# International Linkages and National Innovation Rates: An Exploratory Probe[1]

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## Abstract

*The conventional wisdom among political economists holds that domestic institutions determine national innovation rates. However, after decades of research, there is still no agreement on precisely which domestic institutions matter or exactly how they affect innovation rates. Anecdotal observations within the research on institutions suggest that international linkages may be the missing piece to the national innovation rate puzzle. An exploratory probe is therefore performed here using regression analysis of various measures of innovation, domestic institutions, and international linkages. The results suggest that countries' relationships with the lead innovator strongly affect their innovation rates. The probe further suggests that research should move beyond institutions and linkages, and should focus instead on their political origins. That is, the current focus on institutions or linkages studies effects, not causes. It fails to get at the politics of technological change: the fundamental choices which nations must make in order to innovate successfully in the long run.*

**KEY WORDS:** distributive politics, domestic institutions, educational exchanges, foreign direct investment, national innovation rates, trade

## Introduction

Among political economists, the conventional wisdom holds that domestic institutions determine national innovation rates. However, after decades of research, scholars have yet to identify any specific institution, or set of institutions, that consistently explain innovation rates across time and space. This article argues that much of the existing domestic institutions literature that seeks commonalities does not help us to solve the national innovation rate puzzle. Certainly countries need institutions in order to overcome the fundamental political economic obstacles to innovation, but the empirical evidence reveals a myriad of different institutional designs by which to do so. Failure to appreciate this diversity tends to force scholars into a never-ending search for the "right" institutions that determine national innovation rates and economic growth. This article argues that this search is futile, and may yield little in the way of generalizeable results.

However, anecdotal observations within the evidence provided by domestic institutionalists suggest that certain kinds of international linkages (e.g., capital goods imports, foreign direct investment, educational exchanges) might have a significant role in determining national innovation rates. Further, because political-economic research on innovation rates tends to focus solely on domestic institutions, failure to control for international linkages may constitute a source of omitted variable bias in these studies. In order to probe this possibility, regression analysis is performed on various measures of innovation, domestic institutions, and international relationships. The results suggest that international linkages with the lead innovator (the United States) strongly affect countries' innovation rates, even when controlling for some prominent domestic institutions. But as with institutions, this data fails to identify any specific linkage, or set of linkages, that consistently explain innovation rates across time and space.

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If institutions and linkages do not necessarily create a technologically innovative economy, then what does? This article speculates that, at root, a country's success in accomplishing its technological goals ultimately depends upon its ability to sustain interest in allocating resources toward, and accepting the disruptions caused by, technological progress. Indeed, without sustained interest in technological progress, even a country with "good" institutions and linkages will not use them to achieve higher innovation rates. Also, because sustained technological change involves issues of resource allocation and economic distribution, then it will depend upon politics. Therefore, understanding the politics of technological change is essential for explaining differences in national innovation rates.

The conventional research focus on institutions and linkages ignores the politics of technological change. It assumes that technological change is a widely supported national goal, and then attempts to identify which are the "best" national strategies (institutions, policies, linkages) by which to achieve this goal. This preoccupation prevents scholars from getting at the fundamental choices that nations must make in order to successfully increase innovation rates in the long run. If we want to explain differences in national innovation rates, then they must follow the relevant institutions and linkages back to the domestic political bargains from which they originated, and the international context within which these bargains occurred. Thus this article seeks to provide a detour around the endless debate over "best" institutions and points toward a more promising discussion about politics.

This research is new in several respects. First, it challenges the prevailing sentiment regarding a deterministic relationship between domestic institutions and innovation that, despite its problems, remains little criticized. Second, it does so by examining the roles of several independent variables which have either not previously been considered or not simultaneously controlled for in single tests. Third, the research presented here is more generalizeable than much prior research in that linkages are investigated below using data on cross-national quantitative datasets covering several decades, rather than single case studies. Finally, it suggests a new avenue of innovation research, one in which institutions and linkages are redefined as tools rather than causal forces. The primary research question then becomes: why do some nations choose to pursue innovation, and to employ these costly tools, rather than determine whether a "best" tool exists?

## Domestic Institutions and National Innovation Rates

Over the years, a number of explanations for differences in national innovation rates have been proposed by researchers across the social sciences; however, explanations based on domestic institutions have come to dominate the innovation debate within political economy. Why? Institutions are the proximate tools that governments use to promote innovation, and institutions differ across the industrialized democracies as do innovation rates, therefore a causal linkage between domestic institutions and technological change makes sense to many policy makers and empirically minded innovation scholars. Some of these scholars highlight the nonrival and nonexcludable aspects of inventive activity, thus casting innovation as a public goods problem (Aghion & Howitt, 1998; Arrow, 1962; Hall & Jones, 1999; Romer, 1990). Other scholars emphasize the high levels of uncertainty, risk, high

transactions costs, and incomplete information associated with innovation (Nelson, 1959; North, 1990). Still other researchers call attention to the distributive aspects of technological change, and the ability of interest groups hurt by it to influence government policy and obstruct innovation (Acemoglu, Johnson, & Robinson, 2005; Mokyr, 1990; Solingen, 1996).

In theory, domestic institutions help solve all of these problems. Institutions solve the free-rider problem by providing selective incentives. Institutions also lower information and transaction costs; they lower and spread risk and uncertainty. Hence as social scientists, when we see the problems associated with the production of scientific public goods, we are naturally drawn to institutional explanations. Finally, properly designed domestic institutions can also prevent the Stiglerian capture of government policy by status-quo interest groups who might oppose technological change. Thus domestic institutions have come to play a determining causal role in theories of national innovation rates.

Yet, despite decades of research, scholars have yet to identify any specific institution or set of institutions that consistently explain innovation rates across time and space.[2] Indeed, both qualitative case studies and statistical analysis find nations with all varieties of domestic institutions innovating at all different levels (Breznitz, 2007; Nelson, 1993; North, 1990; Rodrik, 2007; Taylor, 2007; Zysman, Nielsen, Breznitz, & Wong, 2007). There are simply many countries with "good" institutions that do not innovate at the technological frontier (e.g., Spain, Norway, Australia), and many countries with "bad" institutions that have nonetheless built impressive records of technological progress (e.g., Japan, Taiwan, South Korea, Israel). Thus the debate has evolved into a curious situation where there exists a wide consensus among political economists that domestic institutions determine innovation rates, but no agreement on precisely how this happens, exactly which institutions matter, and with little aggregate evidence supporting any particular hypothesis.

## International Linkages: Anecdotal Observations

International linkages are often overlooked as an independent variable in the aforementioned debates over innovation, but an interest in international linkages emerges out of the research on institutional theories. First, empirical studies consistently point to the United States as an important outlier in global patterns of innovation. Meanwhile, innovation scholars also observe that many of the world's most innovative countries are those that also tend to have the strongest military and economic ties with the United States, such as Japan, Canada, the UK, Israel, and Taiwan (Taylor, 2004). Second, there are strong indications of an important role for international linkages within the empirical evidence put forward by domestic institutionalists themselves, who often cite the importance to innovation of foreign technical assistance, international joint ventures, contacts with foreign suppliers and consumers, and other forms of cross-national contacts (Amsden, 1989, 2001; Kim & Nelson, 2000; Yamashita, 1991). Third, atheoretical histories of technological development and industrialization in eighteenth-, nineteenth-, and twentieth-century Europe and the United States are replete with instances of national innovation rates being affected by international linkages (Cowan, 1997; Jeremy, 1991). And these phenomena are not necessarily limited to technological catch-up by lesser

**Table 1.** International Relationships Important for National Innovation Rates

| |
|---|
| • Overseas training and education in science engineering |
| • Use of foreign consultants and technical assistance |
| • Overseas plant visits |
| • Consultations with foreign capital goods & high technology suppliers/consumers |
| • Inward FDI in production and R&D facilities from more advanced countries |
| • Mergers and acquisitions |
| • Joint R&D projects |
| • Immigration of scientists, engineers, and highly skilled labor |
| • Establishing R&D facilities in high-tech countries |
| • Attendance to international expositions, conferences, & lectures |
| • Technology licensing |
| • Imports of capital goods and high technology products |

developed states, because even advanced industrialized nations seem to benefit technologically from ties to lead innovators (Cantwell, 1995; Keller, 2004).

Together, these stylized observations suggest a possibility: that in order to better understand differences in national innovation rates, research should examine more deeply the effects of international linkages. International linkages may affect innovation rates by acting as conduits for valuable scientific and technical knowledge, by allowing the formation of epistemic communities, or perhaps via mechanisms not yet identified. This is not to argue that domestic institutions are insignificant, but that failure to control for the scope and depth of a country's relationships may constitute a source of omitted variable bias. Therefore linkages such as those listed in Table 1 should be examined for their effects on innovation. Such a plausibility probe will comprise the next section of this article.

## Methods and Data

If the international linkages listed in Table 1 are important for explaining differences in national innovation rates, then such linkages should be evident in the empirical data. That is, countries with more of these kinds of international linkages and higher levels of them, should be observed to innovate relatively more than countries that are less well connected, even when we control for the quality of domestic institutions. In order to probe for this in the empirical data, we turn in this section to ordinary least squares (OLS) regression analysis of innovation rates, international linkages, and domestic institutions across several dozen countries during the 1980–95 period.

Time-series cross-section (TSCS) regressions are applicable here, but they are not my first choice because there is still significant debate over which standard error calculations are the most appropriate for my data, and how accurate are the resulting estimates. These issues are further complicated by the relative brevity of the time series used, the bell-shaped characteristics of citations-weighted innovation data, and the tendency for fixed-effects to sweep out the significance of slowly changing domestic institutions measures. I therefore use TSCS as supplementary analysis, to corroborate the less problematic, more transparent OLS regressions.

Of course, one also has to ask: can we conduct such an investigation given the paucity of causal theory? Yes! First, it is important to point out that the purpose here

is *not* theory testing: I do not seek to rigorously specify or test a particular hypothesis or causal mechanism. Rather, the purpose here is to conduct an exploratory probe of anecdotal anomalies observed by researchers. Thus the relatively thin theoretical foundations are not a major hindrance; the purpose here is to examine anomalies upon which we might generate future theory and a shift in the research program. And although this article is a predominately empirical exercise, it is certainly not *ex nihilo*. It queries the plausibility of an often ignored avenue of research. Finally, despite its simplicity, a probe of the type described further in the article has never been reported: researchers have not yet controlled for international linkages when testing domestic institutions.

#### *Dependent Variable: Innovation*

As my measure of innovation, I follow the established practice of using citations-weighted patents (per capita). The patent data is taken from the National Bureau of Economic Research (NBER) patent dataset of over 2.9 million utility patents granted by the U.S. Patent & Trademark Office (USPTO) to applicants from the United States and 162 other countries during 1963–99, and the 16 million citations made to these patents between 1975 and 1999 (Hall, Jaffe, & Trajtenberg, 2001). Because patent measures suffer increasing construct-validity problems when they are disaggregated into smaller time and space units, my regressions are conducted on three consecutive 5-year subperiods (1980–85, 1985–90, 1990–95). Also, because a time lag may occur between the activity of independent variables and their effects on innovation rates, the independent variables are lagged 1, 5, and 10 years in the regressions wherever possible.

Nonetheless, for those scholars who remain skeptical of citations-weighted patents as a measure of innovation, the results reported here have been corroborated with regressions using as an alternate measure of innovation: a factor analysis of three independent and distinct measures of innovation: citations-weighted patents (per capita), citations-weighted scientific publications (per capita), and high-technology exports (per GDP).

#### *Independent Variables: International Linkages*

Unfortunately, there is no single variable which captures the myriad international linkages listed in Table 1. Also, different countries have different combinations of these international linkages depending on their availability, costs, benefits, and historical experience. For example, discussions of innovation in Japan have highlighted that country's reliance on the reverse-engineering of imports, licensing, and the use of foreign consultants (Morris-Suzuki, 1994); while Israel has depended heavily on the immigration of scientists and high-skilled labor (Gandal, Hanson, & Slaughter, 2004; Toren, 1994); and many Finnish firms prefer to establish ties with major foreign research universities (Steinbock, 2001). While this diversity handicaps empirical research, we can as a "first cut" look at some of the most likely, and best-measured, indices of international linkages to see if there is any macrolevel evidence at all for a relationship between international linkages and national innovation rates. These measures include (each vis-à-vis the United States): graduate

students sent to study science or engineering in U.S. universities, imports of capital goods from, inward FDI received from, and outward FDI into the United States. Clearly, these measures only capture an imperfect subset of the many international linkages listed in Table 1, and therefore the results should be interpreted as a step in a larger research program.

Also, each of these measures focuses specifically on countries' relationships with the lead innovator, the United States. Although this is done primarily for purposes of data availability and cost, it also has several desirable properties. First, the international linkages described in the last section should ideally be geared toward relatively more innovative countries, preferably the lead innovator. In other words, Mexico (or any other country) should gain far more by establishing multiple strong ties with the world's leading innovator, as opposed to creating these same ties with, say, Spain. Second, limiting the observables to relationships with the United States actually strengthens the probe of these relationships. Continuing the previous example, Mexico sends its students to study science and engineering in the United States, Spain, Britain, and several other advanced countries. Ideally we would want data on all of these student flows. But by restricting measurement of student flows to those destined only for the United States, a potential bias is created *against* finding evidence supporting an international linkages relationship, and thus a stronger probe. On the other hand, focusing only on linkages with the United States also introduces the possibility of selection bias: there may be some variable specific to U.S. linkages that affects national innovation rates. Note that this would not nullify a positive finding of the significance of international linkages, but rather would particularize it to the United States. This issue will be discussed further later.

As for the specific observables used to measure international linkages, first I use science and engineering PhD's awarded by U.S. graduate schools to foreign students. This data is collected annually by the National Science Foundation in their Survey of Earned Doctorates (SED). Second, I use United Nations data on imports of capital goods, which Alice Amsden emphasizes as being important for technical development both for their ability to directly transfer technology,[3] but also knowledge in the form of international consultants and technical advice from the exporting firm (Amsden, 2001). Finally, FDI, in either direction, is a major conduit of scientific and technical knowledge, and here I use United Nations (UNCTAD) data. Inward FDI not only brings in plant, equipment, and research facilities, but along with it expertise and training from the investing firms (Yamashita, 1991). For outward FDI, I focus on FDI into the United States, which often represents foreign firms setting up shop to capture spillovers of tacit knowledge from U.S. domestic R&D (United States Department of Commerce, 1992, 1987).

Finally, in some of the regressions to be presented, these measures of student flows, capital goods imports, and FDI are combined by means of factor analysis into a single "international linkages" factor, which is then used as an independent variable in the regressions. The summary statistics and factor analysis of the international linkages data (capital goods imports, FDI flows, student flows) are presented below in Table 2. Note the relative size of the eigenvalues, which strongly suggests that a single factor is appropriate, with its heaviest weighting in capital

**Table 2.** IR-Factor

Summary Stats of Components:

| Variable | Description | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| Infdius | Inward FDI from U.S.* | 434 | 2,431 | 13,607 | 0 | 243,797 |
| Capim | Capital goods imports (U.S.)* | 450 | 1,840 | 6,750 | 0 | 22,600 |
| Usphds | U.S. PhDs in science | 486 | 200 | 638 | 0 | 6,989 |
| Outfdi | FDI into U.S.* | 489 | 2,253 | 11,740 | –204.76 | 132,041 |

Factor Analysis:

| Factor | Eigenvalue | Difference | Cumulative |
|---|---|---|---|
| 1 | 2.15 | 2.11 | 1.10 |
| 2 | 0.04 | 0.15 | 1.12 |
| 3 | –0.10 | 0.03 | 1.07 |
| 4 | –0.14 | | 1.00 |

Creation of IR-Factor as a New Variable:

| Scoring coefficients: | (Based on unrotated factors) |
|---|---|
| Variable | New "International Relationships" Factor |
| Infdius | 0.31 |
| Capim | 0.42 |
| Usphds | 0.03 |
| Outfdi | 0.27 |

*Millions of $U.S. (previous 5 years).

goods imports, slightly less weightings in inward and outward FDI, and a relatively minor weighting in students sent to obtain science-engineering PhD's in U.S. graduate schools.

### *Independent Variables: Domestic Institutions*

While the effects of international linkages alone are of interest, in some regressions I also experiment with controls for some domestic institutions. The addition of these controls can tell us how large an effect international linkages have in the presence of these domestic institutions (and vice versa), and whether the effects of one set of variables are conditional on the other (via the use of multiplicative terms). They provide an initial probe of the interplay between institutions and linkages.

But which domestic institutions? Given space constraints and the probatory nature of this exercise, I focus on those institutions most likely to show a significant positive effect on national innovation rates: democracy, property rights, and markets for trading them. These are the institutions most often invoked by the conventional wisdom and by innovation scholars, development researchers, and growth economists including Arrow (1962), Mokyr (1990), Nelson (1993), Acemoglu and others (2005) and Rodrik (2007). While these scholars may disagree on specific policies and institutional designs, they all describe democracy, property rights, and markets as essential "meta-institutions" upon which the success of other institutions and policies depend. Thus these are the institutions generally prescribed by social scientists, and even many policy makers, as the fundamental and core requirements for an innovative economy. Future research should experiment with others.

As my measure of democratic institutions, I employ Polity2 from the University of Maryland's *Polity IV Database*, which ranks nations on a −10 to +10 scale of democracy (Marshall, Jaggers, & Gurr, 2003). I alternately use the POLCON Index developed by Henisz (2000) and experiment with the Freedom House measures (1–7 scale) of "political rights," "civil liberties," and "free" (1–3 scale). As my measure of quality for property rights and markets, I use the "Economic Freedom of the World Index" produced by the Fraser Institute, which ranks the strength of nations' market institutions on a 1–10 scale. These institutional measures are frequently used by social scientists who study comparative institutions, and therefore allow me to conduct my probe with relative confidence. The summary statistics are provided in Table 3.

#### *Additional Control Variables*

The basic question we wish to ask here is: given a nation with a particular set of economic resources, at a particular level of development, to what extent do its international linkages and domestic institutions affect its innovation rate? Hence the additional control variables I focus on are found in the World Bank's *World Development Indicators* database: *GDP* (to control for the amount of economic resources upon which innovators can draw), *population* (to control for the number of potential innovators), and either *per capita electric power consumption* or *GDP per capita* (to control for base-level of economic development).[4] Finally, if a country's ability to innovate depends in part on its existing stocks of knowledge, then it is important to control for local science and engineering education. While level of development or a lagged dependent variable may partially control for this, in some regressions I also experiment with a control for *local science and engineering undergraduate students per capita*.

The regressions are based on log–log specification, except for the domestic institutions variables. The estimates are therefore less sensitive to outliers and can be interpreted in terms of elasticities; log–log models are also consistent with much of the prior work in this type of research (Furman, Porter, & Stern, 2002; Jones, 1998). This results in a primary regression model along the following lines:

$$\begin{aligned}\text{Innovation Factor}_{t=0\text{ thru }1} = {} & B_0 + B_1 * (\text{IL Factor}_{t=0}) + B_2 * (\text{Domestic Insts}_{t=0}) \\ & + B_3 * \text{Ln}(\text{Economic Resources}_{t=0}) \\ & + B_4 * \text{Ln}(\text{Level of Econ. Dvlpmnt}_{t=0}) \\ & + B_5 * \text{Ln}(\text{Domestic Sci-Eng students})\end{aligned}$$

where innovation in period $t = 0$ through $t = 1$ is a function of the independent variables at time $t = 0$. Questions about multicollinearity naturally arise with this combination of observables. Therefore I not only report the maximum variance inflation factor in each regression result, but also experiment with omitting some of the worst potential offenders.

## Regression Results

The first and most important finding of the regressions is that international linkages appear to strongly affect national innovation rates. Almost every regression yielded

**Table 3.** Summary Statistics

| Total Sample | | | | | | 1990–1995 period | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Obs | Mean | Std. Dev. | Min | Max | Variable | Obs | Mean | Std. Dev. | Min | Max |
| Cite-weighted patents per capita | 720 | 0.00028 | 0.000952 | 0 | 0.0086 | Cite-weighted patents per capita | 145 | 0.000203 | 0.000678 | 0 | 0.005817 |
| GDP | 563 | 1.59E + 11 | 5.81E + 11 | 7.85E + 07 | 6.25E + 12 | GDP | 133 | 1.83E + 11 | 6.97E + 11 | 9.17E + 07 | 6.25E + 12 |
| Population | 735 | 3.01E + 07 | 1.02E + 08 | 30,000 | 1.12E + 09 | POP | 148 | 3.51E + 07 | 1.19E + 08 | 42,170 | 1.12E + 09 |
| Per cap GDP | 563 | 6,963.21 | 9,192.50 | 101.6 | 50,081 | per cap GDP | 133 | 7,273.07 | 9,605.19 | 101.5772 | 44,725.5 |
| Democracy | 587 | –0.09 | 7.94 | –10 | 10 | Democracy | 117 | 1.95 | 7.73 | –10 | 10 |
| Econ freedom | 412 | 5.61 | 1.16 | 2.30 | 8.64 | Econ freedom | 99 | 5.68 | 1.21 | 2.937 | 8.219 |
| Free | 486 | 1.04 | 0.82 | 0 | 2 | Free | 124 | 1.12 | 0.83 | 0 | 2 |
| U.S. SE PhDs | 810 | 164.74 | 557.67 | 0 | 6,989 | U.S. SE PhD | 162 | 241.85 | 741.23 | 0 | 6,989 |
| IL-Factor | 416 | 0 | 0.92 | –0.42 | 11.09 | IL-Factor | 139 | 0.22 | 1.40 | –0.34367 | 11.09433 |
| Domestic SE undergrads per captia | 434 | 0.004168 | 0.003971 | 0 | 0.020472 | Domestic SE undergrads | 70 | 0.006672 | 0.005271 | 0.000184 | 0.020472 |

| 1985–1990 period | | | | | | 1980–1985 period | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Obs | Mean | Std. Dev. | Min | Max | Variable | Obs | Mean | Std. Dev. | Min | Max |
| Cite-weighted patents per capita | 145 | 0.000318 | 0.00106 | 0 | 0.008396 | Cite-weighted patents per capita | 145 | 0.000299 | 0.00098 | 0 | 0.007649 |
| GDP | 122 | 1.66E + 11 | 6.09E + 11 | 1.27E + 08 | 5.34E + 12 | GDP | 109 | 1.65E + 11 | 5.81E + 11 | 9.91E + 07 | 4.92E + 12 |
| POP | 148 | 3.24E + 07 | 1.10E + 08 | 35,000 | 1.04E + 09 | POP | 148 | 2.98E + 07 | 1.01E + 08 | 30,000 | 9.69E + 08 |
| Per cap GDP | 122 | 7,081.07 | 8,992.11 | 114.64 | 40,514.42 | Per cap GDP | 109 | 7,443.47 | 9,837.56 | 160.2024 | 50,080.53 |
| Democracy | 118 | 0.03 | 8.01 | –10 | 10 | Democracy | 118 | –0.54 | 8.00 | –10 | 10 |
| Econ freedom | 99 | 5.49 | 1.21 | 2.296 | 8.371 | Econ freedom | 93 | 5.46 | 1.14 | 2.932 | 8.644 |
| Free | 124 | 1.10 | 0.79 | 0 | 2 | Free | 118 | 1.01 | 0.80 | 0 | 2 |
| U.S. SE PhD | 162 | 184.77 | 580.84 | 0 | 5,244 | U.S. SE PhD | 162 | 175.17 | 581.24 | 0 | 5,177 |
| IL-Factor | 139 | –0.05 | 0.62 | –0.38071 | 3.917559 | IL-Factor | 138 | –0.17 | 0.36 | –0.41768 | 2.388347 |
| Domestic SE undergrads | 92 | 0.004482 | 0.003801 | 0 | 0.013831 | Domestic SE undergrads | 92 | 0.004803 | 0.003997 | 0 | 0.015736 |

a significant and positive coefficient for the "international linkages" factor (IL-Factor), regardless of regression technique employed, lag structure used, or control variable included (or omitted). Representative results of these regressions are tabulated in Tables 4–6. Also, the coefficients for the IL-Factor are relatively robust to changes in the regression model, though they do change significantly across different time periods and lag structures. The regressions suggest that in the 1990–95 period, a unit increase in the IL-Factor results in a 20–30% increase in innovation rates. Earlier time periods show an even greater effect of international linkages on innovation rates, as do longer lag structures. These effects are considerable when one considers that the mean IL-Factor for the entire dataset is approximately 0.0, with a standard deviation of 0.9. The time dependence of the IL-Factor could reflect a decrease in knowledge flows out of the United States over time, either due to the rise of Japan and Western Europe as competing sources of technical knowledge, or to a decline in demand due to countries such as Japan, South Korea, Finland, and Israel reaching the technological frontier.

How do we know that international linkages affect innovation rates, rather than the reverse? In other words, perhaps an increasing innovation rate is a prerequisite to receiving increased flows of FDI, capital goods imports, and so on, rather than an effect of them. I attempted to answer this question in several ways. First, I ran time-series cross-section regressions, which corroborated the OLS findings. Second, in a more transparent approach, I reran the OLS regressions above, but with increasing time lags between the independent and dependent variables (Table 4, middle columns). Again, I found that the coefficients for the IL-Factor are consistently positive and significant, and match the values of the coefficients produced in the nonlagged regressions fairly well. Third, the measure for economic development (either per capita electric power consumption or GDP per capita) should likewise control for countries' base level of technological capability. However, in order to be sure, in some regressions I add a control for the earliest level of national innovation rate possible with the data: citations-weighted patents received in 1970 (Table 3, rightmost columns). This observable allows me to control for each country's base innovation rate a full decade or two prior to the observed international linkages. Note that the while the 1970 patent measure is significant and positive in many regressions, its effect is small and its inclusion has little impact on the coefficients for the IL-Factor, except for the sole case of the 1980–85 time period.

Of course, the IL-Factor itself raises questions because, as one colleague warns, with enough wit and straining, one can create a weighted factor that explains just about everything. I therefore reran the IL-Factor's individual components independently. As one might predict, the individual components of the IL-Factor reveal a more complex story when run independently (Table 5). Outward FDI is consistently significant though small, with a 10% increase in outward FDI corresponding to a 1.5–2.4% increase in innovation rates. Over longer periods of time, however, student exchanges appear to have a greater impact. With a 10% increase in graduate science-engineering students sent abroad corresponding with a 2.5–5.5% increase in innovation rates after a decade. Inward FDI and capital goods imports are surprisingly weak and not robust across different models. At its strongest, a 10% gain in capital goods imports is reflected by a 0.4% gain in innovation rates, and inward FDI is only significant when domestic institutions are excluded from the

**Table 4.** Basic Models

| Dependent Var = Log (Citations-Weight Patents Per Capita) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | W/ time lag | | W/ lagged DV | | |
| Time for Dependent Var: | | 1990–1995 | 1985–1990 | 1980–1985 | 1990–1995 | 1990–1995 | 1990–1995 | 1985–1990 | 1980–1985 |
| Time for Indep. Vars: | | 1989 | 1984 | 1979 | 1984 | 1979 | 1989 | 1984 | 1979 |
| Level of Develpmt | Lagged DV (1970) | | | | | | 0.003 | 0.004 | 0.01 |
| | | | | | | | (0.002)* | (0.002)* | (0.003)** |
| | Log (gdppc) | 1.51 | 1.53 | 1.47 | 1.46 | 1.43 | 1.43 | 1.44 | 1.30 |
| | | (0.22)*** | (0.16)*** | (0.15)*** | (0.19)*** | (0.22)*** | (0.22)*** | (0.15)*** | (0.15)*** |
| Domestic Institutions | Democracy | 0.06 | 0.03 | 0.06 | 0.07 | 0.05 | 0.06 | 0.03 | 0.04 |
| | | (0.04) | (0.03) | (0.03)* | (0.03)* | (0.03) | (0.03) | (0.02) | (0.03) |
| | Econ freedom indx | 0.19 | 0.27 | 0.2 | 0.2 | 0.54 | 0.18 | 0.2 | 0.24 |
| | | (0.22) | (0.16) | (0.21) | (0.16) | (0.26)* | (0.21) | (0.15) | (0.18) |
| International Relationships | IL-Factor | 0.28 | 0.64 | 1.16 | 0.69 | 0.96 | 0.20 | 0.48 | 0.08 |
| | | (0.10)** | (0.16)*** | (0.27)*** | (0.19)** | (0.29)** | (0.10)* | (0.17)** | (0.35) |
| | _cons | −9.38 | −8.95 | −8.02 | −8.63 | −9.91 | −8.76 | −7.97 | −7.33 |
| | | (1.17)*** | (1.19)*** | (1.27)*** | (1.30)*** | (1.41)*** | (1.21)*** | (1.17)*** | (1.16)*** |
| | *R*-squared | 0.85 | 0.85 | 0.82 | 0.84 | 0.82 | 0.86 | 0.86 | 0.85 |
| | Number of obs | 74 | 72 | 65 | 74 | 68 | 74 | 72 | 65 |
| | Max VIF | 2.52 | 1.90 | 1.56 | 2.12 | 1.59 | 2.67 | 2.03 | 2.89 |

*p < .05, **p < .01, ***p < .001.

**Table 5.** IR Components

| | | Dependent Var = Log (Citations-Weight Patents Per Capita) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time for dependent var: | | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 |
| Time for indep. vars: | | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 |
| Level of Develpmt | log (gdppc) | 1.42 | 1.58 | 1.59 | 1.6 | 1.31 | 1.81 | 1.76 | 1.85 | 1.87 | 1.69 |
| | | (0.35)*** | (0.2)*** | (0.2)*** | (0.2)*** | (0.3)*** | (0.2)*** | (0.1)*** | (0.1)*** | (0.1)*** | (0.2)*** |
| Domestic Institutions | Democracy | 0.08 | 0.07 | 0.07 | 0.06 | 0.09 | | | | | |
| | | (0.05) | (0.04) | (0.04) | (0.04) | (0.04)* | | | | | |
| | econ freedom indx | 0.4 | 0.36 | 0.37 | 0.31 | 0.34 | | | | | |
| | | (0.40) | (0.23) | (0.23) | (0.23) | (0.3) | | | | | |
| International Relationships | Inward FDI | –0.07 | 0.01 | | | | –0.01 | 0.1 | | | |
| | | (0.06) | (0.04) | | | | (0.06) | (0.04)* | | | |
| | Cap imports | –0.007 | | –0.004 | | | –0.04 | | 0.02 | | |
| | | (0.03) | | (0.02) | | | (0.04) | | (0.02) | | |
| | U.S. phds | 0.17 | | | 0.16 | | 0.18 | | | 0.21 | |
| | | (0.16) | | | (0.09) | | (0.17) | | | (0.1)* | |
| | Outwrd FDI | 0.18 | | | | 0.22 | 0.15 | | | | 0.21 |
| | | (0.18)* | | | | (0.06)** | (0.08) | | | | (0.07)** |
| | _cons | –11.1 | –10.8 | –10.8 | –11.4 | –9.8 | –11.1 | –10.5 | –11 | –11.8 | –10.4 |
| | | (2.2)*** | (1.2)*** | (1.1)*** | (1.1)*** | (1.5)*** | (1.8)*** | (0.88)*** | (0.8)*** | (1.0)*** | (1.1)*** |
| | *R*-squared | 0.85 | 0.84 | 0.85 | 0.85 | 0.85 | 0.81 | 0.76 | 0.76 | 0.8 | 0.81 |
| | Obs | 59 | 75 | 77 | 76 | 60 | 63 | 95 | 96 | 85 | 64 |
| | Max VIF | 3.32 | 2.52 | 2.68 | 2.57 | 2.56 | 2.15 | 1.16 | 1.09 | 1.00 | 1.52 |

*p < .05, **p < .01, ***p < .001.

**Table 6.** Basic Models (with vs. without Institutions or IL-Factor)

| | | Dependent Var = Log (Citations-Weight Patents Per Capita) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time for depndt var: | | 1990–1995 | 1990–1995 | 1990–1995 | 1985–1990 | 1985–1990 | 1985–1990 | 1980–1985 | 1980–1985 | 1980–1985 |
| Time for indep. vars: | | 1989 | 1989 | 1989 | 1984 | 1984 | 1984 | 1979 | 1979 | 1979 |
| Level of Develpmt | log (gdppc) | 1.51 | 1.58 | 1.65 | 1.53 | 1.63 | 1.71 | 1.47 | 1.59 | 1.61 |
| | | (0.22)*** | (0.22)*** | (0.12)*** | (0.16)*** | (0.16)*** | (0.13)*** | (0.15)*** | (0.16)*** | (0.14)*** |
| Domestic Institutions | democracy | 0.06 | 0.07 | | 0.03 | 0.04 | | 0.06 | 0.07 | |
| | | (0.04) | (0.04) | | (0.03) | (0.03) | | (0.03)* | (0.03)* | |
| | econ freedom indx | 0.19 | 0.37 | | 0.27 | 0.43 | | 0.20 | 0.37 | |
| | | (0.22) | (0.23) | | (0.16) | (0.16)* | | (0.21) | (0.21) | |
| International Relationships | IL-Factor | 0.28 | | 0.36 | 0.64 | | 0.64 | 1.16 | | 1.41 |
| | | (0.10)** | | (0.12)** | (0.16)*** | | (0.19)** | (0.27)*** | | (0.32)*** |
| | _cons | −9.38 | −10.83 | −9.32 | −8.95 | −10.5 | −8.92 | −8.02 | −9.97 | 8.00 |
| | | (1.17)*** | (1.11)*** | (0.93)*** | (1.19)*** | (1.12)*** | (1.03)*** | (1.27)*** | (1.25)*** | (1.10)*** |
| | *R*-squared | 0.85 | 0.85 | 0.77 | 0.85 | 0.84 | 0.82 | 0.82 | 0.82 | 0.77 |
| | Number of obs | 74 | 77 | 93 | 72 | 75 | 78 | 65 | 69 | 73 |

*p < .05, **p < .01, ***p < .001.

regressions. Interestingly, if we combine capital goods imports and inward FDI into an "inward" integration term; and U.S. PhD students and outward FDI into an "outward" integration term, then the inward international linkages appear to have a negative effect on innovation rates, the outward international linkages appear to have a positive effect.

But most of these results were expected. They reflect the fact that different countries use different combinations of international linkages to increase their technological capabilities. Therefore we should not expect any single type of international linkage to have a powerful aggregate effect on innovation rates; rather, international linkages as a whole should, which is what the IL-Factor attempts to model. This is not to argue that we should accept the IL-Factor, or any other measure, blindly. But neither should we dismiss its usefulness simply because it has the potential for abuse or misinterpretation (as do all statistical constructs). Recall that the IL-Factor is intended here as a probatory device; a good measure, not a perfect one.

The second, and perhaps more interesting, result is that the coefficients for domestic institutions are generally small and often insignificant. The coefficients for the Polity 2 measure of democracy suggest that a unit increase in democracy results in a mere 2–9% increase in innovation, regardless of the model specification or lag time. These coefficients are only rarely significant, and even then often just barely at the $p < 0.05$ level. Substitution of the POLCON index for Polity 2 produces similar results while inclusion of both POLCON and Polity 2 together in the same regressions yields insignificant coefficients for both (variance inflation factors suggest that this is not due to multicollinearity). The substitution of Freedom House's measures of "political rights" or "civil liberties" for the Polity 2 measure produces similarly insignificant coefficients; however, the use of "Free," "Partly Free," and "Not Free" (1–3 scale) does produce strong and significant results, with a unit increase in "Free" corresponding to a ~60% increase in innovation. However, the mean value of the "Free, Partly Free, Not Free" measure is approximately 2.0, with a large standard deviation of 0.8, thus this is a particularly dull tool with which to measure democracy. Its coefficient may merely suggest that large shifts in democracy matter far more for innovation than do smaller shifts (such as those measured by Polity 2).

As with the democracy measures, the Economic Freedom measure is also generally insignificant throughout the regressions. The coefficients here are somewhat larger however, generally suggesting a ~20% increase in innovation rates (and sometimes as high as a ~50% increase) for a unit increase in economic freedom. Furthermore, in those rare cases where Economic Freedom is significant, it is often just barely so (at the $p < 0.05$ level). The effects of economic freedom do strongly increase in both significance and strength over time. When lagged, a unit increase in the Fraiser Index corresponds with a 50–80% increase in innovation rates a decade later. Beta coefficients suggest that economic freedom has, at best, just as powerful an effect as international linkages (or outward FDI). Thus while markets seem to perform better in these regressions than does democracy, their performance does not match the strong expectations of the ability of markets to affect innovation generated by free market theorists. Again, variance inflation factors suggest that high multicollinearity is not to blame for the poor performance by

domestic institutions. This conclusion is supported by a low correlation of the two main institutional measures, Polity 2 and Economic Freedom Index, with each other (ranging from 0.34 to 0.43 depending on the time period).

Interestingly, neither the strength of the IL-Factor nor the relative weakness of the domestic institutions measures is much affected by each other's presence or absence in the regression models. That is, the coefficients for the IL-Factor, and its individual components, remain relatively unchanged when the domestic institutions controls are omitted from the model. Likewise, the domestic institutions coefficients do not gain much strength or significance when the IL-Factor is omitted. This is not to say that there is no effect at all, since there clearly are some mild changes in values and significances. However, the regression results are fairly robust and reveal that we do not need to hold domestic institutions constant in order for international linkages to have their effects, nor does the IL-Factor absorb significance away from the domestic institutions.

Controls were also experimented with using data on local education of scientists and engineers. Theoretically, this local education variable should be important; however, their inclusion did not have a major effect on the other variables. This is likely due to variation in the quality and depth of science education programs across countries. Experiments with substituting a control for literacy tended to strengthen the significance and size of the IR coefficient, but had no consistent effect on institutions (though helping markets in some regressions). Experiments with substituting a control for education spending (as percentage of GNP) had little effect on the IR coefficient, but aided the coefficient for markets in some regressions. In no case was the coefficient for democracy significantly and positively affected in these experiments. Certainly controls for R&D spending would have been highly desirable; but, measures of these expenditures prior to the 1990s are spotty and inconsistent, and are often not comparable across time and country.

A final possibility for the results above is that domestic institutions might benefit innovation more in the advanced economies, while international linkages might be more helpful to lesser developed countries in a somewhat Gerschenkronian fashion. That is, with their luxury of having the advanced economies as models, backward economies may benefit more from international flows of technical knowledge which can be used by them to leap ahead, down a well-trodden path towards technological development. Conversely, advanced economies, by nature of their position at the economic frontier, must find their way forward more by experiment than by government direction. In these advanced economies, domestic institutions may be of more relative benefit, helping to alleviate the risks and information costs associated with experimentation; and since they are already innovating near the technological frontier, these economies may have relatively less to gain from international ties with other lead innovators. I experimented with two probes for this relationship. First I added controls for OECD membership and an interaction of OECD membership with the IL-Factor. The latter was not statistically significant, suggesting no conditionality. Second, I repeated this exercise, instead using a "wealthy" control, where "wealthy" is defined as being in the top 10% of GDP per capita. The "wealthy-IR" interaction term had little effect in the 1990–95 period but, as with the lone IL-Factor, the effect of the interaction term increased in

significance and size in earlier time periods. Thus the benefits for innovation from international linkages are neither particular to, nor higher for, lesser developed states.

## Alternate Explanations

The regressions reported above provide us with evidence of another route by which to understand national innovation rates. International linkages appear to have a strong, robust, and significant link to national innovation rates; even when controlling for democracy, property rights, and markets. I propose three possible explanations of these empirical findings, and recommend them as avenues to be more fully developed theoretically and explicitly tested in future research.

As with all statistical analyses, one potential explanation has to be methodological. Issues of construct validity and measurement error affect several of the measures used, and omitted variable bias is always a potential problem in macroeconomic regression analysis such as that reported here. Hence, the findings in this article could always be spurious, the result of bad measures or data, a missing control variable, or an overly vague factor analysis. Or of course, we may have simply not yet identified the right institutions, or combination of institutions, that affect innovation rates. However, I would argue that the data and models employed in this article contain no more potential errors or biases than are found in similar statistical analyses routinely performed by economic growth scholars or comparative political economists. Moreover, extensive use of data triangulation where possible, and experimentation with different model specifications, should establish an acceptable level of confidence in the general thrust of the results reported here. This is not to say that my data and methods cannot be improved upon, but rather that there is ample justification for accepting the more general results they produce.

A second possible explanation for the findings reported here is that domestic institutions may determine international linkages, and that this causal relationship is not being properly controlled for. The argument here would be that market institutions limit government discretion, while participatory democracy increases the input of diverse interest groups. These domestic institutions combine to increase investor confidence, both foreign and domestic, and thereby lead to greater innovation (Henisz, 2000; Jensen, 2003; Rodrik, 2000). Certainly there is considerable research which shows that extremely poor domestic institutions (child labor, forced labor, lack of property rights, incompetent bureaucrats, and so on) correspond with lowers levels of FDI, capital goods imports, educational exchanges, and so on (Braun, 2006; Harms & Ursprung, 2002). Also, high levels of regular expropriation do have a negative effect on inward FDI, general investment, and hence the basis for innovation.

However, there is also much research which suggests that domestic institutions need to be quite dysfunctional or perverse before they begin to interfere significantly with foreign trade and investment (Archer & DeRouen, 2007; Busse, 2004; Gallagher, 2002). Moreover, neither high levels of democracy nor free markets are requisites for avoiding institutional dysfunction. This is not to suggest that investors are indifferent towards strong property rights, political and economic stability, and minimal taxes, but rather that democracy and free markets do not always improve

these conditions. Indeed, according to recent scholarship, "good" institutions have actually worsened the incentives for investment in some countries (Biglaiser & DeRouen, 2006; Egger & Winner, 2004; Li & Resnick, 2003). In the last decade, empirical research using large cross-national time-series, regional datasets, and even single-country case studies have consistently found that general political and economic freedoms do not determine the international linkages important to innovation discussed here. Again, one need only consider the cases of Japan, Taiwan, South Korea, Israel, and so on (each of which achieved high innovation rates accompanied by either relatively repressive regimes, heavy government intervention in the economy, or both) to conclude that we need better research and more nuanced theorizing in this area.

For the sake of the exploratory probe I report here, I tried to further address these concerns in several ways. I experimented with two-way and three-way interaction terms, which were consistently insignificant, suggesting that the effects of international linkages are not conditional on either economic freedom or democracy.[5] Nor did regressions of the IL-Factor on domestic institutions reveal a strong linear relationship between the two: the standardized coefficients are significant but small, sensitive to time period and level of development, and the R2's are low (Table 7). Admittedly these are simple *prima facie* tests. I do not pretend that they fully resolve the issue, or that domestic institutions and international linkages have no connection. But they do suggest that the findings above cannot be cavalierly dismissed as unmodeled conditionality. They contribute to the evidence that national innovation rates present an anomaly which deserves greater attention, and cannot be explained away as a simple statistical error.

A third possible explanation for the findings reported here is that international linkages may determine domestic institutions, and thereby affect innovation rates. The argument here would be that international flows of technology, investment, people, and perhaps military alliances strengthen those domestic institutions that foster innovation. However, this hypothesis fails to meet some simple face validity tests. First, the same empirical analysis above which failed to find strong correlations between domestic institutions and international linkages applies equally well to a hypothesis of reverse causality. Second, this argument implicitly assumes a causal relationship between specific domestic institutions and national innovation rates. That is, international linkages would produce changes in domestic institutions which would then flow through to affect innovation. But as this article has emphasized, scholars have yet to identify any specific domestic institutions that determine innovation in the aggregate. Third, while international linkages clearly influence domestic institutions, and perhaps do so in a general manner (e.g., Keller, 2004), it is not clear that they produce specific institutional changes. For example, during the previous century, both the United States and U.S.S.R. used their international linkages to influence domestic institutions in nations around the world, but the results varied substantially, rarely produced close institutional duplication between mentor and disciple, and often had perverse outcomes (e.g., frequent U.S. support for dictatorships and economically interventionist governments). One could certainly argue that the United States has succeeded in generally spreading democracy and capitalism in many cases; but this has rarely resulted in the loyal replication of specific American democratic or capitalist institutions in foreign countries.

**Table 7.** Relationship between IR-Factor and Domestic Institutions

| | Dependent Var = IR-Factor | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time for DV: | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1990–1995 | 1985–1990 | 1980–1985 | 1985–1990 | 1980–1985 |
| Time for IV's: | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 | 1989 | 1984 | 1979 | 1984 | 1979 |
| Democracy | 0.35 | | 0.14 | 0.17 | 0.10 | | 0.05 | 0.07 | 0.29 | 0.30 | 0.17 | 0.16 |
| | (3.68)*** | | (2.31)* | (2.92)** | (1.45) | | (0.6) | (1.19) | (3.61)** | (3.13)*** | (1.98) | (1.89) |
| Econ freedom indx | | 0.48 | 0.42 | 0.31 | | 0.28 | 0.27 | 0.16 | 0.35 | 0.26 | 0.23 | 0.17 |
| | | (3.98)*** | (3.93)*** | (4.36)*** | | (2.88)** | (2.78)** | (2.14)* | (3.73)*** | (2.83)** | (2.42)* | (1.87) |
| Econ Freedom * Democ | | | | 0.32 | | | | 0.31 | | | | |
| | | | | (3.44)** | | | | (3.37)** | | | | |
| log (gdppc) | | | | | 0.43 | 0.28 | 0.28 | 0.26 | | | 0.27 | 0.29 |
| | | | | | (4.00)*** | (3.44)** | (2.99)** | (2.85)** | | | (2.68)** | (2.94)** |
| _cons | −3.72 | 0.25 | −2.91 | −2.31 | −2.96 | −4.15 | −4.05 | −3.27 | −1.10 | −0.68 | −1.69 | −1.19 |
| | (4.02)*** | (2.19)* | (3.96)*** | (4.33)*** | (4.09)*** | (4.29)*** | (4.17)*** | (4.81)*** | (4.08) | (3.74)*** | (4.49) | (4.33)*** |
| R-squared | 0.23 | 0.12 | 0.25 | 0.34 | 0.24 | 0.27 | 0.28 | 0.37 | 0.27 | 0.21 | 0.30 | 0.26 |
| Obs | 95 | 107 | 91 | 91 | 100 | 94 | 90 | 90 | 91 | 84 | 89 | 79 |

*p < .05, **p < .01, ***p < .001.

Coefficients reported above are standardized "beta" coefficients (*t*-stats in parentheses).

In sum, research shows that domestic institutions matter. But there is no single institution or set of institutions that determine innovation rates. International linkages also matter, but probably also not in a deterministic or generalizeable way. We do not need regressions or in-depth case studies to know that nations with a wide variety of international linkages innovate at all different levels. Finally, there is likely some interplay between countries' institutions and linkages, but the analysis above suggests that this may not be simple or generalizeable either. These results would seem to create a tangled mess of causality for the research scholar to unfold; the next section recommends a path out of this mess.

## Speculation

In this final section, I enter into admittedly speculative territory. I do not specify a particular hypothesis or model here. Instead I propose a shift in research focus prompted by the analysis above. We must begin this shift by recognizing that much of the existing domestic institutions literature which seeks commonalities does not help us to solve the innovation rate puzzle. Such research can force us to conclude, for example, that countries such as Germany or Japan are not that innovative, which is empirically untenable. For similar reasons, we should also avoid distracting debates over which are the "right" international linkages for achieving rapid innovation rates.

A growing body of empirical research broadly supports this assertion. As this article has shown, both domestic institutions and international linkages influence, but do not determine, national innovation rates. This is consistent with the findings of several other contributions to this special edition (Cowhey, Aronson, & Richards, 2009; Doner, Hicken, & Ritchie, 2009). Also, the *prima facie* evidence appears not to indicate a generalizeable causal relationship between institutions and linkages. Therefore we should explore the possibility that these two variables are *not* conditionally independent. That is, research should now ask whether there is some omitted variable that determines both national innovation rates *and* the institutions/linkages used to achieve (or obstruct) technological progress.

Some additional clarification is important. I do not argue here that causal relationships between institutions and linkages do not exist. I also acknowledge that much more work needs to be done to resolve the interplay between domestic institutions and their international linkages. What I do argue is that, if we seek to understand why nations innovate differently, then we need to examine the politics driving the decisions to innovate, which includes the selection of the institutions and linkages by which to achieve it.

If we take this approach, then domestic institutions become means to an end. Institutions are vehicles, but they do not guarantee arrival at a particular destination. Moreover, if a polity realizes an interest in pursuing technological progress, then for all practical purposes it may not much matter which specific institutional designs they use to achieve it *as long as those institutions solve the primary problems endemic to innovation* (public goods problems, high costs and risks, Stiglerian capture). Certainly, at the margins, differences in institutional design may result in slightly different rates or directions of inventive activity. Also, social planners might prefer institutional designs that best fit the culture, historical experience, or

political-economic conditions of their country. But as long as a country's institutions solve the basic technical problems of innovation, then *ceteris paribus* it should technologically outperform countries without these types of institutions. Such an interpretation dovetails with the evidence cited in this article, as well as with the "many recipes" realization emerging in the NIS debate and within the economic growth literature about institutions (Rodrik, 2007).

International linkages are also means to an end. They are useful conduits by which skills, knowledge, capital (and even institutions) can be acquired from more experienced nations at far lower cost and risk than developing them indigenously. As with domestic institutions, specific differences in international linkages may matter for innovation rates at the margins. So too will their fit with the culture, historical experience, and political-economic conditions of their country. But as long as a country's international linkages deliver technical skills and knowledge at lower cost and risk than developing them domestically, then the results should be higher innovation rates *ceteris paribus*. However, as with institutions, these international linkages are merely tools, they do not guarantee successful innovation.

If institutions and linkages do not necessarily create a technologically innovative economy, then what does? At root, a country's success in accomplishing its technological goals ultimately depends upon its ability to sustain interest in allocating resources towards, and accepting the disruptions caused by, technological progress. Indeed, without sustained interest in technological progress, even a country with "good" institutions and linkages will not use them to achieve higher innovation rates (e.g., Norway, Austria, Spain, Portugal, Greece). Therefore the key research question is not which institutions or linkages are employed, but what are the politics *behind* a country's pursuit of innovation and its strategy by which to achieve it (i.e., the selection of its institutions and linkages).

Politics affect national innovation rates via several mechanisms (see also Kushida & Zysman, 2009). First, as with any other economic activity, actors interested in technological change must compete for resources with actors with other political-economic priorities. Second, unlike most other activities, technological innovation also suffers from exceptionally high costs, risks, and uncertainty. These conditions magnify the collective action problems that prevent successful technological change. Third, technological progress increases the wealth of society as a whole, but it is distributive within society. Technological change therefore creates winners and losers. And the losers often seek to resist technological changes which threaten the value of their assets. Finally, the state should also have an interest in influencing technological change, as a source of power, revenue, or as a disruptive force within the polity. Of course, this implies that international context will matter too, because security concerns may condition the interests of the state.

All of these factors pit different actors and the state into potential conflict (or cooperation) over whether or not to pursue technological change, and different strategies by which to do so. These conflicts will demand fundamental political deals which will then structure a country's domestic institutions and international linkages. But the current focus on institutions and linkages tends to ignore these conflicts and their politics. Therefore if we follow the relevant domestic institutions and international linkages back to their formative conditions, then we can discover the domestic political deals that lead to the decisions to pursue innovation. And if

we understand these underlying politics, then we may be able to more generally explain *both* (1) differences in national innovation rates and (2) differences in national innovation systems and strategies (i.e., which combinations of institutions and linkages are selected, and why).

## Conclusions

In sum, I have examined quantitative data on innovation, domestic democratic and market institutions, and four types of international linkages, and found that international linkages are as important as domestic institutions in explaining national innovation rates. This conclusion is admittedly tentative, and considerable work remains to be done in establishing the importance of international linkages relative to domestic institutions, and identifying the exact mechanisms by which they foster innovation. However, the research reported here suggests that a single-minded focus on finding an institutional explanation can blind scholars to important political variables, such as international linkages, that play powerful roles in affecting technological change.

I do not contend that institutions do not matter, but the data does suggest that existing institutional theories have been over stated and over simplified in the literature. Certainly, in order for a society to succeed at long-run technological change, it must first overcome some basic political-economic obstacles: public goods problems, high costs and risks, and Stiglerian capture. Solving these problems will inevitably necessitate domestic institutions, and perhaps international linkages, but these can vary widely both in kind and degree. Our problem is that, until recently, much of the political-economic debate has focused primarily on identifying the "right" set of domestic institutions for maximizing national innovation rates. This debate has produced excellent case studies and statistical research, but little general theory. The data reveals that highly innovative countries possess a wide diversity of institutions, while many countries with stereotypically "good" institutions do not necessarily innovate. Therefore the search for an institutional "silver bullet" is a distraction, and does not help us to solve the innovation rate puzzle.

Ultimately both domestic institutions and international linkages are means to an end; they help us to explain *how* nations become more innovative, but not *why* they choose to pursue and sustain progress. They therefore fail to get at the root causes, the fundamental choices over resources and redistribution, which must be resolved between competing political-economic actors. Domestic institutions, generally speaking, have their roots in these fundamental deals that create mass politics and markets. Likewise, the pursuit and consequences of a nation's international linkages will ultimately hinge on domestic arrangements. Therefore, innovation research should move beyond domestic institutions and international linkages, and focus instead on their political-economic origins. Thus this article seeks to provide a detour around the endless debate over "best" institutions and points toward a more promising discussion about politics.

## Notes

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with ETLA (The Research Institute of the Finnish Economy) for enabling two conference panels and a research workshop in which these articles were developed. The thoughtful comments from the reviewers were invaluable and much appreciated.

2 For a more thorough review of this debate see Taylor (2007) .

3 Including: power generating machinery and equipment, machinery specialized for particular industries, metalworking machinery, general industrial machinery and equipment, office machines and automatic data processing equipment, telecommunications, sound recording and reproducing equipment, electric machinery, apparatus and appliances.

4 Per capita electric power consumption (kilowatt-hours per capita) makes theoretical sense as an indicator of development for the time period under consideration since the more developed a country is, the more its populace will conduct electricity-based activities. It also correlates well empirically with other development measures, specifically GDP per capita and lagged innovation, either of which can produce high variance inflation factors (and hence high multicollinearity) when used alongside GDP.

5 Although tangential to my hypothesis, I did find a conditional relationship between economic freedom and democracy on innovation rates, which was significant, robust, but small.

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