The International Determinants of National Innovation Rates: An Exploratory Probe

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ABSTRACT

This article documents an empirical anomaly in the debate over national innovation rates. The dominant explanation amongst political-economists is that domestic institutions determine national innovation rates. However, after decades of research, there is still no agreement on precisely how this happens, exactly which institutions matter, and little aggregate evidence has been produced to support any particular hypothesis. Anecdotal observations within the research on institutions suggest that international relationships may be the missing piece to the national innovation rate puzzle. An exploratory probe is therefore performed using regression analysis of various measures of innovation, domestic institutions, and international relationships. It suggests that countries' relationships with the lead innovator (the United States) strongly affect their innovation rates, while the institutions of democracy and free markets have far smaller effects than expected. In other words, explaining national innovation rates may be not so much a domestic institutions story as an international story.

KEYWORDS: technology, innovation, endogenous growth, institutions,

I. Introduction

Why are some countries more technologically innovative than others?[1] Amongst political economists, the conventional wisdom holds that domestic institutions determine national innovation rates. However, after decades of research, there is little consensus as to which institutions determine innovation rates or precisely how they do so. Also, the empirical evidence for a causal relationship between domestic institutions and national innovation rates remains equivocal, with theories often established only on the basis of anecdotal evidence, temporally limited deviant cases, or often stylized single case studies. Yet, despite these problems, a core belief in a causal relationship between institutions and innovation remains widely held and little challenged.[2]

This paper will dispute the conventional wisdom and suggest that international relationships, not domestic institutions, may be the missing piece to the national innovation rate puzzle. In it, the evidence for several prominent institutional hypotheses will be reviewed. It will be pointed out that, contrary to the accepted wisdom, there is little empirical support for domestic institutions causing innovation in the aggregate, regardless of the type of institution tested or the measure of innovation used. That is, although institution or policy "X" might appear to explain a certain country's innovation rate at a specific point in time, it does not do so over time nor in other countries. However, anecdotal observations within the evidence provided by domestic institutionalists suggests that certain kinds of international relationships (e.g. capital goods imports, foreign direct investment, educational exchanges) might have a significant role in determining national innovation rates. In order to probe this linkage, regression analysis is performed on various measures of innovation, domestic institutions, and international relationships. *The results suggest that certain kinds of international relationships with the lead innovator (the United States) strongly affect countries' innovation rates, even when controlling for the most prominent domestic institutions.*

This research is new in several respects. First, it challenges the prevailing sentiment regarding domestic institutions and innovation which, 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.

II. Literature Review: Domestic Institutions and National Innovation Rates

Over the years, a number explanations for differences in national innovation rates have been proposed by researchers across the social sciences. Often generated by individual case studies, these hypotheses have

[1] *Technology* is defined here as a physical product, or a process of handling physical materials, which is used as an aid in problem solving. More precisely, technology is a product or process which allows social agents to perform entirely new activities or to perform established activities with increased efficiency. *Innovation* is defined as the discovery, introduction, and/or development of new technology, or the adaptation of established technology to a new use or to a new physical or social environment.

[2] Though not specifically addressing innovation, recent exceptions include Przeworski, Adam. 2004. "Institutions Matter?" *Government and Opposition* 39(2): 527-540; Durham, J. Benson. 2004. "Economic Growth and Institutions: Some Sensitivity Analyses, 1961-2000" *International Organization* 58(3):485-529.

covered a wide range of independent variables. They have included: the importance of military spending and weapons systems development,[3] factor scarcity,[4] first-mover advantages,[5] population or economic size, late-industrialization,[6] culture,[7] and historical contingencies.[8]

However, explanations based on domestic institutions have come to dominate the innovation debate within political economy. Institutions are the proximate tools which 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 also makes sense to many policymakers and more empirically-minded innovation scholars. Some scholars highlight the non-rival and non-excludable aspects of inventive activity, thus casting innovation as a public goods problem.[9] Other scholars emphasize the high levels of uncertainty, risk, high transactions costs, and incomplete information associated with innovation.[10] 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.[11]

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 logically drawn to institutional explanations. And properly designed domestic institutions can also prevent the Stiglerian capture of government policy by status-quo interest groups, thereby ensuring political competition, or checks and balances, between domestic interest groups. Thus domestic institutions have come to play a determining causal role in theories of national innovation rates.

Yet, after decades of research, the empirical evidence for a causal relationship between domestic institutions and national innovation rates remains equivocal. There are simply many countries with "good" institutions that do not innovate at the technological frontier, and many countries with "bad" institutions that have nonetheless built impressive records of technological progress. In fact, the debate has evolved to a point

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[3] Smith, Merritt Roe ed. 1985. *Military Enterprise and Technological Change: Perspectives on the American Experience*. MIT Press.
[4] Hicks, J. 1932. *Theory of Wages*. London: Macmillan; Habakkuk, H.J. 1962. *American and British Technology in the 19th Century*. Cambridge Univ. Press.
[5] Porter, Michael E. 1990. *The Competitive Advantage of Nations*. New York, NY: Free Press.
[6] Gerschenkron, Alexander. 1962. *Economic Backwardness in Historical Perspective*. Cambridge, MA: Harvard Press.
[7] Dore, Ronald. 1987. *Taking Japan Seriously: A Confucian Perspective on Leading Economic Issues*. Stanford, CA: Stanford Press.
[8] Burke, James. 1978. *Connections*. Little, Brown, & Co: London.
[9] Arrow, Kenneth. 1962. "Economics of Welfare and the Allocation of Resources for Invention" in *The Rate and Direction of Inventive Activity* edited by Nelson, Richard R., 609-626. Princeton, NJ: Princeton Press; Romer, Paul M. 1990. "Endogenous Technological Change". *Journal of Political Economy* 98(5):S71-S102; Hall Robert E., Charles I. Jones. 1999. "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *Quarterly Journal of Economics* 114(1): 83-116; Aghion, Philippe and Peter Howitt. 1998. *Endogenous Growth Theory*. Cambridge, MA: MIT Press.
[10] Nelson, Richard R. 1959. "The Simple Economics of Basic Scientific Research" *Journal of Political Economy* 67(3): 297-306; North, Douglass. 1990. *Institutions, Institutional Change and Economic Performance* Cambridge; New York: Cambridge Press.
[11] Mokyr, Joel. 1990. *The Lever of Riches: Technological Creativity and Economic Progress*. New York : Oxford Press; Acemoglu, Daron, Simon Johnson, James Robinson. 2005. "Institutions as the Fundamental Cause of Long-Run Growth" in *Handbook of Economic Growth* ed. Philippe Aghion & Steve Durlauf (Amsterdam : Elsevier).

such that there exists a large consensus amongst 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 given hypothesis.

For example, perhaps the first systematic cross-national approach to studying innovation rates was the "national systems of innovation" (NSI) research program which emerged during the late-1980s.[12] Often using a case study approach, NSI scholars have probed the roles of dozens of specific mid-level national institutions and policies on innovation rates in dozens of countries. For example, NSI case studies have examined the interactions and effects of different science policies, trade regimes, legal frameworks, financial institutions, anti-trust laws, etc. on national innovation rates. However, after almost two decades of research, NSI scholars have yet to identify any institution, or set of institutions, that consistently explain innovation rates across time and space.[13]

Recently, there have since been several attempts to explain why NSI institutions and policies are unable to explain innovation rates in the aggregate. Most of these arguments imply that NSI explanations do not generalize well because the mid-level institutions and policies they focus on are endogenous: their technological goals, and their efficiency in achieving these goals, are determined by yet broader political and economic institutions. For example, "Varieties of Capitalism" (VOC) theory as put forward by Peter Hall & David Soskice (2001) argues that the behavior of a country's NSI institutions and innovators are both endogenous to markets.[14] That is, the more a nation allows markets to structure its domestic economic relationships, the more innovative its economic actors will be. Conversely, the more a nation chooses to coordinate economic relationships via non-market mechanisms, the more slowly and incrementally innovative its economic actors will be.

Another approach can be found in the decentralization arguments made by scholars such as Joel Mokyr, Daniel Drezner, and others, who argue that NSI institutions and policies are endogenous to government structure.[15] In their view, the economic and political "losers" created by the distributive nature of technological change will influence or capture NSI institutions and policies in order to obstruct technological innovations which threaten them. Even the presence of markets cannot prevent this phenomena, since markets are but institutions subject to the will of captured state apparatus. They conclude that government structure affects a state's vulnerability to interest-group capture, and hence innovation rates. Put simply, more centralized governments are more vulnerable to interest-group capture because there are fewer decision-making points and veto-players to control. Therefore, *ceteris paribus*, more capture-able centralized governments are more likely to

[12] Nelson, Richard R. *National Innovation Systems: A Comparative Analysis* (Oxford Univ. Press, 1993); Lundvall, Bengt-Ake *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (St. Martin's Press, 1992); Edquist, Charles *Systems of Innovation : Technologies, Institutions, and Organizations* (Pinter, 1997).
[13] To be fair, the atheoretical nature of much NSI scholarship was a strategic choice to increase "the number of 'points' that a causal theory had to 'fit'", not a product of bad research design. See Nelson 1993.
[14] Hall, Peter A. and David Soskice. 2001. "Introduction" in *Varieties of Capitalism : The Institutional Foundations of Comparative Advantage*, Edited by Hall, Peter A. and David Soskice, 1-68. New York, NY: Oxford Press.
[15]Mokyr, Joel.2002.*The Gifts of Athena:Historical Origins of the Knowledge Economy*. Princeton, NJ: Princeton Univ. Press; Drezner, Dan. 2001. "State Structure, Technological Leadership and the Maintenance of Hegemony" *Review of International Studies* 27(1): 3-25.

make policies which slow technological innovation.[16] And once made, such policies will be imposed across the entire nation due to the centralized nature of government in these states. Conversely, in decentralized states, even if similar policies arise, they can be reversed or overridden by sub-national governments.[17]

Yet, none of these theories is supported in the aggregate by empirical evidence. For example, in the last five years, cross-national tests of VOC theory have revealed that its success in explaining national innovation rates depends entirely on the classification of the US as a more market-oriented economy. If the US is taken out of the equation then, empirically, VOC's liberal market and coordinated market economies innovate almost exactly alike.[18] Meanwhile, recent analysis of data on international patent activity, scientific publications, and high-technology exports reveals that, in general, firms and individuals in decentralized states are empirically no more technologically innovative than those in more centralized states.[19] Indeed, both qualitative case studies and statistical analysis find nations with all varieties of domestic institutions innovating at all different levels. Hence the puzzle of national innovation rates continues to be unresolved.

The current state of the debate, or at least one major strand of it, has seen revival of interest in basic Northian institutions. Domestic institutions were originally brought into the economic growth debate by Douglass North & Robert Thomas, who used historical analysis to suggest that technological change is endogenous to them.[20] The institutions they focused on were property rights and efficient markets for trading them, and for motivating the investments and risk-taking necessary for innovation.[21] North later noted that the specification and enforcement of property rights and markets are political issues, hence political institutions need also be efficient and therefore democratic.[22] These arguments have recently been further developed by Acemoglu, Robinson, and Johnson. In a series of papers, they describe property rights, free markets, and competitive democracy as solutions to the commitment problems which prevent Coasian bargaining (and thereby discourage elite support for technological change).[23] Yet the significance of these institutions as causal variables for innovation has never been tested against the effects of international relationships. As the latest

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[16] Drezner, Daniel. 2001.

[17] Further support for the technological advantages of decentralized states can also be inferred from various lines of federalism theory. See Hayek, Friedrich A. 1945. "The Use of Knowledge in Society." *American Economic Review* 35(4): 519-530; Tiebout, Charles. 1956. "A Pure Theory of Local Expenditures." *Journal of Political Economy* 64(5): 416-424; Weingast, Barry R. 1995. "The Economic Role of Political Institutions: Market-Preserving Federalism and Economic Development" *Journal of Law, Economics, and Organization* 11(1): 1-31; Cary, William L. 1974. "Federalism and Corporate Law: Reflections Upon Delaware" *Yale Law Journal*, 83(4): 663-705.

[18] Taylor, Mark Z. "Empirical Evidence Against Varieties of Capitalism's Theory of Technological Innovation" International Organization 58(3) (Summer 2004)

[19] Author 2005

[20] North, Douglass and Robert P. Thomas. 1973. *The Rise of the Western World: A New Economic History*. Cambridge; New York, NY: Cambridge Press.

[21] North & Thomas 1973.

[22] North, Douglass. 1981. *Structure and Change in Economic History* New York, NY: Cambridge Press; North, Douglass. 1990. *Institutions, Institutional Change and Economic Performance* Cambridge; New York: Cambridge Press.

[23] Acemoglu, Daron, Simon Johnson, James Robinson. 2005. "Institutions as the Fundamental Cause of Long-Run Growth" in *Handbook of Economic Growth* ed. Philippe Aghion & Steve Durlauf (Amsterdam : Elsevier); Acemoglu, Daron and James A. Robinson. 2000. *American Economic Review* 90(2):126-130; Acemoglu, Daron. 2003. "Why Not a Political Coase Theorem? Social Conflict, Commitment, and Politics." *Journal of Comparative Economics* 31(4):620-652.

contenders in the institutions-innovation debate, it is these Northian institutions which will be the subject of the exploratory probe below.

III. International Relationships: Anecdotal Observations

International relationships are often overlooked as an independent variable in the aforementioned debates over innovation, but an interest in international relationships as an alternate explanation for differences in national innovation rates emerges out of the research on institutional theories. For example, M.Z. Taylor's statistical analysis of the VOC theory of technological innovation consistently points to the United States as an important outlier in global patterns of innovation. He also observes that many of the world's most innovative countries are those which also tend to have the strongest military and economic ties with the US, including Japan, Canada, the UK, Israel, and Taiwan. Other research on comparative innovation rates in East Asia has also emphasized the importance of linkages between international relationships and innovation, though specifically in the cases of Japan vis-a-vis the US during the Cold War, and Southeast Asia vis-a-vis Japan during the mid-1980s through mid-1990s.[24] Might these anecdotal observations be indicative of a more general causal relationship?

There are also strong indications of an important role for international relationships within the empirical evidence put forward by domestic institutionalists themselves.[25] For example, although Alice Amsden emphasizes institutional explanations in her studies of industrialization in East Asia, her evidence consistently reports the vital role of foreign technical assistance in helping South Korea, Taiwan, China, etc. approach the technological frontier. Similarly, in a 2000 collection of case studies on innovation in the developing world assembled by lead NSI researcher, Richard Nelson, scholars repeatedly mention the importance of international relationships: joint ventures, contacts with foreign suppliers and consumers, and other forms of cross-national contacts.[26] Meanwhile, atheoretical histories of technological development and industrialization in 18th, 19th, and 20th century Europe and the United States are replete with instances of national innovation rates being affected by international relationships.[27] And this phenomenon is not necessarily limited to technological catch-up by lesser developed states, since even advanced industrialized nations seem to benefit technologically from ties to lead innovators.[28]

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[24] Taylor Mark Z. 1995. "Dominance Through Technology" *Foreign Affairs* 74(6): 14-20.
[25] Amsden, Alice H. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. New York, NY: Oxford Press; Amsden, Alice H. 2001. *The Rise Of "The Rest": Challenges to the West from Late-Industrializing Economies*. Oxford; New York, NY: Oxford Press; Yamashita, Shoichi (ed.) 1991. *Transfer of Japanese Technology and Management to the ASEAN Countries.* Tokyo: Univ. of Tokyo Press.
[26] Kim, Linsu. and Richard R. Nelson (eds). 2000. *Technology, Learning and Innovation: Experiences of Newly Industrializing Economies*. Cambridge, U.K. : New York, NY : Cambridge Press.
[27] Jeremy, David J. (ed.). 1991. *International technology transfer: Europe, Japan, and the USA, 1700-1914* Brookfield, VT: E. Elgar; Cowan, Ruth Schwartz, 1997. *A Social History of American Technology*. New York, NY: Oxford Press.
[28] Keller, Wolfgang. 2004. "International Technology Diffusion" *Journal of Economic Literature* 42(3): 752-782; Cantwell, J. 1995. "The Globalization of Technology—What Remains of the product Cycle Model" *Cambridge Journal of Economics* 19(1):155-174.

It is also interesting that many of the countries which suffer from low innovation rates also appear to have poor international relationship with the world's lead innovators. For example, African, Latin American, and ex-communist bloc nations all tend to have relatively low levels of technological progress. Countries in these regions are indeed typified by low levels of democracy, poorly functioning markets, loosely enforced property rights, and high levels of corruption. Hence domestic institutions seem like a good candidate as a causal explanation for their low innovation rates. However, these same countries are also typified by fewer and shallower international relationships with the lead innovators. Meanwhile, countries such as Taiwan and South Korea recently emerged as highly innovative states during prolonged periods of poor institutions: martial law, one-party rule, and military dictatorship; while democratic Israel saw increased innovation rates during the 1970s when its economic market institutions suffered from an increase in non-market government coordination, subsidies, and transfers. Similar stories could be told regarding Japan during the last century, in which both democratic and market institutions gyrated drastically against a backdrop of steadily increasing innovation. Yet, as noted above, each of South Korea, Taiwan, Israel, and Japan is typified by strong international relationships with the lead innovators, especially the United States, involving major transfers of scientific & technical knowledge via imports, foreign direct investment, and educational exchanges.

Together, these stylized observations suggest a possibility: that in order to better understand the political economy of national innovation rates, research should perhaps focus less exclusively on comparisons of domestic institutions, and examine more deeply the effects of international relationships. International relationships 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 and a competing explanation for innovation rates. Therefore factors such as those listed below in Figure 1 between the lead innovator and other countries should be examined for their effects on innovation. Such a plausibility probe will comprise the remainder of this paper.

[*FIGURE 1 ABOUT HERE***]**

IV. Methods and Data

If the international relationships listed in Figure 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 relationships 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 relationships, and domestic institutions across several dozen countries during the 1980-1995 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 the resulting estimates are. 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 major shift in the research program. And although this paper is a predominately empirical exercise, it is certainly not *ex nihilo*. It queries the plausibility of a rival and much ignored avenue of research. Finally, despite its simplicity, a probe of the type described below has never been reported: researchers have never controlled for international relationships 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 US Patent & Trademark Office (USPTO) to applicants from the United States and 162 other countries during 1963-1999, and the 16 million citations made to these patents between 1975 and 1999.[29]

Patents do not capture all technological innovation; however the current consensus amongst innovation scholars holds that they do appear to capture a representative sample of it when weighted by forward citations and used in large aggregates. Empirical support for this interpretation has arisen in various quarters: citation weighted patents have been found to correlate well with market value of the corporate patent holder, the likelihood of patent renewal and litigation, inventor perception of value, and other measures of innovation outputs.[30] National patent data also correlate highly with other measures which we generally associate with aggregate innovation rates, including GDP growth, manufacturing growth, exports of capital goods, R&D

[29] Hall, Bronwyn H., Adam Jaffe, and Manuel Trajtenberg. 2001. "The NBER Patent Citations Data File: Lessons, Insights, and Methodological Tools" Working Paper 8498. Cambridge, MA.: National Bureau of Economic Research. database available at http://www.nber.org/patents.

[30] Lanjouw, Jean O and Mark Schankerman. 1997. "Stylized Facts of Patent Litigation: Value, Scope, and Ownership". Working Paper, 6297. Cambridge, MA: National Bureau of Economic Research; Lanjouw, Jean O. and Mark Schankerman. 2004. "Patent Quality And Research Productivity: Measuring Innovation With Multiple Indicators," *Economic Journal* 114(495):441-465.

spending, capital formation, Nobel Prize winners, etc.[31] Perhaps a simple litmus test of the appropriateness of patents is that one cannot find a technologically innovative country which is not relatively well represented by its aggregate patent data; even the Soviet Union during its period of isolation from the West regularly patented at a rate roughly representative of its overall relative technological prowess. Certainly there are nations which do not patent, but which are highly innovative in fashion, design, arts, and culture, and see noticeable economic gains from these accomplishments. But when it comes to *technological* innovation per se, patents appear to be a useful quantitative measure. A summary of this debate can be found in Jaffe & Trajtenberg (2002) and Griliches (1990).[32]

One point worth elaborating from this debate: scholars who specialize in the empirical measurement of innovation report that patent measures suffer increasing construct-validity problems when they are disaggregated into smaller time and space units. That is, patent and publications data are acceptable measures of innovation when used in the aggregate (e.g. as a rough measure of national levels of innovation across long periods of time), but are less appropriate when used as a measure of micro-level innovation (e.g. to compare the innovativeness of individual firms or specific industries from year to year). While my aggregation of patent data at the national level certainly meets these requirements, annual comparisons of these national innovation rates might not. Rather, five-year aggregates provide even more reliable estimates of relative national innovation rates. Therefore, the OLS regressions are conducted on three consecutive five-year sub-periods (1980-1985, 1985-1990, 1990-1995). And since 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 OLS regressions wherever possible.

Nonetheless, for those scholars who remain skeptical of citations-weighted patents as a measure of innovation, the results reported below 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 Relationships

Unfortunately, there is no single variable which captures the myriad international relationships listed in Figure 1. Also, different countries have different combinations of these international relationships 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

[31] Amsden, Alice H. and Mona Mourshed. 1997. "Scientific Publications, Patents and Technological Capabilities in Late-Industrializing Countries" *Technology Analysis and Strategic Management* 9(3):343-359.
[32] Jaffe, Adam B. and Manuel Trajtenberg. 2002. *Patents, Citations, and Innovations: A Window on the Knowledge Economy*. Cambridge, MA. MIT Press; Griliches, Zvi. 1990. "Patents Statistics as Economic Indicators: A Survey" *Journal of Economic Literature* 28 (4):1661-1707.

consultants;[33] while Israel has depended heavily on the immigration of scientists and high-skilled labor;[34] and many Finnish firms prefer to establish ties with major foreign research universities.[35]

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 relationships to see if there is any macro-level evidence at all for a linkage between international relationships and national innovation rates. These measures include (each vis-a-vis the United States): graduate students sent to study science or engineering in US universities, imports of capital goods from, inward FDI received from, and outward FDI into the US. Clearly, these measures only capture an imperfect subset of the many international relationships listed in Figure 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 relationships described in the last section should ideally be geared towards 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 lead innovator as opposed to creating these same ties with say Spain. Second, limiting the observables to relationships with the US actually strengthens the probe of these relationships. For example, Mexico sends its students to study science and engineering in US, Spain, Britain and several other advanced countries. Ideally we would want data on all of these student flows. And by restricting measurement of student flows to those destined only for the US, a potential bias is created *against* finding evidence supporting an international relationships linkage, and thus a stronger probe. On the other hand, focusing only on relationships with the US also introduces the possibility of selection bias: there may be some variable specific to US relations which affects national innovation rates. Note that this would not nullify a positive finding of the significance of international relationships, but rather particularize it to the US. This issue will be discussed further below.

As for the specific observables used to measure international relationships, first I use science and engineering PhD's awarded by United States' graduate schools to foreign students. This data is collected annually by the National Science Foundation in their Survey of Earned Doctorates (SED).[36] Second, I use United Nations on imports of capital goods, which Alice Amsden emphasizes as being important for technical development both for their ability to directly transfer technology,[37] but also knowledge in the form of

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[33] Morris-Suzuki, Tessa. 1994. *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century.* New York, NY: Cambridge Press.

[34] Toren N. 1994. "Professional-Support and Intellectual-Influence Networks of Russian Immigrant Scientists in Israel" *Social Studies of Science* 24(4):725-743; Gandal N, Hanson GH, Slaughter MJ. 2004. "Technology, Trade, and Adjustment to Immigration in Israel" *European Economic Review* 48(2):403-428

[35] Steinbock, Dan. 2001. *The Nokia Revolution: The Story of an Extraordinary Company That Transformed an Industry.* New York, NY: AMACOM.

[36] National Science Foundation. Various years. *Survey of Earned Doctorates.* Washington DC.

[37] 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.

international consultants and technical advice from the exporting firm.[38] Finally, FDI, in either direction, is a major conduit of scientific & 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.[39] For outward FDI, I focus on FDI into the US, which often represents foreign firms setting up shop to capture spillovers of tacit knowledge from US domestic R&D.[40]

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

[*FIGURE 2 ABOUT HERE***]**

Independent Variables: Domestic Institutions

To control for domestic institutions, I focus on those most likely to show a significant positive effect on national innovation rates: democracy and free markets. These are the institutions which North first introduced thirty years ago, and have since become those most often invoked by the conventional wisdom. They are generally prescribed by social scientists, and even many policymakers, as the fundamental and core requirements for an innovative economy.

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.[41] I alternately use the POLCON Index developed by Witold Henisz (U. Penn).[42] The POLCON Index is a 0-1 measure which takes into account the number of independent branches of government with veto power over policy, modified by the extent of party alignment across branches of government and the extent of preference heterogeneity within each legislative branch. POLCON is therefore a measure of what both Acemoglu et. al. and Keefer have respectively described as decentralized democracy or "democracy *cum* checks and balances".[43] The inclusion of party alignment and legislative preferences means that POLCON is not a pure measure of structural decentralization. However,

[38] Amsden 2001.
[39] Yamashita 1991.
[40] United States Department of Commerce. 1992, 1987. *Foreign Direct Investment in the United States: Benchmark Survey.* Economics and Statistics Administration, Bureau of Economic Analysis: Washington, D.C.
[41] Marshall, Monty G., Keith Jaggers, and Ted Robert Gurr. 2003. "Polity IV Project: Political Regime Characteristics and Transitions, 1800-2002" Integrated Network for Societal Conflict Research, Univ. of Maryland: http://www.cidcm.umd.edu/inscr/polity/.
[42] Henisz, Witold J. 2000. "The Institutional Environment for Economic Growth" *Economics & Politics* 12(1): 1-31.
[43] Acemoglu, Johnson, & Robinson 2005; Keefer, Philipe. 2004. "What Does Political Economy Tell Us about Economic Development-And Vice Versa?" *Annual Review of Political Science* 7:247-272.

unlike measures which rely purely on formal institutional structure, the POLCON measure allows us to control for states which may be formally decentralized but which may suffer ineffective *de facto* checks and balances. The POLCON index has been shown to be statistically and positively significant in affecting both business investment decisions and technological diffusion in various countries, therefore it is natural to ask whether it holds similar significance for innovation rates.[44] I also experiment with the Freedom House measures (1-7 scale) of "political rights", "civil liberties", and "Free" (1-3 scale).[45]

As my measure of quality for market institutions, 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. This index is a composite measure which attempts to quantify and combine: size of government sector in the national economy, legal structure & security of property rights, access to sound money, free trade, and degree of government regulation of finance, labor, and private business. Triangulation of this measure is difficult because most quantitative indices of market institutions began during the 1990s, which is towards the close of my innovation time-series. However, I can use dummies for "liberal market economies" (LME's) and "coordinated market economies" (CME's) as described by Hall & Soskice in their research on Varieties of Capitalism.[46] The former represent economies where economic actors tend to coordinate their activities via market arrangements (US, UK, Canada, Australia, New Zealand); in the latter market institutions are restrained, and instead actors coordinate via political agreements and private collaborations (Austria, Belgium, Denmark, Finland, Germany, Japan, Netherlands, Norway, Sweden, and Switzerland).

These institutional measures are also 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 Figure 9. If the domestic institutions hypothesis is correct, then those nations with higher levels of democracy and free markets should be observed to innovate more than others, regardless of the depth of their international relationships.

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, do its international relationships or domestic institutions determine 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*

[44] Delios, Andrew and Witold J. Henisz. 2000. "Japanese Firms' Investment Strategies in Emerging Economies" *Academy of Management Journal* 43(3):305-323; Henisz, Witold J. 2002. "The Institutional Environment for Infrastructure Investment" *Industrial and Corporate Change* 11(2): 355-389; Henisz, Witold J. & Bennet A Zelner. 2001. "The Institutional Environment for Telecommunications Investment" *Journal of Economics & Management Strategy*, 10(1): 123-147.
[45] Freedom House. Various Years. *Freedom in The World*. New York : Freedom House. Available online www.freedomhouse.org
[46] Hall & Soskice 2001.

consumption or *GDP per capita* (to control for base-level of economic development).[47] 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 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 (democracy, decentralization, and markets). 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.[48] This results in a primary regression model along the following lines:

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

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.

V. Regression Results

The first and most important finding of the regressions is that international relationships appear to strongly affect national innovation rates. Almost every regression yielded a significant and positive coefficient for the IR-factor, regardless of regression technique employed, lag structure used, or control variable included (or omitted). Representative results of these regressions are tabulated in Figures 3 through 7. Note that in the regressions the coefficients for the IR-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 IR-factor results in a 20-30% increase in innovation rates. Earlier time periods show an even greater effect of international relationships on innovation rates, as do longer lag structures. These effects are considerable when one considers that the mean IR-factor for the entire dataset is approximately 0.0, with a standard deviation of 0.9. The time dependence of the IR factor could reflect a decrease in knowledge flows out of the US over time, either due to the rise of Japan and Western Europe as competing

[47] 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.

[48] Furman Jeffrey, Porter Michael, Stern Scott. 2002. "The Determinants of National Innovative Capacity" *Research Policy* 31(6): 899-933; Jones, Charles. 1998. *Introduction to Economic Growth.* New York, NY: WW Norton & Company.

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 relationships affect innovation rates, rather than the reverse? In other words, perhaps an increasing innovation rate is a pre-requisite to receiving increased flows of FDI, capital goods imports, etc, 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 re-ran the OLS regressions above, but with increasing time lags between the independent and dependent variables (Figure 3, middle columns). Again, I found that the coefficients for the IR Factor are consistently positive and significant, and match the values of the coefficients produced in the non-lagged 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 (Figure 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 relationships. 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 IR Factor, except for the sole case of the 1980-1985 time period.

Of course, the IR Factor itself raises questions since, as one colleague warns, with enough wit and straining, one can create a weighted factor that explains just about everything. I therefore re-ran the IR Factor's individual components independently. As one might predict, these regressions reveal a more complex story (Figure 10). 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 regressions. Interestingly, if we combine capital goods imports and inward FDI into an "inward" integration term; and US Phd students and outward FDI into an "outward" integration term, then the inward international relationships appear to have a negative effect on innovation rates, the outward international relationships 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 relationships to increase their technological capabilities. Therefore we should not expect any single type of international relationship to have a powerful aggregate effect on innovation rates; rather, international relationships as a whole should, which is what the IR Factor attempts to model. This is not to argue that we should accept the IR Factor, or any other measure, blindly. But neither should we simply

dismiss its usefulness because it has the potential for abuse or misinterpretation (as do all statistical constructs). Recall that the IR 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 2-7% increase in innovation. And these coefficients are only rarely significant, and even then just barely at the $p<0.05$ level. The substitution of Freedom House's measures of "political rights" or "civil liberties" for the Polity 2 measure produces similarly insignificant coefficients (Figures 5a-b); 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. However, this effect is not so large when one considers that mean for Economic Freedom is 5.6 with a standard deviation of 1.1, again a somewhat dull measure of institutions. Furthermore, in those rare cases where Economic Freedom is significant, it is just barely so (at the $p<0.05$ level). Thus while markets seem to perform better in my 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.

Throughout the regressions, the variance inflation factors suggest that high multicollinearity is not to blame for the poor performance by domestic institutions. This a conclusion supported by the low correlation of the two main institutional measures, Polity 2 and Economic Freedom Index, with each other (ranging 0.34 - 0.43 depending on the time period). Unfortunately there are few similar institutional measures available for the time periods in question, hence I cannot triangulate further. Attempts were made using dummies for "liberal market economies" vs. "coordinated market economies" according to Varieties of Capitalism theory, the results of which matched the other regressions. However, the number of observations was too low ($n = 12$-14) to allow a high level of confidence.

Interestingly, neither the strength of the IR Factor nor the relative weakness of the domestic institutions measures is much affected by each other's presence or absence in the regression models (Figure 6). That is, the coefficients for the IR Factor 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 IR 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 relationships to have their effects, nor does the IR Factor absorb significance away from the domestic institutions.

Since there is considerable missing data on local education of scientists and engineers, I tend to omit it from many of the regressions reported here, except for those in Figure 4. Theoretically, this local education variable should be important. Note however that its inclusion does not have a major effect on the other variables. Nor does the control for local science and engineering undergraduate students per capita show up as significant. This is likely due to variation in the quality and depth of science education programs across countries. Unfortunately we have no way of consistently controlling for the quality or depth of different national education programs during the time period covered here, and therefore must remain agnostic on this issue until more data comes available. 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.

Indeed, quantitative data on several other of my variables is missing for some countries, therefore we have to ask how representative is the sample included in the regressions? For example, the regression most limited by data constraints (Figure 4, first column) has only 51 observations, and is missing countries which should most strongly support an international relationships hypothesis (e.g. Taiwan, Japan, Germany, Singapore). Yet, despite these omissions, T-tests reveal that the regressed sample does not select on the dependent variable: countries included in even the most restricted regressions are no more innovative than those which are excluded. Of course, as is often the case with large cross-national time-series, there is a lack of data for many lesser developed and non-democratic countries. Thus, the sample does appear to be somewhat biased on some of the other independent variables. The countries included in the regressions tend to be slightly more developed, and have larger economies, larger populations, stronger democracies, more domestically trained undergraduates in science & engineering, and stronger international relationships (in educational exchanges, capital goods imports, but not inward or outward FDI) than those countries not included in the regressions. Interestingly, T-tests of the measure of economic freedom reveal no significant different between those countries included in the regressions and those omitted. Hence overall, we have to be careful when generalizing the findings in these regressions, however I would argue that the biases here are not unusual, and are common to the large-N datasets analyzed throughout the comparative political economy literature.

An alternate explanation for the results above is that domestic institutions might benefit innovation more in the advanced economies, while international relationships might be more helpful to lesser developed

countries in a somewhat Gerschenkronian fashion.[49] 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 experiment with two probes for this relationship (Figure 7). First I controlled for OECD membership and interaction of OECD membership with the IR Factor. Second I repeated this exercise, instead splitting the data into "wealthy" and "non-wealthy" subgroups, where "wealthy" is defined as being in the top 10 percent of GDP per capita. The control for OECD membership is not statistically significant, nor is the "OECD-IR" interaction term; though adding the latter to the model does noticeably alter the coefficients for the IR factor, which is likely a result of high co-linearity between the two (note the high VIF's). The "wealth" control is statistically significant, but its inclusion in the model does not noticeably affect the coefficients for domestic institutions or the IR factor. Adding a "wealth-IR" interaction term has little additional effect in the 1990-1995 period but, as with the lone IR Factor, the effect of the interaction term increases in significance and size in earlier time periods. Thus the benefits for innovation from international relationships are neither particular to, nor higher for, lesser developed states.

VI. Alternate Explanations

The regressions and literature review reported above provide us with an anomaly in need of an explanation: international relationships appear to have a strong, robust, and significant link to national innovation rates; domestic institutions do not. I propose three possible explanations of these empirical findings, and recommend them as avenues to be more fully developed 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 paper could always be spurious, the result of bad data or a missing control variable. 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 paper 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.

[49] Gerschenkron 1962.

A second possible explanation for the findings reported here is that domestic institutions may determine international relationships, and that this linkage 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.[50] Certainly there is considerable research which shows that extremely poor domestic institutions (child labor, forced labor, lack of property rights, incompetent bureaucrats, etc.) correspond with lowers levels of FDI, capital goods imports, educational exchanges, etc.[51] Also, high-levels of regular expropriation do have a negative affect 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.[52] 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 & 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.[53] 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 relationships important to innovation discussed here. Again, one need only consider the cases of Japan, Taiwan, South Korea, Israel, etc. (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 research 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 relationships are not conditional on either economic freedom or democracy.[54] Nor did regressions of the IR-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 (Figure 8). Admittedly these are simple *prima facie* tests. I do not pretend that they fully resolve the issue, or that domestic institutions and international relationships have no connection. But they do suggest that the findings above cannot be cavalierly dismissed as un-modeled 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.

[50] Henisz 2000; Rodrik 2000; Jensen 2003
[51] Braun 2006; Harms & Ursprung 2002
[52] Gallagher 2002; Busse 2004; Archer, Biglaiser & DeRouen 2007
[53] Li & Resnick 2003; Egger and Winner 2004; Biglaiser and Derouen 2006.
[54] Though tangential to my hypothesis, I did find a conditional relationship between economic freedom and democracy on innovation rates, which was significant, robust but small.

A third possible explanation for the findings reported here is that a nation's innovation rate may be determined by its access to the superior tacit scientific and technical knowledge possessed by the lead innovators. Admittedly, this hypothesis has sat implicitly behind the regressions above; though I have tried to focus on probing for general linkages, not on theorizing such specific mechanisms. According to this view, domestic institutions theories fail to explain innovation because they focus almost entirely on the public goods nature of scientific and technical knowledge, and ignore its private goods aspects. Most scholars agree that, since technological innovation is a knowledge-based activity, the costs of acquiring useful knowledge necessarily affect national innovation rates. If knowledge is purely a public good, then acquiring existing knowledge is practically cost free. The problem then lies with creating the right incentives, via domestic institutions, for people to generate new knowledge. And this is exactly how most institutions theories tend to treat scientific and technical knowledge, as if it were merely an accumulated stockpile of data to which everyone has free access.

However, if innovation also depends on tacit knowledge (the aspect of all knowledge that cannot be, or is not, codified),[55] then international relationships with the lead innovators may provide the best conduits for it. That is, since tacit knowledge is not codified, it is rival and largely excludeable, therefore it cannot be treated like a public good.[56] Hence in order to get it, one must either create it anew through experimentation and trial-and-error learning, or acquire it from others via a process of apprenticeship. The extremely high costs and risks of generating new-to-the-world tacit knowledge suggest that innovators should prefer to transfer existing tacit knowledge wherever possible. Or put more simply, innovators should prefer not to re-invent costly wheels. And since tacit knowledge exists in the minds, actions, and technologies of scientists and engineers in other countries, we need to focus on international relationships such as those listed above in Figure 1. Thus differences in national innovation rates might be explained by differences in access to tacit knowledge that has been developed by lead innovators.

As a fourth possible explanation, it is tempting to suspect that the use of US-based patent measures creates an automatic bias in favor of significance for the US-based international-relationships factor, however this appears not to be the case. A check of an independent dataset of European Patent Office international patent data reveals them to correlate highly with USPTO international patent data; which means that whatever phenomena the US patent data are capturing, the EU patent data capture comparably well. This makes sense since, as discussed in the data section, citations-weighted patents are a valid measure of national innovation rates, and correlate well with other macro indicators which we tend to associate with innovation. Therefore either there is not a significant US bias in the international patent data, or it somehow exists in all of the measures with which this data correlates. In order to be sure, a set of regressions was run in which the dependent

[55] Polanyi, Michael. 1966. *The Tacit Dimension.* Anchor Day; Langlois, Richard N. 2001. "Knowledge, Consumption, and Endogenous Growth" *Journal of Evolutionary Economics* 11:77-93.
[56] Von Hippel, Eric. 1994. "Sticky Information and the Locus of Problem-Solving: Implications for Innovation" *Management Science* 40(4): 429-439; Saviotti, Pier P. 1998. "On the Dynamics of Appropriability, of Tacit, and of Codified Knowledge" *Research Policy* 26: 843-856.

variable was broadened, via factor analysis, to include citations-weighted international scientific publications and high tech exports. These regressions yielded results similar to those using only patents. Another set of regressions was then run in which the international-relationships factor was broadened to include overall FDI flows and capital goods imports, not just those with the US; again yielding similar results. Thus although the acquisition or citation of an international patent may be a type of international relationship, it is of a distinctly different kind than those measured by the regressors.

Nevertheless, it does suggest a fifth possible explanation for the findings reported in this paper: that innovation is a community-based activity. While the above "tacit knowledge transfer" explanation assumes that knowledge is relatively objective, this fourth explanation springs from the opposite assumption. Researchers such as Thomas Kuhn, Loren Graham, and Ian Hacking have shown that social factors such as culture, politics, and national histories can affect the ways in which scientists and engineers frame scientific problems and construct theories in different societies.[57] In other words, the intellectual and social community to which people belong can affect how scientific "common-sense" and what is "natural" are construed within that community. This will in turn affect the ways in which scientists, policymakers, and perhaps even the general public think about science, technology, and the ways in which scientific and technical explanations are interpreted locally. Some scholars even argue that all scientific rationality, methods, and truths are subjective.[58] If knowledge is socially constructed, then we get very different picture of innovation; one in which innovation rates are a function of, and in part defined by, the community to which a nation belongs. In this view, for example, when Japanese firms reverse-engineer American technology and consult US technical advisors, they are not just acquiring new knowledge but joining the Western knowledge community. Therefore one could describe Japan's rapid rise in innovation rates during the 1960s-1990s as a natural result, or perhaps indicator of, its increased membership in the Western knowledge-based economy. This view of innovation would give causal emphasis to the same international relationships, and predict very similar results to, those discussed here.

VII. Potential Problems

Other issues for future research include potential problems and criticisms of this paper. I would argue that there are two important criticisms worth noting: one methodological, the other theoretical. First, amongst all of my quantitative measures, those of domestic institutions are the most problematic. They are often necessarily broad, and occasionally highly subjective, which means that they can fail to capture significant differences in institutions, or non-quantifiable characteristics. Hence there are limits on what can be established on the basis of statistical analysis. And while qualitative analysis may have its drawbacks in terms of generalizeability and

[57] Graham, Loren R. 1998. *What Have We Learned About Science and Technology From the Russian Experience?* Stanford, Calif.: Stanford Press; Kuhn, Thomas S. 1962. *The Structure of Scientific Revolutions*. Chicago, IL. Univ. of Chicago Press; Hacking, Ian. 1990. *The Taming of Chance.* New York: Cambridge Univ. Press.

[58] Latour, Bruno. 1987. *Science in Action: How To Follow Scientists and Engineers Through Society*. Cambridge, Mass.: Harvard Press; Friedman, Micheal. 1998. "On the Sociology of Scientific Knowledge and its Philosophical Agenda" *Studies in the History and Philosophy of Science* 29A(2): 239-271.

potential for subjective analysis, well-designed case-studies may well offer value here. And although there are already a plethora of case-studies of national innovation rates, few if any are designed to probe the comparative effects of domestic institutions versus international relationships.

Second, even if one were to fully accept the empirical findings described in this paper, they still would not completely explain why some countries are more innovative than others. Rather, international relationships or domestic institutions are only the vehicles or techniques by which nations become more innovative. They tell us more about "how", rather than "why", some countries become more innovative than others. For if establishing international relationships with lead innovators is the key, then how do we explain the lead innovators themselves? The innovation data may hint at the answer. If we observe change in technological patent and scientific publication behavior over time, we can see the rapidly and increasingly innovative countries (Taiwan, Israel, South Korea, Japan, etc.) are each typified by conditions in which the perceived security threat is external rather than internal. That is, the material benefits of technological change to national military or economic security outweigh the costs imposed by the redistributive aspects of technological change. This is arguably even the case in Finland, whose Cold War security depended on keeping internal tensions low so as to prevent Soviet or NATO interventions, but whose post-Cold War security depends on being economically competitive.[59] Meanwhile in countries such as Spain, Italy, Norway, and Sweden, there is relatively little focus on external threats to national security, and relatively more focus on maintaining good relations between disparate domestic interest groups. This is admittedly mere conjecture driven by stylized facts; though Acemoglu & Robinson (2006) have recently presented a formal model proposing a similar dynamic in early industrializing states. But it does point to a possible research program which would consider the hypothesis that national innovation rates are driven by the balance of internal vs. external security concerns; by the redistributive consequences of technological innovation for domestic interest groups versus the need for technological change in order to maintain military or economic competitiveness.

VIII. Contributions & Conclusions

In sum, I have examined quantitative data on innovation, democratic and market institutions, and four types of international relationships, and found that, contrary to the conventional wisdom, international relationships are as important as, and perhaps more important than, domestic institutions in determining national innovation rates. This conclusion is admittedly tentative, and considerable work remains to be done in establishing the importance of international relationships relative to domestic institutions, and identifying the exact mechanisms by which they foster innovation. However, the *prima-facie* evidence reported here confirms what economic historian Eric Hobsbawm wrote almost forty years ago: "It is often assumed that an economy of private enterprise has an automatic bias towards innovation, but this is not so. It has a bias only towards

[59] Jakobson, Max. 1998. *Finland in the New Europe* .Westport, CT: Praeger..

profit."[60] One might now add that the inhabitants of democracies are likewise not automatically biased towards technological progress, but perhaps only towards their personal pursuit of happiness.

The theoretical contribution of this paper is two-fold. First it points to the necessity for a better understanding of micro-level innovation processes. Domestic institutions theories of innovation may be built on inaccurate and inconsistent assumptions of what innovation is and how it works. It may be that they ignore the creation and sharing of tacit knowledge, or that they neglect the social construction of knowledge, but the overall implication is that there is a political component of knowledge that is being overlooked. And I would argue that failure to appreciate this shortcoming, failure to question the assumptions upon which domestic institutions theories are based, is what tends to force scholars into a never-ending search for the "right" institutions which determine national innovation rates and economic growth. Thus, absent a proper understanding of the fundamental political-economy of technological innovation, this search may yield little in the way of productive or generalizeable results.

Second, the research reported here suggests that a single-minded focus on finding an institutional explanations can blind scholars to important political variables, such as international relationships, that play powerful roles in affecting technological change. I am not suggesting that institutions do not matter at all (though this may yet prove to be the case). But the data does suggest that existing institutional theories have been over-stated and over-simplified in the literature. There is sufficient empirical evidence (or lack thereof) for social scientists to say that institutions are not causal in-and-of themselves, or at least they are not necessary and sufficient causes of differences in innovation. Achieving sustained technological innovation is not as simple as "set up democracy and free markets". It is more complicated than that. In fact, as speculated above, there may even be some sort of causal interaction going on between domestic institutions, security issues, and innovation that needs to be explored. In other words, this paper should be seen as an attempt to change the debate over the sources of technological innovation, not to end it.

[60] Hobsbawm, Eric J. 1969. *Industry and Empire from 1750 to the Present Day.* Barmondsworth: Penguin p. 40.

Figure 1: International Relationships Important for National Innovation Rates

- **overseas training & education in science-engineering**
- **use of foreign consultants & 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 & 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 & high technology products**

Figure 2: IR-Factor

Summary Stats of Components:

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Infdius	Inward FDI from US†	434	2431	13607	0	243797
Capim	Capital goods imports (US)†	450	1840	6750	0	22600
Usphds	US PhDs in science	486	200	638	0	6989
Outfdi	FDI into US†	489	2253	11740	-204.76	132041

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 $US, (previous 5 years)

Figure 3: 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	IR-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<0.05, **p<0.01 ***p<0.001**

Figure 4: Expanded Models

Dependent Var = Log (Citations-Weight Patents Per Capita)						
Time for Depndt Var:		1990-1995	1985-1990	1980-1985	1990-1995	1990-1995
Time for Indep. Vars:		1989	1984	1979	1984	1979
Level of Develpmt	log (gdppc)	**1.61**	**1.42**	**1.43**	**1.36**	**1.21**
		[0.29]* **	**[0.24]*** **	**[0.23]*** **	**[0.29]*** **	**[0.30]*** **
	log (sci-eng undergrads/pop)	-0.01	0.28	0.02	0.29	0.40
		[0.24]	[0.23]	[0.31]	[0.24]	[0.29]
Size	log (GDP)	-0.006	-0.03	0.07	-0.05	0.05
		[0.13]	[0.15]	[0.13]	[0.17]	[0.17]
Domestic Institutions	democracy	0.05	0.02	0.05	0.05	0.05
		[0.04]	[0.03]	[0.03]	[0.04]	[0.03]
	econ freedom indx	0.09	**0.36**	0.17	0.30	0.51
		[0.28]	**[0.18]***	[0.24]	[0.17]	[0.30]
International Relationships	IR-factor	**0.21**	**0.59**	**1.04**	**0.68**	**0.86**
		[0.11]*	**[0.21]** **	**[0.30]** **	**[0.29]***	**[0.39]***
	_cons	**-9.28**	-6.08	-9.08	-5.41	-7.01
		[3.19] **	[4.23]	[4.98]	[4.40]	[4.73]
	R-squared	0.87	0.84	0.80	0.84	0.81
	Number of obs	51	60	54	62	57
	Max VIF	4.35	3.11	2.34	3.36	2.40

***p<0.05, **p<0.01 ***p<0.001**

Figure 5a: Basic Models (experiments with additional institutional measures)

		Dependent Var = Log (Citations-Weight Patents Per Capita)					
Time for Depndt Var: 1990-1995							
Time for Indep. Vars: 1989							
Level of Develpmt	log (gdppc)	**1.51**	**1.50**	**1.60**	**1.75**	**1.48**	**1.59**
		[0.22]* **	**[0.23]*** **	**[0.17]*** **	**[0.16]*** **	**[0.23]*** **	**[0.18]*** **
Domestic Instituions	democracy	0.06	0.06			0.06	
		[0.04]	[0.04]			[0.04]	
	econ freedom indx	0.19	0.21			0.20	
		[0.22]	[0.23]			[0.23]	
Freedom House Measures	political rights		0.01	0.17	0.20		
			[0.09]	[0.1]	[0.11]		
	civil liberties					0.06	0.21
						[0.12]	[0.12]
	Free						
World Bank	Checks2a						
International Relationships	IR-factor	**0.28**	**0.27**	**0.25**		**0.27**	**0.25**
		[0.10] **	**[0.10]** **	**[0.09]** **		**[0.10]** **	**[0.09]** **
	_cons	**-9.38**	**-9.43**	**-9.47**	**-10.6**	**-9.44**	**-9.56**
		[1.17]* **	**[1.18]*** **	**[1.02]*** **	**[0.93]*** **	**[1.18]*** **	**[1.00]*** **
	R-squared	0.85	0.85	0.82	0.81	0.85	0.82
	Max VIF	2.52	2.9	1.77		2.83	
	Number of obs	74	73	80	83	73	80

***p<0.05, **p<0.01 ***p<0.001**

Figure 5b: Basic Models (experiments with additional institutional measures)

		Dependent Var = Log (Citations-Weight Patents Per Capita)					
Time for Depndt Var: 1990-1995							
Time for Indep. Vars: 1989							
Level of Develpmt	log (gdppc)	**1.73**	**1.46**	**1.51**	**1.57**	**1.72**	**1.45**
		[0.17]* **	**[0.22]*** **	**[0.21]*** **	**[0.14]*** **	**[0.13]*** **	**[0.21]*** **
Domestic Instituions	democracy		0.04				0.05
			[0.04]				[0.03]
	econ freedom indx		0.20	0.20			0.22
			[0.23]	[0.23]			[0.21]
Freedom House Measures	political rights						
	civil liberties	0.25					
		[0.13]					
	Free		0.39	**0.62**	**0.66**	**0.73**	
			[0.26]	**[0.25]** **	**[0.23]** **	**[0.26]** **	
World Bank	Checks2a						0.20
							[0.12]
International Relationships	IR-factor		**0.26**	**0.25**	**0.25**		**0.28**
			[0.10] **	**[0.09]** **	**[0.09]** **		**[0.10]** **
	_cons	**-10.7**	**-9.44**	**-9.93**	**-9.27**	**-10.4**	**-9.50**
		[0.91]* **	**[1.13]*** **	**[0.94]*** **	**[0.95]*** **	**[0.86]*** **	**[1.14]*** **
	R-squared	0.81	0.86	0.85	0.83	0.82	0.86
	Max VIF		2.61	2.52			2.56
	Number of obs	83	73	75	80	83	73

***p<0.05, **p<0.01 ***p<0.001**

Figure 6: Basic Models (with vs. without Institutions or IR 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	IR-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<0.05, **p<0.01 ***p<0.001**

Figure 7: Basic Model (with wealth dummies & interaction terms)

		Dependent Var = Log (Citations-Weight Patents Per Capita)					
Time for Depndt Var:		1990-1995	1990-1995	1990-1995	1990-1995	1990-1995	1990-1995
Time for Indep. Vars:		1989	1989	1989	1989	1989	1989
Level of Develpmt	log (gdppc)	**1.38 [0.26]*** **	**1.37 [0.26]*** **	**1.53 [0.23]*** **	**1.51 [0.28]*** **	**1.48 [0.27]*** **	**1.52 [0.23]*** **
Domestic Institutions	democracy	0.06 [0.03]	0.06 [0.03]	0.07 [0.04]	0.06 [0.03]	0.07 [0.03]	0.06 [0.04]
	econ freedom indx	0.20 [0.23]	0.19 [0.23]	0.32 [0.23]	0.19 [0.22]	0.12 [0.23]	0.25 [0.22]
International Relationships	IR-factor	**0.29 [0.09]** **	**0.31 [0.19]* **		**0.28 [0.11]* **	**0.77 [0.32]* **	
Wealth 1	Wealthy Dummy	**1.02 [0.43]* **	**1.20 [0.53]* **				
	Wealthy*IR		-0.11 [0.16]	**0.31 [0.13]* **			
Wealth 2	OECD Dummy				-0.03 [0.66]	0.19 [0.73]	
	OECD*IR					-0.52 [0.34]	**0.23 [0.08]** **
	_cons	**-8.51 [1.30]*** **	**-8.44 [1.33]*** **	**-10.17 [1.17]*** **	**-9.41 [1.50]*** **	**-8.85 [1.57]*** **	**-9.77 [1.16]*** **
	R-squared	0.86	0.86	0.84	0.85	0.86	0.85
	Number of obs	74	74	74	74	74	74
	Max VIF	1.87	3.00	2.56	3.14	**19.59†**	2.42

***p<0.05, **p<0.01 ***p<0.001 † high multicollinearity**

Figure 8: 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 [3.68]*** **		**0.14 [2.31]* **	**0.17 [2.92]** **	0.10 [1.45]		0.05 [0.6]	0.07 [1.19]	**0.29 [3.61]** **	**0.30 [3.13]*** **	0.17 [1.98]	0.16 [1.89]
Econ freedom indx		**0.48 [3.98]*** **	**0.42 [3.93]*** **	**0.31 [4.36]*** **		**0.28 [2.88]** **	**0.27 [2.78]** **	**0.16 [2.14]* **	**0.35 [3.73]*** **	**0.26 [2.83]** **	**0.23 [2.42]* **	0.17 [1.87]
Econ Freedom *Democ				**0.32 [3.44]** **				**0.31 [3.37]** **				
log (gdppc)					**0.43 [4.00]*** **	**0.28 [3.44]** **	**0.28 [2.99]** **	**0.26 [2.85]** **			**0.27 [2.68]** **	**0.29 [2.94]** **
_cons	**-3.72 [4.02]*** **	**0.25 [2.19]* **	**-2.91 [3.96]*** **	**-2.31 [4.33]*** **	**-2.96 [4.09]*** **	**-4.15 [4.29]*** **	**-4.05 [4.17]*** **	**-3.27 [4.81]*** **	**-1.10 [4.08]** **	**-0.68 [3.74]*** **	**-1.69 [4.49]** **	**-1.19 [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<0.05, **p<0.01 ***p<0.001**

Coefficients reported above are standardized "beta" coefficients; [t-stats in brackets]

Figure 9: Summary Statistics

Total Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Cite-Weighted Patents Per Capita	720	0.00028	0.000952	0	0.0086
GDP	563	1.59E+11	5.81E+11	7.85E+07	6.25E+12
Population	735	3.01E+07	1.02E+08	30000	1.12E+09
per cap GDP	563	6963.21	9192.50	101.6	50081
Democracy	587	-0.09	7.94	-10	10
Econ Freedom	412	5.61	1.16	2.30	8.64
Free	486	1.04	0.82	0	2
US SE PhDs	810	164.74	557.67	0	6989
IR Factor	416	0	0.92	-0.42	11.09
Domestic SE Undergrads Per Captia	434	0.004168	0.003971	0	0.020472

1990-1995 period

Variable	Obs	Mean	Std. Dev.	Min	Max
Cite-Weighted Patents Per Capita	145	0.000203	0.000678	0	0.005817
GDP	133	1.83E+11	6.97E+11	9.17E+07	6.25E+12
POP	148	3.51E+07	1.19E+08	42170	1.12E+09
per cap GDP	133	7273.07	9605.19	101.5772	44725.5
Democracy	117	1.95	7.73	-10	10
Econ Freedom	99	5.68	1.21	2.937	8.219
Free	124	1.12	0.83	0	2
US SE PhD	162	241.85	741.23	0	6989
IR Factor	139	0.22	1.40	-0.34367	11.09433
Domestic SE Undergrads	70	0.006672	0.005271	0.000184	0.020472

1985-1990 period

Variable	Obs	Mean	Std. Dev.	Min	Max
Cite-Weighted Patents Per Capita	145	0.000318	0.00106	0	0.008396
GDP	122	1.66E+11	6.09E+11	1.27E+08	5.34E+12
POP	148	3.24E+07	1.10E+08	35000	1.04E+09
per cap GDP	122	7081.07	8992.11	114.64	40514.42
Democracy	118	0.03	8.01	-10	10
Econ Freedom	99	5.49	1.21	2.296	8.371
Free	124	1.10	0.79	0	2
US SE PhD	162	184.77	580.84	0	5244
IR Factor	139	-0.05	0.62	-0.38071	3.917559
Domestic SE Undergrads	92	0.004482	0.003801	0	0.013831

1980-1985 period

Variable	Obs	Mean	Std. Dev.	Min	Max
Cite-Weighted Patents Per Capita	145	0.000299	0.00098	0	0.007649
GDP	109	1.65E+11	5.81E+11	9.91E+07	4.92E+12
POP	148	2.98E+07	1.01E+08	30000	9.69E+08
per cap GDP	109	7443.47	9837.56	160.2024	50080.53
Democracy	118	-0.54	8.00	-10	10
Econ Freedom	93	5.46	1.14	2.932	8.644
Free	118	1.01	0.80	0	2
US SE PhD	162	175.17	581.24	0	5177
IR Factor	138	-0.17	0.36	-0.41768	2.388347
Domestic SE Undergrads	92	0.004803	0.003997	0	0.015736

Figure 10: 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 [.35]*** **	**1.58 [0.2]*** **	**1.59 [0.2]*** **	**1.6 [0.2]*** **	**1.31 [0.3]*** **	**1.81 [0.2]*** **	**1.76 [0.1]*** **	**1.85 [0.1]*** **	**1.87 [0.1]*** **	**1.69 [0.2]*** **
Domestic Institutions	Democracy	0.08 [.05]	0.07 [.04]	0.07 [0.04]	0.06 [0.04]	**0.09 [0.04]***					
	econ freedom indx	0.4 [.40]	0.36 [.23]	0.37 [0.23]	0.31 [0.23]	0.34 [0.3]					
International Relationships	Inward FDI	-0.07 [.06]	0.01 [.04]				-0.01 [0.06]	**0.1 [0.04]***			
	Cap Imports	-0.007 [.03]		-0.004 [0.02]			-0.04 [0.04]		0.02 [0.02]		
	US Phds	0.17 [.16]			0.16 [0.09]		0.18 [0.17]			**0.21 [0.1]***	
	Outwrd FDI	**0.18 [.18]***				**0.22 [0.06]** **	0.15 [.08]				**0.21 [0.07]** **
	_cons	**-11.1 [2.2]*** **	**-10.8 [1.2]*** **	**-10.8 [1.1]*** **	**-11.4 [1.1]*** **	**-9.8 [1.5]*** **	**-11.1 [1.8]*** **	**-10.5 [0.88]*** **	**-11 [0.8]*** **	**-11.8 [1.0]*** **	**-10.4 [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<0.05, **p<0.01 ***p<0.001**

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