infrastructure, the environment for innovation in industrial clusters, and the strength of linkages between these two areas. Equations (4-3) and (4-4) examine the robustness of (4-2) to subsets of the data after 1984 and to a model which only includes European countries. In all models, the measures reflecting elements associated with national innovative capacity are quantitatively and statistically significant (and indeed explain an extremely high percentage of the overall variance in innovative output among OECD countries over the last quarter century). This implies that the extent and nature of investments in national innovative capacity are associated with observed levels of innovative output and R&D productivity.[14]

In addition to the factors identified by endogenous growth theory (GDP PER CAPITA and the employment of technical workers, FTE S&E) our analysis suggests that the level of observed national innovative output is significantly affected by both (a) more nuanced elements of the common innovation infrastructure and (b) the *composition* of investments in innovation. In particular, observed international patenting is a function of several related measures of R&D effort (FT S&E and R&D $), investments in higher education (ED SHARE), and policy variables such as the degree of openness by an economy (OPENNESS) and the strength of intellectual property protection (IP) from the perspective of the inventing country. As well, the extent to which R&D is *financed* by industry (PRIVATE R&D FUNDING) and *performed* by universities (UNIV R&D PERFORMANCE) has a positive and significant effect on national innovative output. Overall, looking at the various factors which help explain

[14] It is important to properly interpret the coefficients on these measures. For those variables specified in log form, coefficients reflect elasticities. For example, (4-1) suggests that a 10 percent increase in GDP PER CAPITA is associated with an approximate increase of 13 percent in PATENTS. The coefficients associated with the Likert scale measures are equal to the predicted percentage change in PATENTS which would result from a one *unit* change in that variable. For example, (4-2) implies that a one unit change in IP (e.g., from 7 to 8) is associated with a 25 percent increase in PATENTS. Finally, coefficients on the variable expressed as a share (ED SHARE) can be interpreted as the percentage increase in PATENTS resulting from a one *percentage point* increase in that variable.

the observed level of international patenting output, our analysis suggests that no single factor is sufficient to drive national innovative capacity. Thus, our results suggest innovation leadership will tend to result from concerted strength along a number of distinct dimensions which contribute to innovative capacity.

Using the results of (4-2), we analyze the innovative capacity of our sample of seventeen OECD economies since 1973 and eight emerging economies since 1990 (Figures E-1 and E-2). Essentially, a country's innovative capacity is equal to its expected per capita international patenting rate, as calculated from its observed levels and regression coefficients from (4-2). This counterfactual analysis allow us to reach several overarching conclusions about the development of innovative capacity. First, and perhaps most importantly, innovative capacities are converging across the OECD. Although the United States and Switzerland appear at the top of the "index" of national innovative capacity across three decades, the relative advantage of the leader countries has declined over time. Over this time period, there have been substantial differences across countries in the extent to which they have invested in factors contributing to national innovative capacity. In particular, despite an economic slowdown in the 1990s, Japan has dramatically improved its innovative capacity since the early 1970s and evidences little sign of weakening its pace of investment. Further, the Scandinavian economies of Denmark and Finland have made major gains in innovative capacity since the mid-1980s, joining Sweden in establishing a region of world class innovation. By contrast, the estimates associated with several Western European economies, including the United Kingdom, France, and Italy, suggest constant (or slightly declining) levels of innovative capacity.[15]

[15] Related analysis in Porter and Stern (1999) suggests that new centers of innovative activity are emerging outside of the OECD. Singapore, Taiwan, South Korea, and Israel have made substantial investments and upgraded their innovative capacity over the past decade. Ireland has also established the infrastructure and industrial clusters consistent with strong innovative activity. In contrast, several countries that have drawn much attention as potential economic powers—India, China, and Malaysia—are not yet generating a meaningful level of innovative output on an absolute or relative basis. None of these countries is investing rapidly enough to be considered to possess high per capita levels of national innovative capacity.

E. National Innovative Capacity in Central Europe

We conclude our analysis with a brief discussion of the historical experience and contemporary challenges facing Central Europe. The three German-speaking countries of Central Europe – Germany, Austria, and Switzerland – have had substantially different experiences with respect to national innovative output and estimated national innovative capacity over the past few decades (see Figures D & E). Within this group of three countries, Switzerland, a relatively small country with several internationally prominent technology-intensive clusters, has been a consistent leader, not only within the regional group but, indeed, across the entire OECD. In contrast, the German experience has been much more varied. Over the course of the 1980s, Germany emerged among the world's technological leaders, a fact reflected both in terms of international patenting per capita as well as in terms of estimated national innovative capacity. Re-unification, however, appears to have altered national priorities and slowed investment in and policy commitments towards innovative capacity. For example, after having increased steadily since 1973, Germany's number of scientists and engineers per capita has declined somewhat in the mid-1990s. Finally, while Austria has historically enjoyed a level of per capita income around the median of OECD countries, this country has consistently ranked below the OECD median with respect to measured national innovative capacity. As well, while a number of countries whose levels of national innovative capacity in the 1970s were similar to Austria's have substantially increased their underlying patterns of investment in innovative activities (e.g., Northern European economies, such as Denmark and Finland), Austrian investment has remained essentially constant. Consequently, Austria has experienced a relative decline in innovative capacity over the past quarter century.

These results can be understood more fully by considering the Central European record with respect to some of the individual drivers of national innovative capacity. For example, Germany and Switzerland have been consistent leaders in per capita R&D expenditures and the supply of technical and scientific workers. Despite recent economic slowdowns, these countries have continued to increase R&D expenditures (both as a fraction of GDP and in absolute terms) and remain among the highest tier

OECD countries with respect to resources dedicated to innovative activities. Austria has increased per capita R&D expenditure since 1975 at a rate faster than the OECD average, but nonetheless remains relatively among the lower tier OECD countries on this dimension.

Second, over the course of the past twenty-five years, the Central European economies have not substantially increased the level of their investments in higher education. For example, ED SHARE in Switzerland has declined from among the highest in the OECD to a level below the median (and neither Austria nor Germany has increased investment to levels appreciably above the OECD median).

In contrast, the Central European countries have been more proactive with respect to the attractiveness of their innovation-oriented policies. For example, by the mid-1990s, each country is considered to maintain strong intellectual property institutions, and Germany and Austria are perceived to maintain a relatively high level of openness to international competition (though Switzerland's openness has been perceived to be declining through the 1990s relative to other countries).

F. Concluding Thoughts

Overall, the national innovative capacity profile of the Central European economies seems mixed. While Switzerland continues to be among the OECD leaders with respect to its overall investments in national innovative capacity, it has not increased its investments and policy commitments in recent years as substantially as some emerging innovator countries. Perhaps not surprisingly, given the economic and political upheaval created by reunification, estimates of German national innovative capacity underwent a relative decline during the 1990s (after a period of increase during the 1980s). A clear issue for policymakers in Germany, then, is whether sufficient time has elapsed since reunification to refocus investment and policy attention towards further upgrades in factors associated with national innovative capacity. Finally, whereas several countries whose measured innovative capacity during the 1970s was quite similar to the estimated Austrian level have focused on increasing their commitments, the Austrian estimates are essentially constant over the period, suggesting a lack of sustained focus on innovation policy issues.

REFERENCES

Ambramovitz, M. (1956). "Catching Up, Forging Ahead and Falling Behind," *Journal of Economic History*, 46, 385-406.

Arora, A., R. Landau, and N. Rosenberg (1998). *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*. New York (NY): Wiley.

Bush, V. (1945). *Science: The Endless Frontier*. Washington (DC): United States GPO.

Council on Competitiveness (1998). *Going Global: The New Shape of American Innovation*. Washington (DC).

Dertouzos, M.L., Lester, R.K. and R.M. Solow (1989). *Made In America: Regaining the Productive Edge*, Cambridge (MA): MIT Press.

Dosi, G.; C. Freeman; G. Silverberg; and L. Soete (1988). *Technical Change and Economic Theory*. London (UK): Pinter Publishers.

Dosi, G., K. Pavitt, and L. Soete (1990). *The Economics of Technical Change and International Trade*. New York (NY): Columbia University Press.

Eaton, J. and S. Kortum (1996). "Trade in Ideas: Patenting & Productivity in the OECD," *Journal of International Economics*, 40(3-4), 251-278.

Eaton, J. and S. Kortum (1999). "International Technology Diffusion: Theory and Measurement," *International Economic Review*. 40(3), 537-570.

Evenson, R. (1984). "International Invention: Implications for Technology Market Analysis," in Zvi Griliches, ed., *R&D, Patents, and Productivity.* Chicago (IL): University of Chicago Press: 89-126.

Henderson, R. and I. Cockburn (1994). "Measuring competence? Exploring firm effects in pharmaceutical research," *Strategic Management Journal*, 15 (Special Issue), 63-84.

Henderson, R. and I. Cockburn (1996). "Scale, Scope, and Spillovers: The Determinants of Research Productivity in Drug Discovery," *Rand Journal of Economics*, 27(1), 32-59.

Griliches, Z. (1984). *R&D, Patents, and Productivity.* Chicago(IL): University of Chicago Press.

Griliches, Z. (1990). "Patent Statistics as Economic Indicators: A Survey," *Journal of Economic Literature*, 92, 630-653.

Griliches, Z. (1994). "Productivity, R&D, and the Data Constraint," *American Economic Review* 84(1): 1-23.

IMD, *World Competitiveness Yearbook*, Lausanne, Switzerland, 1989-1999.

Jones, C. (1995). "R&D Based Models of Economic Growth," *Journal of Political Economy*, 103, 739-784.

Jones, C. (1998). *Introduction to Economic Growth.* New York (NY): W.W. Norton & Co.

Murmann, J.P. (1998). *Knowledge and Competitive Advantage in the Synthetic Dye Industry, 1850-1914: The Coevolution of Firms, Technology, and National Institutions in Great Britain, Germany, and the United States*. Unpublished doctoral dissertation, Columbia University.

Nelson, R., ed. (1993). *National Innovation Systems: A Comparative Analysis* New York (NY): Oxford University Press.

Patel, P. and K. Pavitt (1994). "National Innovation Systems: Why They Are Important, and How They Might Be Measured and Compared," *Economics of Innovation and New Technology*, 3(1), 77-95.

Porter, M.E. (1990). *The Competitive Advantage of Nations*. New York (NY): Free Press.

Porter, M.E. (1998). "Clusters and Competition: New Agendas for Companies, Governments, and Institutions," *On Competition*. Boston (MA): Harvard Business School Press.

Porter, M.E. and S. Stern (1999a). "Measuring the 'Ideas' Production Function," mimeo, MIT Sloan School of Management.

Porter, M.E. and S. Stern (1999b). *The New Challenge to America's Prosperity: Findings from the Innovation Index*. Washington (DC): Council on Competitiveness.

Romer, P. (1990). "Endogenous Technological Change," *Journal of Political Economy*, 98, S71-S102.

Rosenberg, N. (1976). *Perspectives on Technology*. Cambridge (UK): Cambridge University Press.

Schumpeter, J.A. (1950). *Capitalism, Socialism, and Democracy*. New York : Harper & Row.

Solow, R.M. (1956). "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70, 65-94.

Stern, S., M.E. Porter, and J.L. Furman (1999). "The Determinants of National Innovative Capacity," Harvard Business School Working Paper 00-034.

Trajtenberg, M. (1990). "Patents as Indicators of Innovation," *Economic Analysis of Product Innovation*. Cambridge (MA): Harvard University Press.

TABLE 1
SAMPLE COUNTRIES (1973-1995)

Australia	France	Netherlands	United Kingdom
Austria	Germany*	Norway	United States
Canada	Italy	Spain	
Denmark	Japan	Sweden	
Finland	New Zealand	Switzerland	

* Prior to 1990, data for the Federal Republic of Germany include only the federal states of West Germany; beginning in 1991, data for Germany incorporate the New Federal States of the former German Democratic Republic.

TABLE 2
VARIABLES* & DEFINITIONS

VARIABLE		FULL VARIABLE NAME	DEFINITION	SOURCE
INNOVATIVE OUTPUT				
$PATENTS_{j,t+3}$		International Patents	Patents granted in the US to establishments in country j in year (t+3); for the United States, the number of patents granted both domestically and in at least one other CHI-documented country	CHI US patent database
$PATENTS / MILLION\ POP_{j,t+3}$		International Patents per Million Persons	PATENTS divided by million persons in the population	CHI US patent database
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE				
A	$GDP\ PER\ CAPITA_{j,t}$	GDP Per Capita	Gross Domestic Product in thousands of PPP-adjusted 1985 US$	World Bank
$\mathbf{H^A}$	$FT\ S\&E_{j,t}$	Aggregate Employed S&T Personnel	Full Time Equivalent scientists and engineers in all sectors	OECD Science & Technology Indicators
$\mathbf{H^A}$	$R\&D\ \$_{j,t}$	Aggregate R&D Expenditures	R&D expenditures in all sectors in millions of PPP-adjusted 1985 US$	OECD Science & Technology Indicators
$\mathbf{X^{INF}}$	$OPENNESS_{j,t}$	Openness to International Trade & Investment	Average survey response by executives on a 1-10 scale regarding relative openness of economy to international trade and investment (Available 1986-1995)	IMD World Competitiveness Report
$\mathbf{X^{INF}}$	$IP_{j,t}$	Strength of Protection for Intellectual Property	Average survey response by executives on a 1-10 scale regarding relative strength of IP (Available 1989-1995)	IMD World Competitiveness Report
$\mathbf{X^{INF}}$	$ED\ SHARE_{j,t}$	Share of GDP Spent on Higher Education	Public spending on secondary & tertiary education divided by GDP	World Bank
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT				
$\mathbf{Y^{CLUS}}$	$PRIVATE\ R\&D\ FUNDING_{j,t}$	Percentage of R&D Funded by Private Industry	R&D expenditures funded by industry divided by total R&D expenditures	OECD Science & Technology Indicators
QUALITY OF LINKAGES				
$\mathbf{Z^{LINK}}$	$UNIV\ R\&D\ PERFORMANCE_{j,t}$	Percentage of R&D Performed by Universities	R&D expenditures performed by universities divided by total R&D expenditures	OECD Science & Technology Indicators

* The natural logarithm of a variable, X, is denoted L X.

TABLE 3
MEANS & STANDARD DEVIATIONS

		N	MEAN	STANDARD DEVIATION
INNOVATIVE OUTPUT				
PATENTS		378	3986.23	8219.89
PATENTS / MILLION POP		378	3.73	1.02
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE				
A	GDP / POP	357	18.66	5.10
H^A	FT S&E	353	226344.60	407124.50
H^A	R&D $	355	12859.86	27930.46
X^{INF}	ED SHARE	351	3.08	1.20
X^{INF}	IP	162	6.87	0.97
X^{INF}	OPENNESS	216	7.00	1.10
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT				
Y^{CLUS}	PRIVATE R&D FUNDING	355	48.60	12.88
THE QUALITY OF LINKAGES				
Z^{LINK}	UNIV R&D PERFORMANCE	355	21.50	6.20

TABLE 4
DETERMINANTS OF THE PRODUCTION OF NEW-TO-THE-WORLD TECHNOLOGIES (GDP/POP AS KNOWLEDGE STOCK)

		Dependent Variable = ln(PATENTS)$_{j,t+3}$			
		(4-1) Baseline Ideas Production Function	**(4-2)** National Innovative Capacity: Complete Model	**(4-3)** (4-2), using only post-1984 observations	**(4-4)** (4-2), using only European countries
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE					
A	L GDP PER CAPITA	**1.384 (0.086)**	**0.783 (0.096)**	**0.538 (0.133)**	**0.641 (0.102)**
H_A	L FT S&E	**1.160 (0.016)**	**0.883 (0.045)**	**0.890 (0.073)**	**0.857 (0.049)**
H^A	L R&D $		**0.272 (0.044)**	**0.309 (0.070)**	**0.331 (0.048)**
X^{INF}	ED SHARE		**0.152 (0.016)**	**0.153 (0.025)**	**0.244 (0.025)**
X^{INF}	IP		**0.221 (0.045)**	**0.229 (0.044)**	**0.239 (0.051)**
X^{INF}	OPENNESS		**0.061 (0.030)**	**0.066 (0.028)**	0.040 (0.037)
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT					
Y^{CLUS}	PRIVATE R&D FUNDING		**0.016 (0.002)**	**0.019 (0.003)**	**0.013 (0.002)**
QUALITY OF THE LINKAGES					
Z^{LINK}	UNIV R&D PERFORMANCE		**0.009 (0.003)**	**0.015 (0.005)**	**0.015 (0.004)**
CONTROLS					
Year fixed effects			**Significant**	**Significant**	**Significant**
US dummy			0.001 (0.088)	0.042 (0.123)	
Constant		**-10.327 (0.307)**			
R-Squared		0.9378	0.9983	0.9986	0.9979
Adjusted R-Squared		0.9375	0.9981	0.9984	0.9976
Observations		353	347	153	267