National Innovative Capacity

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Introduction

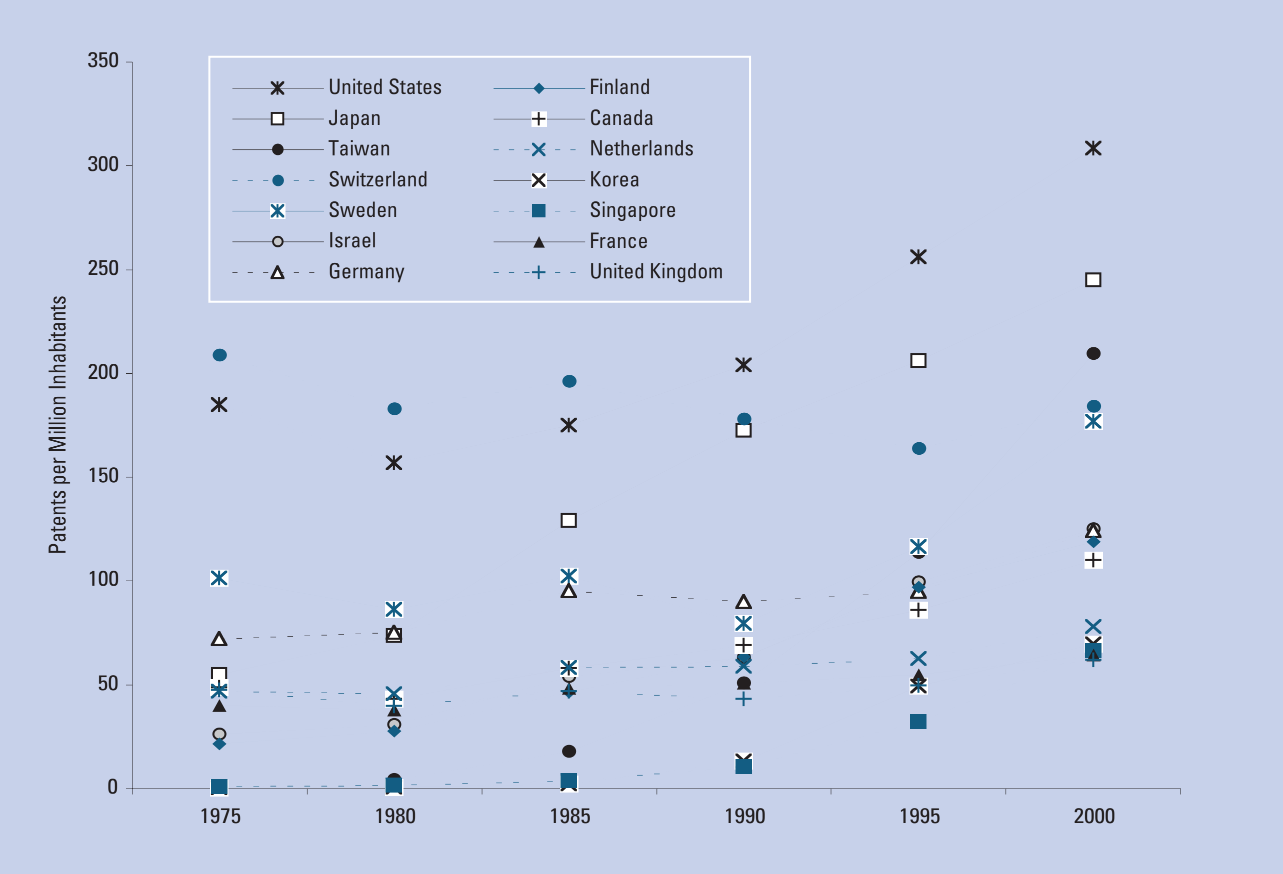
The defining challenge for competitiveness has shifted, especially in advanced countries. The challenges of a decade ago were to restructure, lower cost, and raise quality. Today, continued operational improvement is a given, and companies in many countries are able to acquire and deploy the best current technology. In advanced nations with relatively high labor costs and equal access to global markets, producing standard products using standard methods will not sustain competitive advantage. Instead, advantage must come from the ability to create and then commercialize new products and processes, shifting the technology frontier as fast as their rivals can catch up.

Although R&D investments are undertaken in all countries, a small number of geographic locations tend to dominate the process of global innovation in specific sectors and technological areas. For example, though biomedical research takes place throughout the world, more than three-fourths of all biotechnology pharmaceutical patents have their origin in a handful of regional clusters in the United States.

Overall innovative activity also concentrates in a relatively small, though growing, number of countries. From the early 1970s through the late 1980s, the United States and Switzerland maintained a per capita "international" patenting rate well in excess of all other economies (Figure 1). The rate of growth of international patenting has varied dramatically among OECD countries. The Scandinavian nations, Japan, and emerging East Asian economies have registered sharp increases, while Western European nations such as France and the United Kingdom have realized a relatively constant rate of innovation.

Why does the intensity of innovation vary across countries? How does innovation depend on location? On the one hand, firms and the private sector are the ultimate engines of innovation. On the other hand, the innovative activities of firms within a country are strongly influenced by national policy and the presence and vitality of public institutions. In other words, innovation intensity depends on an interaction between private sector strategies and public sector policies and institutions. Competitiveness advances when the public and private sectors together promote a favorable environment for innovation.

Figure 1: International patents per capita, leading countries, 1975–2000



Understanding the role of innovation in competitiveness and economic development has become increasingly important. As advanced nations face the prospect of declining population growth and the completion of the structural reforms that have propelled OECD economies over the past two decades, a stepped-up rate of innovation is needed to drive the faster productivity growth that will be required to sustain healthy economic growth rates. A higher rate of innovation in one nation need not come at the expense of others. Increasing the rate of innovation in many nations can improve their productivity and prosperity and collectively speed the rate of world economic growth.

Ultimately, innovation also holds the potential to address our most pressing social and human challenges. Many policy discussions assume the existence of a sharp tradeoff between goals such as health, environment, safety, and short-term economic growth. However, a healthy rate of innovation increases the likelihood that new technologies will emerge that substantially temper or even eliminate such tradeoffs.

Over the last several years, we have undertaken a series of research projects aimed at evaluating the role of location in innovation and the ways in which the geographic distribution of innovation has shifted over time.[i] In this paper, we first review our framework for understanding national differences in the intensity of innovation. Then we extend our prior studies by drawing on new data and more nuanced measures available from the 2001 *Global Competitiveness Report* (GCR). We use these data to rank countries in terms of national innovative capacity along a series of dimensions (see Table 1).

Table 1: Innovation capacity index and subindexes

	Innovative Capacity Index		Proportion of Scientists and Engineers Subindex		Innovation Policy Subindex		Cluster Innovation Environment Subindex		Linkages Subindex	
COUNTRY	RANK	INDEX	RANK	INDEX	RANK	INDEX	RANK	INDEX	RANK	INDEX
United States	1	30.3	6	4.3	1	8.1	1	10.9	1	7.1
Finland	2	29.1	7	4.2	4	7.3	2	10.9	3	6.7
Germany	3	27.2	11	4.1	7	7.0	4	9.9	10	6.1
United Kingdom	4	27.0	18	3.9	13	6.8	3	10.0	9	6.3
Switzerland	5	26.9	13	4.0	15	6.7	5	9.9	7	6.3
Netherlands	6	26.9	23	3.8	3	7.4	14	9.2	4	6.6
Australia	7	26.9	8	4.2	10	6.8	9	9.4	5	6.5
Sweden	8	26.9	2	4.5	21	6.1	6	9.8	6	6.5
France	9	26.8	9	4.1	6	7.1	10	9.3	8	6.3
Canada	10	26.5	14	4.0	5	7.3	12	9.2	11	6.1
Israel	11	26.5	19	3.9	14	6.8	15	9.1	2	6.7
Japan	12	26.4	1	4.5	12	6.8	7	9.7	21	5.4
Singapore	13	26.0	17	3.9	2	7.4	17	8.9	15	5.8
Taiwan	14	26.0	16	4.0	9	6.9	8	9.6	17	5.6
Belgium	15	25.4	15	4.0	11	6.8	19	8.8	14	5.8
Ireland	16	25.4	12	4.0	16	6.6	16	9.1	16	5.7
Austria	17	25.3	29	3.5	8	6.9	11	9.3	18	5.5
Norway	18	25.3	5	4.3	18	6.4	21	8.6	12	5.9
Denmark	19	25.2	10	4.1	19	6.4	20	8.8	13	5.9
Iceland	20	24.8	4	4.3	20	6.2	18	8.8	20	5.5
Spain	21	23.4	30	3.5	17	6.5	23	8.4	28	5.0
Italy	22	23.3	31	3.5	23	6.0	13	9.2	30	4.7
Korea	23	22.9	22	3.9	24	5.6	24	8.3	24	5.1
New Zealand	24	22.1	28	3.6	35	5.0	27	8.0	19	5.5
Portugal	25	21.6	35	3.3	22	6.0	33	7.7	31	4.7
Czech Republic	26	21.3	36	3.2	26	5.5	29	7.9	29	4.7
Estonia	27	21.2	25	3.8	36	5.0	36	7.4	27	5.0
Hungary	28	21.1	34	3.3	25	5.6	38	7.2	25	5.0
South Africa	29	21.0	38	3.1	40	4.7	26	8.1	26	5.0
Russia	30	20.6	3	4.4	52	4.1	30	7.8	42	4.3
Slovenia	31	20.4	20	3.9	32	5.2	50	6.8	33	4.5
Ukraine	32	20.3	21	3.9	56	4.1	28	7.9	35	4.4
Brazil	33	20.1	48	1.9	27	5.4	25	8.2	32	4.6
Slovakia	34	20.0	26	3.7	49	4.5	35	7.6	44	4.2
Chile	35	19.7	42	2.6	31	5.4	34	7.6	45	4.2
Poland	36	19.6	32	3.5	50	4.5	37	7.2	36	4.4
Lithuania	37	19.2	24	3.8	55	4.1	45	6.9	34	4.4
India	38	18.9	59	1.2	39	4.8	31	7.8	23	5.2
Costa Rica	39	18.8	41	2.7	38	4.8	42	7.0	38	4.3
Trinidad and Tobago	40	18.6	49	1.9	41	4.7	32	7.7	39	4.3
Latvia	41	18.5	37	3.1	51	4.2	43	7.0	47	4.1
Greece	42	18.4	39	3.0	33	5.1	60	6.3	50	4.0
China	43	18.1	44	2.3	46	4.6	44	6.9	41	4.3
Turkey	44	17.8	46	2.1	34	5.0	49	6.8	55	3.9
Panama	45	17.4	55	1.5	42	4.7	39	7.2	51	4.0
Thailand	46	17.4	60	0.8	30	5.4	40	7.1	49	4.1
Mauritius	47	17.2	45	2.1	43	4.7	59	6.4	52	4.0
Egypt	48	17.2	43	2.3	44	4.7	66	5.9	43	4.3
Argentina	49	17.0	40	2.9	54	4.1	48	6.8	68	3.3
Bulgaria	50	16.9	27	3.7	64	3.6	67	5.8	56	3.8
Uruguay	51	16.8	51	1.8	47	4.6	52	6.7	58	3.8
Malaysia	52	16.8	63	0.7	28	5.4	54	6.5	46	4.2
Mexico	53	16.8	50	1.8	45	4.6	46	6.9	63	3.5
Indonesia	54	16.4	47	1.9	48	4.6	58	6.4	62	3.5
Romania	55	16.3	33	3.4	65	3.6	53	6.6	73	2.7
Philippines	56	15.8	58	1.2	62	3.8	47	6.8	53	3.9
Sri Lanka	57	15.5	56	1.4	60	3.9	62	6.1	48	4.1
Venezuela	58	15.2	54	1.5	57	4.0	61	6.1	60	3.6
Colombia	59	15.1	53	1.5	58	3.9	63	6.1	61	3.5
Peru	60	14.3	52	1.6	71	3.4	65	6.0	64	3.3
Vietnam	61	13.8	70	0.0	69	3.5	55	6.5	57	3.8
Dominican Republic	62	13.6	68	0.0	61	3.9	57	6.4	65	3.3
Guatemala	63	13.2	66	0.4	70	3.5	64	6.0	66	3.3
Paraguay	64	13.1	64	0.7	66	3.6	68	5.8	72	2.9
Zimbabwe	65	13.0	69	0.0	63	3.6	71	5.5	54	3.9
Nicaragua	66	12.7	62	0.8	72	3.2	70	5.5	69	3.1
El Salvador	67	12.5	71	-0.2	59	3.9	69	5.8	71	3.0
Honduras	68	11.9	65	0.4	67	3.6	72	5.4	75	2.6
Ecuador	69	11.9	61	0.8	73	3.2	74	4.9	70	3.0
Bangladesh	70	11.6	67	0.1	74	3.0	73	5.2	67	3.3
Bolivia	71	11.6	57	1.4	75	2.8	75	4.8	74	2.6
Hong Kong SAR	NA	NA	NA	NA	29	5.4	22	8.6	22	5.2
Jamaica	NA	NA	NA	NA	53	4.1	51	6.7	37	4.3
Jordan	NA	NA	NA	NA	37	4.8	56	6.4	40	4.3
Nigeria	NA	NA	NA	NA	68	3.6	41	7.0	59	3.7

Our findings reveal the striking degree to which the national environment matters for success in innovative activity, and they highlight sharp differences in the environment for innovation across both OECD and emerging economies. The analysis suggests that subtle aspects of a country's institutional and microeconomic environment play an important role in determining the productivity of investments in innovation. Though our results are subject to caveats common to any quantitative study focusing on the causes and consequences of innovation, the findings provide a consistent set of implications for policymakers attempting to enhance the locational foundations of innovation, and with it, international competitiveness.

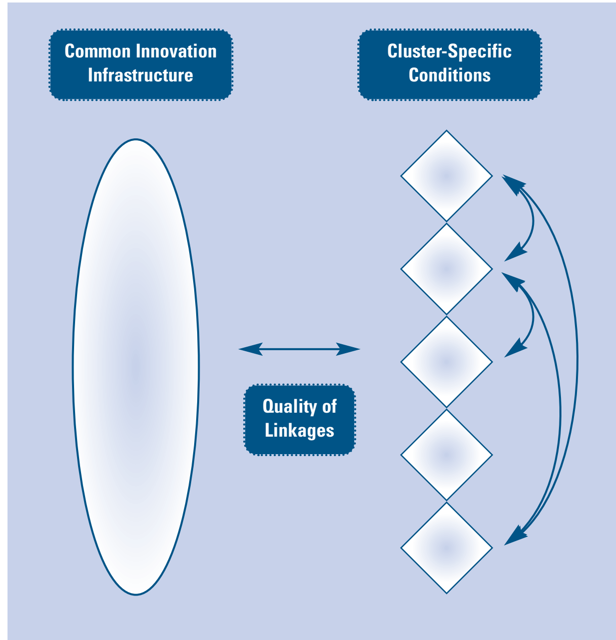
The determinants of national innovative capacity

The vitality of innovation in a location is shaped by *national innovative capacity*. National innovative capacity is a country's potential—as both a political and economic entity—to produce a stream of commercially relevant innovations. This capacity is not simply the realized level of innovation but also reflects the fundamental conditions, investments, and policy choices that create the environment for innovation in a particular location or nation. National innovative capacity depends in part on the technological sophistication and the size of the scientific and technical labor force in a given economy, and it also reflects the array of investments and policy choices of the government and private sector that affect the incentives for and the productivity of a country's research and development activities. National innovative capacity is also distinct from both the purely scientific or technical achievements of an economy, which do not *necessarily* involve the economic application of new technology.

The national innovative capacity framework aims to identify the factors enabling a region to innovate at the global frontier. Although the framework was created for application at the national level, it can also be employed to evaluate innovative capacity at the regional or local level.

National innovative capacity depends on three broad elements that capture how location shapes the ability of companies in a particular location to innovate at the global frontier (see Figure 2). Of course, taking advantage of the national environment for innovation is far from automatic, and companies based in the same location will differ markedly in their success at innovation. Nevertheless, sharp differences in innovative output in different locations suggest that location exerts a strong influence.

Figure 2: Elements of national innovative capacity



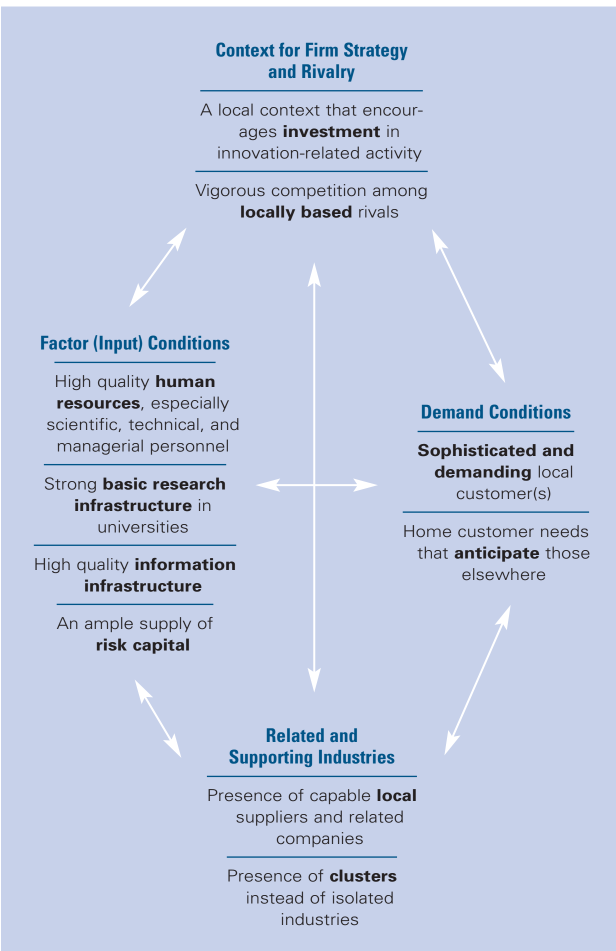
The common innovation infrastructure

A nation's *common innovation infrastructure* is the set of crosscutting investments and policies supporting innovation throughout an entire economy. This set includes the overall human and financial resources a country devotes to scientific and technological advances, the public policies bearing on innovative activity, and the economy's level of technological sophistication. The foundation of a nation's common innovation infrastructure is its pool of scientists and engineers available to contribute to innovation throughout the economy. A strong common innovation infrastructure is also built on excellence in basic research, which advances fundamental understanding and is at the root of much new commercial technology, where government funding remains essential in virtually every country. Crosscutting innovation policy areas include the protection of intellectual property, the extent of tax-based incentives for innovation, the degree to which antitrust enforcement encourages innovation-based competition, and the openness of the economy to trade and investment. Overall, a strong common innovation infrastructure requires a set of national investments and policy choices stretching over decades.

The cluster-specific environment for innovation

Although the common innovation infrastructure sets the basic conditions for innovation, it is ultimately companies that introduce and commercialize innovations. Innovation and the commercialization of new technologies take place disproportionately in clusters—geographic concentrations of interconnected companies and institutions in a particular field. The cluster-specific innovation environment is captured in the "diamond" framework (see Figure 3).[ii] Four attributes of a location's microeconomic environment affect the rate of innovation in a cluster as well as its overall competitiveness—the presence of high-quality and specialized inputs, a context that encourages investment coupled with intense local rivalry, pressure and insight gleaned from sophisticated local demand, and the local presence of related and supporting industries.

Figure 3: The national environment for innovation



Clusters reflect important externalities in innovation that are contained in particular geographic areas. Presence within a cluster offers potential advantages to firms in perceiving both the need and the opportunity for innovation. Equally important, however, are the flexibility and capacity in clusters to act rapidly to turn new ideas into reality. A company within a cluster can often more rapidly source the new machinery, services, components, and other elements to implement innovations. Local suppliers and partners can and do get involved in the innovation process; the complementary relationships involved in innovating are more easily achieved among participants that are nearby. Reinforcing these advantages of clusters for innovation is the sheer pressure—competitive pressure, peer pressure, customer pressure, and constant comparison—that is inherent within a concentrated group of firms in the same field. We focus on clusters (eg, information technology) rather than individual industries (eg, printers), then, because of powerful spillovers and externalities across discrete industries that are vital to the rate of innovation.

The global competitiveness of a cluster depends importantly on its innovation orientation. For example, the Finnish pulp-and-paper cluster benefits from the multiple advantages of pressures from demanding domestic consumers and paper companies, intense local rivalry, and Finnish process-equipment manufacturers that aretop of the line, with companies such as Kamyr and Sunds leading the world in the commercialization of innovative bleaching equipment. This is only one example out of many. A strong innovation environment within national clusters is the foundation for innovation-based competitive advantage in many fields, from pharmaceuticals in the United States to semiconductor fabrication in Taiwan.

The quality of linkages

The relationship between the common innovation infrastructure and a nation's industrial clusters is reciprocal: Strong clusters feed the common infrastructure and also benefit from it. A variety of formal and informal organizations and networks—which we call "institutions for collaboration"—can link the two areas. An especially important example is a nation's university system, which provides a particularly strong and open bridge between technology and companies. Without strong linkages, a nation's upstream scientific and technical advances can diffuse to other countries more quickly than they can be exploited at home. For example, although early elements of VCR technology were developed in the United States, it was three companies in the Japanese consumer electronics cluster that successfully commercialized this innovation on a global scale in the late 1970s.

Measuring national innovative capacity

To assess the sources of differences in innovative capacity across countries, we extend our prior research using new data and measures drawn from the GCR Survey. Using country-level data on innovative output, we identify elements of the national innovation environment with a statistically significant relationship to innovation. These elements are then used to calculate rankings reflecting how countries fare along each of the major dimensions of innovative capacity, as well as to construct an overall national innovative capacity ranking.

National innovative capacity is inherently difficult to measure for several reasons. First, measures of innovative output are imperfect (only certain types of innovation can be measured) and subject to some random fluctuations. Second, traditional data sources make it difficult to develop measures associated with the more nuanced drivers of innovative capacity, such as innovation policy and the cluster-specific innovation environment.

Because our focus here is on innovation at the technology frontier and on comparing innovation across nations, the single most useful measure of innovation is "international" patenting, measured by the number of patents the US Patent and Trademark Office (USPTO) granted to foreign and US inventors in 1999 and 2000. Over the past quarter century, there has been a dramatic increase in the rate of international patenting—from fewer than 25,000 per year in the late 1970s to more than 100,000 by the late 1990s.

We used USPTO patents as a measure of realized national innovative performance for several reasons. When a foreign inventor files a US patent, it is a sign of the innovation's potential economic value because of the costs involved. Also, the use of US patents helps ensure a standard of technological excellence that is at or near the global technology frontier. Of course, no single measure of innovation is ideal. In our related research, we have explored several alternative measures of innovation success, such as the pattern of exports in international high-technology markets. Overall, however, international patents constitute the best available measure of innovation that is consistent across time and location.[iii]

We employ regression analysis to evaluate the relationship of international patenting to nuanced measures of the innovation environment. The regression analysis allows us to assign the *relative* weights to individual elements in our innovative capacity rankings. This procedure provides a level of confidence that our country-level assessments of innovative capacity are clearly tied to long-term measures of international innovative performance.

Assessing innovative capacity across countries

To examine the linkage between realized innovation and measures associated with national innovative capacity, the analysis proceeds in three steps. First, we control for population and historical technological sophistication, and include a measure of the commitment of human resources to innovative activity.[iv] To do so, we regress the national level of international patenting in a sample of 75 countries in 1999 to 2000 on total population, the proportion of scientists and engineers employed within the nation, and a metric of the "stock" of international patents generated by a country between 1985 and 1994.[v] This baseline analysis includes each country's historical patenting in order to account for past differences in the ability of countries to innovate at the international frontier, as well as differences in their propensity to patent their inventions in the United States. The control for population allows us to focus on per capita rates of international patenting, which should relate most closely to a nation's standard of living.[vi] The patent stock number varies substantially across countries and time, as does the number of technological personnel, which is affected by a set of national human resource policies. For example, though their living standards are similar, the percentage of the workforce who are scientists and engineers is three times higher in Japan than in Italy or Spain.

Strikingly, over 80 percent of the total variance in international patenting across the world, controlling for population, can be explained by these two determinants of national innovative intensity. In other words, countries vary significantly in their historical ability to produce global innovation. They also vary significantly in their current resource commitment to innovative activity.

Creating subindexes

This regression becomes the baseline for further analysis. Of the baseline variables, the one that is most affected by current policy is the number of scientists and engineers. To assess national innovative capacity, then, we include the proportion of scientists and engineers in the workforce as the first measure. We use this measure to construct a scientific and technical personnel subindex.

The ranking of countries using this subindex is shown in the second column of Table 1. Japan ranks number1, followed by Sweden. A number of smaller countries, such as Norway and Finland, rank highly. The United States is number 6, well below its overall innovative capacity ranking. This reveals a shortage of scientific and technical graduates that represents a real issue for the United States. Russia ranks higher on this subindex despite a relatively low overall ranking, as do a number of other former Soviet bloc countries. This reflects a legacy of technical training that could emerge as an important strength if other dimensions of competitiveness and innovative capacity can be improved.

Using the baseline regression as a foundation, we then systematically explore the role of innovation-related public policy, the cluster innovation environment, and the strength of linkages on innovation performance. Consider Table 2. For each country, we calculate the difference between the actual and predicted level of international patenting based on the baseline factors, and calculated the percentage gap relative to actual patenting. Some countries—such as the United States, Japan, and Korea—have a patenting level well above that predicted by the baseline model. Others, such as Spain and Russia, are substantially below the benchmark. In the remainder of this paper, we focus on whether measures drawn from the Survey can help explain this gap between predicted and realized international innovation performance.

Table 2: Residuals of the baseline regression model

Country	Standardized Residuals (%)*
United States	94
Paraguay	93
Japan	87
Taiwan	82
Honduras	82
Korea	81
Germany	77
Dominican Republic	72
Canada	66
Malaysia	66
United Kingdom	61
Slovenia	59
France	58
Thailand	52
Bolivia	49
Israel	49
Singapore	48
Sweden	46
Italy	45
Switzerland	44
Netherlands	44
Ukraine	41
Finland	33
Belgium	31
India	28
Costa Rica	28
Austria	25
Denmark	25
Mauritius	13
Guatemala	11
Australia	5
El Salvador	0
New Zealand	–19
Panama	–28
Norway	–28
Uruguay	–34
Brazil	–34
Mexico	–34
Ecuador	–35
Iceland	–37
Spain	–40
Venezuela	–42
Ireland	–53
Argentina	–94
Chile	–96
China	–123
Greece	–131
South Africa	–142
Egypt	–152
Colombia	–158
Philippines	–165
Peru	–236
Sri Lanka	–248
Czech Republic	–259
Romania	–274
Russia	–290
Turkey	–331
Portugal	–335
Indonesia	–381
Hungary	–445
Poland	–454
Trinidad and Tobago	–457
Bulgaria	–5925

*Note: After removing logs and obtaining the residuals, we standardize them by dividing by the actual values.

There are 24 Survey measures that are closely related to innovative capacity and that can be classified into three distinct groupings: innovation-related public policy, the cluster innovation environment, and the strength of innovation linkages. The variables in each of these groupings and the bilateral regressions are listed in the first column of Appendix A. Elements of the innovation policy environment, for example, include such measures as the "effectiveness of intellectual property," "the level of research in public research institutions," and the "effectiveness of competition policy in promoting efficiency." Similarly, measures of the cluster innovation environment include the "presence and depth of clusters," "the sophistication and pressure of local buyers," "the quality of suppliers," and the "availability of specialized research and training services."

We introduced each of these variables, one at a time, into the baseline specification. The results are striking. Out of the 24 measures, 23 proved to be positive as expected and statistically significant.[vii] In other words, even after controlling for the size of a country, the aggregate level of human resources devoted to innovation, and the stock of past ideas to build on, nuanced measures of the national environment are closely associated with the level of innovation realized by a country. This strongly supports the need to go beyond the more aggregate measures available in most of the previous economic literature, and reveals the importance of utilizing surveys and other means to assemble data on hard-to-measure dimensions of national economies.

To build an innovative capacity index, it was not feasible to include all 24 variables in a multivariate regression analysis. The reason is straightforward: Nearly all of the measures are themselves highly correlated with each other. In nearly all cases, the correlation is extremely high (particularly given that our analysis relies on a single cross-section of 75 countries). For measures drawn from similar portions of the GCR Survey (eg, the domestic competition component), the correlation sometimes reaches over .9. Therefore, rather than attempt to disentangle the distinct effects associated with each measure, we created a parsimonious specification using a few variables from each subgroup.

The innovation policy subindex

To assess a nation's innovation public policy environment, three measures were selected, each with a strong and robust relationship to international patenting controlling for population, the patent stock, and the number of scientists and engineers in the workforce:

- The effectiveness of intellectual property protection
- The ability of a country to retain its scientists and engineers
- The size and availability of R&D tax credits for the private sector

To calculate the subindex, we added these three variables to the baseline regression. All the subindex results are reported in Appendix B. Each measure is statistically significant, and each is predicted to have a substantial impact on the level of international patenting. For example, increasing the Survey response on intellectual property protection from 4 to 5 on a scale of 7 (less than one standard deviation) is associated with a 50 percent increase in a country's level of international patenting. The innovation policy subindex for each country is calculated as the weighted sum of the three measures, with the weights determined by the regression coefficients of each measure in the specification presented in Appendix B.

The third column of Table 1 presents the innovation policy subindex ranking. The United States registers the highest ranking, followed by Singapore, the Netherlands, Finland, Canada, and France. Surprisingly, a number of non-OECD economies, including Singapore as well as Taiwan and Israel, register rankings in the top 20, while large OECD economies, including Italy and Korea, lag behind. Sweden is notably weak on this subindex, which pulls down its overall ranking.

Latin American economies register surprisingly weak rankings; Brazil, Chile, and Costa Rica record the best showings, though all are outside the top 25. Though economies such as Mexico and Brazil have shown promising improvements in international competitiveness over the past decade, they have not developed the type of innovation policy environment that supports innovation at the world technology frontier.

Perhaps even more interesting are the results for India and China. Though often cited as emerging innovator countries, both register innovation policy rankings far below that of the main OECD economies. These countries have also not achieved the quality of innovation policy environment found in other emerging economies such as Singapore and Israel. Nevertheless, as will be evident in later analysis, their innovative capacity is more advanced than would be predicted by their current level of income.

The cluster innovation environment subindex

A similar calculation underlies the cluster innovation environment subindex. After exploring a number of the measures, we selected three measures of the cluster innovation environment to use to rank countries:

- The sophistication and pressure to innovate from domestic buyers
- The presence of suppliers of specialized research and training
- The prevalence and depth of clusters

As before, each of these measures is statistically significant and has a quantitatively significant impact on the rate of international patenting, even after controlling for population, the historical propensity to innovate, and the size of the R&D workforce. The cluster innovation environment subindex is calculated by adding together these three factors, using the weights calculated in the regression.

The fourth column of Table 1 reports the results. Finland is virtually tied with the United States as offering the best cluster environment for innovation. Relative to their policy rankings, the United Kingdom, Germany, Switzerland, Sweden, and Japan register relatively high rankings on the cluster innovation environment, while Singapore, the Netherlands, Canada, and France lag on this dimension. These patterns reflect important differences in innovative potential across countries, which are often misunderstood by analyses that focus only on policy indicators. Such weaknesses are also obscured by looking only at short-term innovative performance. Innovative performance is not simply a result of aggregate policy but also of the development and growth of clusters in the private sector. Finland and Germany, for example, have made long-term commitments to nurturing clusters; this commitment is an important source of the continuing competitive advantage held by companies in these countries in technology-intensive sectors.

Among the emerging economies, Israel, Taiwan, Singapore, and Ireland each possess a cluster innovation environment comparable with that of mainstream OECD economies, and outdistance countries such as Spain and Korea along this dimension. Once again, China and India are associated with only a modest cluster innovation environment relative to the most innovative countries. However, China and India are well positioned when compared with most Eastern European and Latin American economies, which have cluster innovation environments that are not yet developed. Brazil and Costa Rica are countries in Latin America that have a higher ranking along this dimension compared with that of their peers.

The linkages subindex

The fourth and final subindex measures the strength of linkages between the common innovation infrastructure and a country's clusters. As discussed earlier, this is perhaps the most difficult area in which to find measures, since it depends on relatively subtle forms of interaction between public sector institutions and private sector initiatives. The subindex is based on two Survey measures that capture important dimensions of the process by which a country's innovation resources are directed toward the needs of individual clusters:

- The overall quality of scientific research institutions
- The availability of venture capital for innovative but risky projects

The overall quality of scientific research institutions (as perceived by managers within a country) highlights the importance of universities and other institutions for collaboration in fostering linkages.[viii] The availability of venture capital reflects the importance of risk capital in translating basic research into commercializable innovation. Each measure is statistically and quantitatively significant in its predicted impact on the rate of international patenting, even after controlling for the baseline variables. The linkages subindex is the weighted sum of the two measures, with the weights determined by the regression coefficients as in the prior subindexes.

The fifth column of Table 1 reports the results. The United States is comfortably at the top of the ranking in this area, followed by Israel and Finland. Relative to the other subindexes, Japan registers a dramatically lower ranking, falling out of the top20. Australia and Sweden improve their relative positions.

These results suggest that countries vary widely in their ability to build universities and other open research institutions, and in their ability to foster collaboration between them and the private sector. This area is particularly slow and challenging, and requires attitudinal shifts and a sustained policy commitment. Whereas Israel's innovation policy has largely succeeded because of initiatives aimed at fostering linkages (Trajtenberg forthcoming), Japan continues to suffer from a relative lack of world-class research institutions and collaboration between such institutions and the private sector. This will limit Japan's ability to become a stronger innovator across a wide variety of industrial areas.

No emerging economy except Israel registers in the top ten on the linkages subindex. Singapore, Taiwan, and Ireland all show relative weakness in this difficult and slow-to-build area. As before, the OECD economies of Italy and Spain have significant disadvantages in this area, as do the Latin American and Eastern European economies.

The national innovative capacity index

All four subindexes are combined into an overall innovative capacity index. The overall index is calculated as the unweighted sum of the subindexes.

The first column of Table 1 reports the results. The United States is ranked first, followed by Finland. Germany, the United Kingdom, Switzerland, the Netherlands, Australia, Sweden, and France round out the first tier. The overall ranking accords well with our earlier research and that of others on the patterns of international innovation. Over the past quarter century, the set of top-tier innovator economies has expanded to include many of the Northern European countries. More recently, Australia, Japan, Israel, and Taiwan have moved to high levels. Singapore has also moved to a high level, though its performance is partly the result of an abundance of US multinationals who have located there. This convergence in innovation achievement among a set of OECD economies is strongly tied to a substantial upgrading in the environment for innovation.

One interesting difference from previous work that emerges in this study is the ranking of Japan. Our earlier research revealed that Japan was developing the elements associated with first-tier level of innovative capacity. We see that here in Japan's strength in scientific and technical personnel. However, this study reveals Japan's weaknesses in innovation policy and in establishing strong linkages, resulting in a lower ranking in the overall innovative capacity index. Japan will need to progress in these areas if it is to become a more broadly based Innovation-Driven economy.[ix]

Overall, the OECD is responsible for the great majority of global innovation, reflecting a more favorable environment for innovation in these advanced economies. However, some of the Asian economies—most notably Taiwan and Singapore, as well as Israel outside Asia—have achieved the conditions to support innovation at a rate consistent with many Western European economies.

Many other areas of the world lag badly behind in innovative capacity. China and India are still at a quite early stage of development in terms of global innovation, though they are progressing well relative to their current level of per capital income. Some Asian economies, such as Indonesia, Malaysia, and Thailand, are far behind their Asian peers in innovative capacity, a major challenge.

Despite impressive improvements in macroeconomic stability over the past two decades in Latin America and positive political change in Eastern Europe, these areas of the world still do not offer environments that support innovation at the global frontier. Similarly, African nations are lagging: none is ranked above 29. South Africa, however, has an innovative capacity index that is higher than expected, given its overall level of economic development.

Corporate practices and innovation

Successful innovation depends not just on a favorable business environment but also on supportive company operating practices and strategies. National innovative capacity in the business environment and corporate behavior tend to move together. Companies must adjust their competitive approaches to attain higher levels of innovative output. Our Survey data allow us to characterize some of the shifts in corporate practices that are associated with countries that produce the highest output of international patents.

The GCR Survey includes 19 measures of the types of corporate strategies and operating practices that are characteristic of each country. We include each of these variables individually in the baseline model, and test for the size and significance of the influence. Again, the relatively high correlation among most of the variables precludes a meaningful multivariate analysis.

Abbreviated results of this analysis are shown in Table 3. First and foremost, the results reveal that firms in innovator countries have strategies that aim for unique products and processes rather than relying on low cost labor or natural resources. Firms in these countries are willing to invest heavily in R&D, and have moved beyond extensive use of technology licensing. Companies focus on building their own brands, controlling international distribution, and selling globally, all of which are complementary to innovation-based strategies. Organizationally, firms from innovator countries engage in extensive training of employees, delegate authority down the organization, and make greater use of incentive compensation than firms in countries with lower innovation output. We will explore the corporate correlates of innovative capacity more fully in subsequent reports.

Table 3: Operations and strategy variables—regressions

Dependent Variable	Coef.	*t*	Adj. R^2
Nature of Competitive Advantage	0.955	6.50	0.8959
Value Chain Presence	0.984	5.89	0.8874
Extent of Branding	0.928	4.50	0.8669
Uniqueness of Product Designs	1.063	4.24	0.8629
Production Process Sophistication	1.229	6.02	0.8892
Extent of Marketing	1.068	4.53	0.8673
Degree of Customer Orientation	0.927	3.26	0.8484
Control of International Distribution	1.218	3.98	0.8590
Prevalence of Foreign Technology Licensing	0.018	0.07	0.8212
Company Spending on R&D	1.263	6.86	0.9005
Extent of Regional Sales	0.443	2.21	0.8348
Breadth of International Markets	0.875	5.02	0.8747
Extent of Staff Training	0.987	4.59	0.8683
Willingness to Delegate Authority	0.939	4.40	0.8654
Extent of Incentive Compensation	0.923	3.97	0.8589
Reliance on Professional Management	0.399	1.53	0.8280
Quality of Management Schools	0.225	1.04	0.8244
Efficacy of Corporate Boards	0.401	1.63	0.8289
Internet Use leading to Inventory Cost Reduction	0.820	3.30	0.8491

*Note: Patents regressed on baseline and individual company operations and strategy variables.

Innovative capacity, competitiveness, and prosperity

Having developed the innovative capacity index, we examine the relationships between the index and our overall assessment of overall competitiveness (the Current Competitiveness Index) with the economy-wide prosperity (GDP per capita) in Figures 4 and 5.

The innovative capacity index and the Current Competitiveness Index are highly correlated (see Figure 4). Improving innovative capacity is integral to achieving the high levels of productivity necessary to achieve and sustain overall competitiveness. Most countries track the regression line from the overall sample. Those countries that diverge from the regression line tend to fall into a number of categories. One category is the countries of the former Soviet bloc (eg, Russia, the Ukraine, and Bulgaria), whose high proportion of scientists, engineers, and research institutions makes their innovative assets more advanced than their overall business environments. A second category of countries that diverge from the overall relationship are those that have access to particularly favorable natural resources or low labor costs relative to their level of economic sophistication (eg, Chile, New Zealand, South Africa, Turkey, and Malaysia). These other sources of competitiveness give these countries Current Competitiveness Index rankings that are significantly higher than their innovative capacity. A final category of countries departing from the typical relationship between innovative capacity and competitiveness are those with an unusual focus on innovation (eg, the United States, Israel, Taiwan, and Costa Rica).

Figure 4: The relationship between innovative capacity and the Current Competitiveness Index

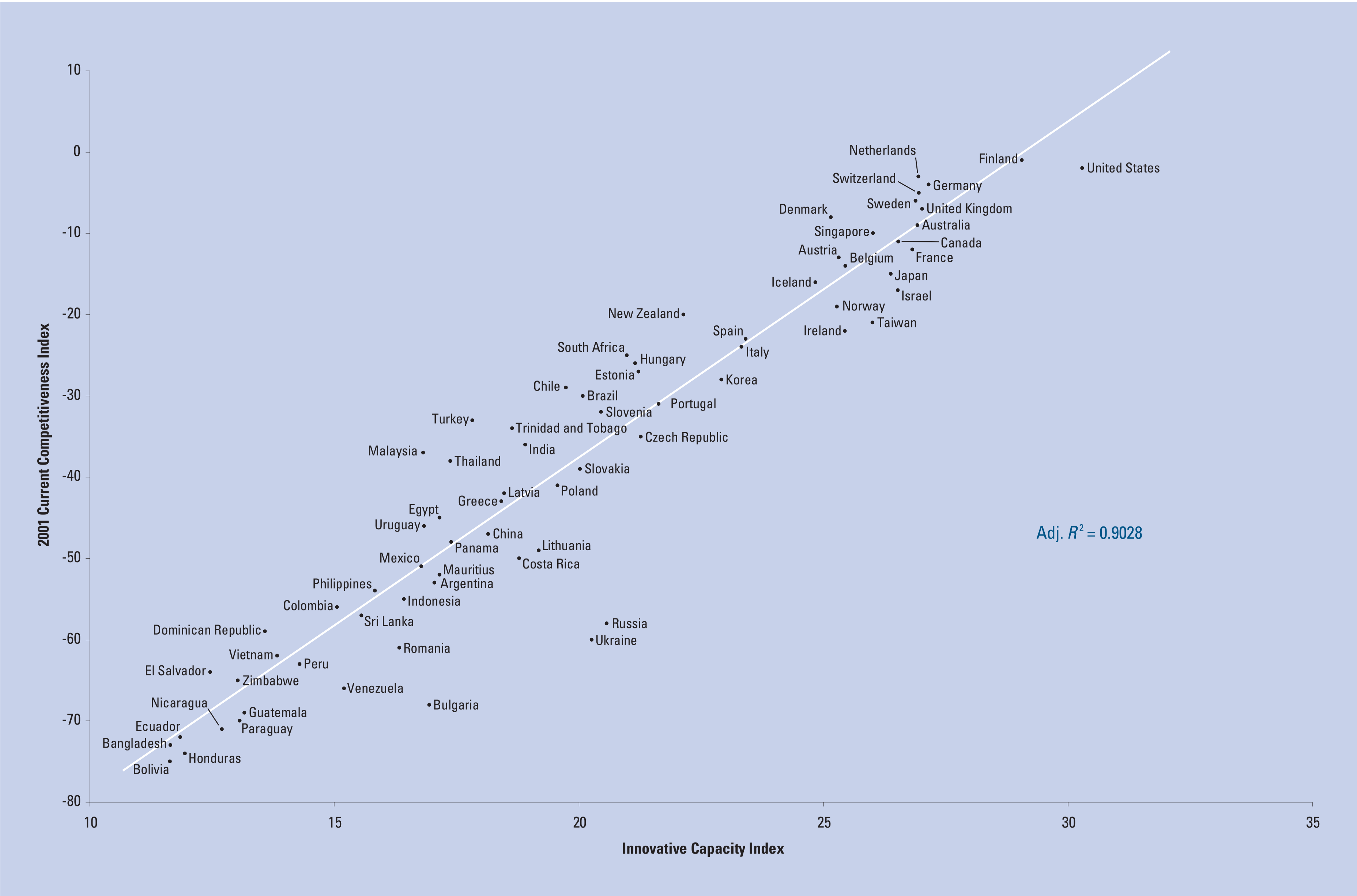
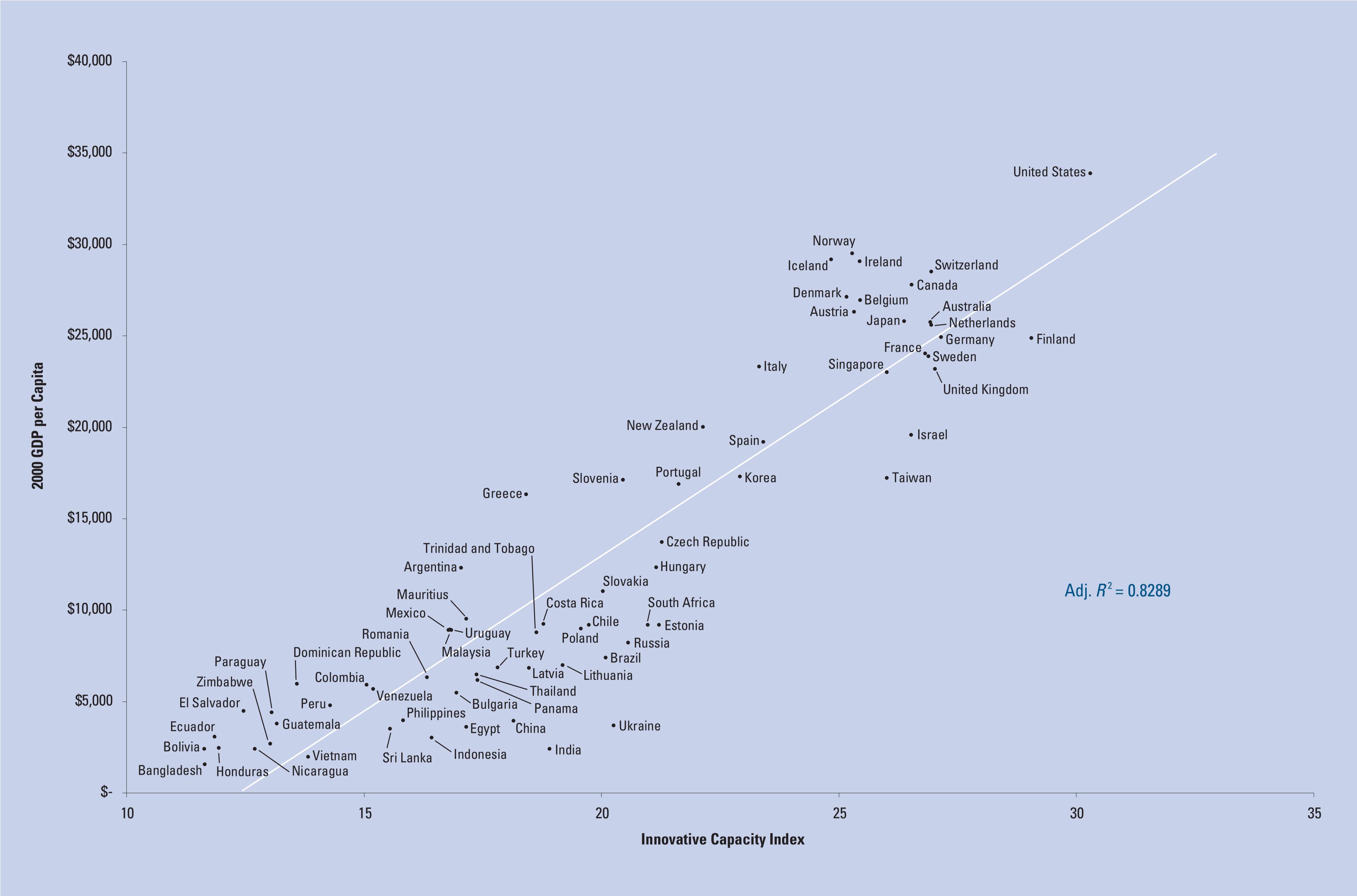


Figure 5: The relationship between innovative capacity and GDP per capita



The relationship between innovative capacity and GDP per capita (Figure 5) is also revealing. The correlation is again high, but noticeably lower than the correlation with overall competitiveness. Analysis of the particular countries that are near, above, or below the regression line is suggestive of a number of economic development models. The first model, represented by countries falling on or near the regression line, is what might be termed "balanced development." Innovative capacity grows in parallel with overall competitiveness to produce a rising standard of living. Over time, successful countries move along the regression line to higher levels of income. A second model, represented by the countries above the regression line, involves reliance on natural resources or a favorable geographic location vis-à-vis other nations to produce a higher standard of living than would be justified by innovative capacity. Countries such as Norway, Iceland, Denmark, Greece, and Argentina fall into this group. Italy's position on the figure may be distorted by the sharp differences between the north and the south.

The United States, interestingly, falls above the regression line even though it is the leader in innovative capacity. This means that the United States' lead in innovative capacity is not great enough to explain its high income. This could reflect a disequilibrium in which US per capita income comes under pressure. More likely, however, is that high US income reflects the fact that the United States also enjoys abundant natural resources, a huge economy, and extraordinary political power in the world.

A third development model, represented by countries falling well below the regression line, is to grow innovative capacity *ahead* of the sophistication of the overall economy to pull the economy forward. China, India, Taiwan, Israel, and Finland are examples of this group of countries. Countries of the former Soviet bloc may be outliers not because of an innovation led national strategy, but because of a legacy of training scientists and engineers and building research institutions.

The consequences of each of model for the rate of economic growth are intriguing. Countries following the innovation-led model tend to be faster growing than those relying on natural endowments. Countries differ in their initial assets, however, which also affects their success. We will explore these issues in subsequent *Report*s.

Conclusions

Innovation has become perhaps the most important source of competitive advantage in advanced economies, and building innovative capacity has a strong relationship to a country's overall competitiveness and level of prosperity. We have offered a framework for analyzing national innovative capacity, drawing on our previous research, and used it to construct an innovative capacity index that allows us to rank countries on overall innovative capacity as well as its important components. Although the data available and statistical procedures face real limitations, the rankings both square with knowledge about individual countries and are revealing of strengths and challenges facing each country surveyed.

Those economies, such as Finland and Taiwan, that have proactively built innovative capacity, have prospered. In contrast, limited focus on innovative capacity will constrain the progress of countries such as Greece and Norway as well as many countries in Latin America and Eastern Europe. Building national innovative capacity will represent the fundamental development challenge facing many countries for years to come.

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Notes

i For a complete exposition of the framework, see J. Furman et al, "The Determinants of National Innovative Capacity," *Research Policy*, forthcoming, as well as M. E. Porter et al (1999), *The New Challenge to America's Prosperity: Findings from the Innovation Index*. Briefly, this framework synthesizes and extends three areas of prior theory: ideas-driven endogenous growth (Romer 1990), cluster-based national industrial competitive advantage (Porter 1990), and national innovation systems (Nelson 1993).

ii For a more complete exposition of the diamond framework and its role in understanding the origins of national competitive advantage, see Porter (1990; 1998).

iii For a more thorough discussion of the use of patenting and international patenting data (and alternatives) in studies of the causes and consequences of innovation, see J. Furman et al, "The Determinants of National Innovative Capacity," *Research Policy*, forthcoming. Trajtenberg (1990) provides a thorough discussion of the role of patents in understanding innovative activity, stretching back to their use by Schmookler (1966) and noting their ever-increasing use by scholars in recent years (eg, Griliches 1984; 1990; 1994). The use of international patents also has precedent in prior work comparing international inventive activity (see Dosiet al 1990; Eaton and Kortum 1996).

iv This specification is simply the "ideas" production function, as developed in endogenous growth theory (Romer 1990). See Porter and Stern (2000) for a full derivation of our empirical formulation.

v We employ the natural logarithm (or a function of the logarithm) of all of these variables, to smooth out the variation in country size and also to provide for easily interpretable coefficient estimates. Science and engineering resources are drawn from several data sources, as summarized in *World Development Indicators*. Specifically, data for OECD countries are drawn from the OECD Main Science and Technology Indicators, Latin American data are drawn from the RICYT, and the Asian data are drawn primarily from the science and technology statistics from individual countries. We were unable to establish a reasonable baseline measure of resources devoted to innovation for four countries, and so we exclude these countries from the regression analysis (though we do include them as available in the rankings).

vi It would also have been possible to control for differences across countries in their overall level of prosperity by including GDP per capita as a variable in this baseline specification. Though we have used this formulation in our related work (see Furman et al2001 for more details), our focus here is on *explaining* the drivers of prosperity, and so we focus our analysis on measures more closely related to the microeconomic foundations of competitiveness in our analysis.

vii It is important to note that the close relationship between each of the 24 measures and international patenting is not a statistical artifact. We explored a wider set of Survey measures (40 in all) with some conceivable relationship with innovation. Those variables most distant from the national innovative capacity framework (such as the overall quality of government) were not significantly related to the level of international patenting.

viii We also experimented with a measure of extent of collaboration between the private sector and leading research institutions. The quality of scientific research institutions measure was marginally more significant and highly correlated with the collaboration measure, so we included it in the subindex.

ix These findings are consistent with our in-depth study of Japan reported in Porter et al, *Can Japan Compete?*, MacMillan Press, 2000.

Appendix A: Subindex regressions

Dependent Variable = Log of US Patents, 1999–2000	Baseline			Innovation Policy Variables			Cluster Variables			Linkages Variables		
Independent Variables	Coef.	*t*-stat	Adj. R^2	Coef.	*t*-stat	Adj. R^2	Coef.	*t*-stat	Adj. R^2	Coef.	*t*-stat	Adj. R^2
Baseline Model												
			0.824									
Log of Patent Stock Metric (patents issued between 1985 and 1994)	3.141	7.070										
Log of Population in 2000	0.231	1.810										
Log of Proportion of Full-time Employed Scientists and Engineers	0.507	2.490										
Controlling for the Baseline Model												
Intellectual Property Protection				0.816	4.220	0.863						
Quality of Math and Science Education				0.114	0.550	0.822						
Attractiveness of National Environment for Retaining Scientists and Engineers				0.776	4.000	0.859						
Company Spending on R&D				1.263	6.860	0.901						
Government Subsidies for R&D				0.669	3.000	0.845						
Government R&D Tax Credits				0.660	3.590	0.853						
Government Procurement of Advanced Technology Products				0.916	2.730	0.841						
Presence of Demanding Regulatory Standards				1.065	4.210	0.863						
Effectiveness of Anti-Trust Policy				0.746	3.150	0.847						
Stringency of Environmental Regulations				0.882	4.220	0.863						
Buyer Sophistication							0.959	3.950	0.859			
Local Supplier Quality							1.144	4.530	0.867			
Consumer Adoption of Latest Products							0.897	3.370	0.850			
State of Cluster Development							0.978	4.390	0.865			
Local Availability of Specialized Research and Traning Services							1.205	4.350	0.865			
Extent of Product and Process Collaboration							1.514	4.960	0.874			
Manufacturing of Information Technology Hardware							0.751	4.950	0.874			
Uniqueness of Product Designs							1.063	4.240	0.863			
Production Process Sophistication							1.229	6.020	0.889			
Inventory Cost Reductions Due to Internet							0.820	3.300	0.849			
Absorption of New Technology										1.246	4.270	0.863
Quality of Scientific Research Institutions										1.107	3.860	0.857
University/Industry Research Collaboration										0.894	3.520	0.852
Venture Capital Availability										0.746	3.830	0.857

Appendix B: Subindex regression models

INNOVATION POLICY SUBINDEX

Regression Statistics	
Adj. R^2	0.8841
Standard Error	1.0396
Observations	64

	Coef.	Std. Error	*t*-stat	P-value
Intercept	–11.6892	2.1325	–5.4815	0.0000
Log (Patent Stock Metric)	1.7808	0.4512	3.9465	0.0002
Log (S&E Proportion)	0.3085	0.1705	1.8099	0.0756
Log (Population)	0.4434	0.1219	3.6388	0.0006
Intellectual Property Protection	0.4707	0.2101	2.2402	0.0290
Attractiveness of Natl. Env. for Retaining S&E	0.4204	0.2070	2.0309	0.0469
Government R&D Tax Credits	0.4600	0.1703	2.7003	0.0091

CLUSTER INNOVATION ENVIRONMENT SUBINDEX

Regression Statistics	
Adj. R^2	0.8891
Standard Error	1.0169
Observations	64

	Coef.	Std. Error	*t*-stat	P-value
Intercept	–12.1029	2.2140	–5.4665	0.0000
Log (Patent Stock Metric)	1.8455	0.4408	4.1866	0.0001
Log (S&E Proportion)	0.3517	0.1190	2.9547	0.0045
Log (Population)	0.1162	0.1786	0.6503	0.5181
Buyer Sophistication	0.4582	0.2495	1.8364	0.0715
State of Cluster Development	0.5519	0.2361	2.3373	0.0230
Local Avail. of Spec. Research and Training Services	0.8034	0.2713	2.9616	0.0045

LINKAGES SUBINDEX

Regression Statistics	
Adj. R^2	0.8618
Standard Error	1.1351
Observations	64

	Coef.	Std. Error	*t*-stat	P-value
Intercept	–10.6576	2.2179	–4.8054	0.0000
Log (Patent Stock Metric)	1.9583	0.4862	4.0276	0.0002
Log (S&E Proportion)	0.4063	0.1213	3.3500	0.0014
Log (Population)	0.2854	0.1922	1.4850	0.1430
Quality of Scientific Research Institutions	0.6728	0.3790	1.7753	0.0811
Venture Capital Availability	0.4407	0.2572	1.7135	0.0920