National innovation rates: the evidence for/against domestic institutions

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National Innovation Rates: The Evidence For/Against Domestic Institutions

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ABSTRACT

Why are some countries more technologically innovative than others? 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. This paper will review the equivocating evidence for domestic institutions explanations of national innovation rates. Its survey will show that, although a specific domestic institution or policy might appear to explain a particular instance of innovation, they generally fail to explain national innovation rates across time and space. Instead, the empirical evidence suggests that certain kinds of international relationships (e.g. capital goods imports, foreign direct investment, educational exchanges) affect national innovation rates in the aggregate, and that these relationships are not themselves determined by domestic institutions. In other words, explaining national innovation rates may not be so much a domestic institutions story as it is an international story.

I. Introduction

Why are some countries more technologically innovative than others? Amongst political economists, the answer seems clear and universal: domestic institutions determine national innovation rates. One encounters this assertion throughout the literature. It is therefore awkward to discover that there exists little consensus on exactly which institutions determine innovation rates or precisely how they do so. Nor is there much empirical support for domestic institutions causing innovation in the aggregate, regardless of the type of institution tested or the measure of innovation used. To be more precise: 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. Yet, despite these problems, a core belief in a causal relationship between domestic institutions and national innovation rates remains widely held and little challenged.

The purpose of this paper is two-fold. First it will attempt to confront head-on this contradiction between theory, evidence, and the popularity of the institutions-innovation hypothesis. Put simply, for a hypothesis to be so widely accepted, but so loosely supported, is a situation that demands greater scrutiny. To that end, I will survey the major domestic institutions theories of innovation and the evidence for (or against) their generalizeability. We will find that, despite decades of research, scholars have yet to specify any institution or policy, or set of institutions (or policies), that consistently explain innovation rates across time and space. Indeed, both qualitative case studies and statistical analysis find nations with all varieties of domestic institutions innovating at all different levels. Let me be clear: I am *not* arguing here that domestic institutions have no causal effect on innovation rates; rather I contend that existing institutional theories of innovation have been over-stated, over-simplified, and need to be re-examined.

Second, this paper will then suggest that international relationships, not domestic institutions, may be the missing piece to the national innovation rate puzzle. Anecdotal observations within the evidence provided by domestic institutionalists suggest 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. Recent research also suggests that these international relationships are not themselves determined by domestic institutions. Empirical analysis of various measures of innovation, domestic institutions, and international relationships confirms these suspicions. *The data 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 surveyed here is new in several respects. First, it challenges the prevailing sentiment regarding domestic institutions and innovation which, despite its contradictions, remains little critiqued. 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 surveyed below is more generalizeable than much prior research; its supporting evidence consists of data on cross-national quantitative datasets covering several decades, rather than relying single case studies as has been the practice in most previous empirical work.

Finally, in order to facilitate discussion, this paper will present elementary analysis; relegating to the footnotes discussions of more complicated statistical approaches and methodological issues. I do this for three reasons. Most importantly, the simple empirical evidence for my argument is clear and compelling. We do not need to control for a dozen conditional variables in a complex statistical estimator in order to see it plainly. Rather, simple scatterplots and time-series will do. I am not attempting to avoid more sophisticated analysis. Certainly, I can and do include controls for numerous economic, political, and demographic factors. I also triangulate measures for each of the major study variables (institutions and innovation) using multiple, distinct, and independent datasets. But the results remain robust and unaffected. Hence a second reason is brevity. The statistically curious researcher can refer to the footnoted papers for thorough technical discussions of competing estimators, measures, and model specifications; discussions which would otherwise bog down the very basic argument I am trying to make here. Lastly, in taking this approach, I acknowledge that many of those involved in the innovation debate specialize in qualitative research (including highly respected scholars on this conference panel and reading its papers). To them, regressions are either opaque or artifice or both. Though I am a practitioner of quantitative methods, I cannot help but sympathize somewhat with this critique. There is simply much quantitative research which takes low quality data and puts it through a "taffy-machine" of statistical analysis. Often only specialists can judge the end product, if at all, while the rest of the scientific community are left out of the debate, skeptical and unconvinced. Therefore in an attempt at greater public scrutiny, this paper will attempt to offer clear points, backed by transparent data and methods. I do this with confidence because I have found that applying the statistical "taffy-machine" only strengthens the findings below. I use only publicly accessible datasets, hence the sophisticated statistical reader is encouraged to confirm this for herself.

II. Why Domestic Institutions?

Various explanations for national differences in innovation rates have been proposed over the years. Often generated by individual case studies from across the social sciences, these hypotheses have covered a wide range of independent variables including: the importance of military spending and weapons systems development,[1] factor scarcity,[2] first-mover advantages,[3] population or economic size, late-industrialization,[4] culture,[5] and historical contingencies.[6] However, explanations based on domestic institutions have come to dominate the innovation debate. [7] This is not due to some clearly identifiable superiority of domestic institutions theories over other schools of thought. So we should start our discussion by asking: why domestic institutions?

Institutions dominate the innovation debate in part because they are the proximate tools which governments use to promote innovation. Also, institutions differ across the industrialized democracies as do innovation rates. Therefore a causal linkage between domestic institutions and technological change

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[1] Smith 1985.
[2] Hicks; 1932; Habakkuk 1962; Leontief 1954.
[3] Porter 1990.
[4] Gerschenkron 1962.
[5] Dore 1987.
[6] Burke 1978.
[7] In this paper, I limit my treatment to those theories which adhere closest to Douglass North's description of institutions as "the rules of the game in a society", sets of established practices, rules, or laws that regulate the relations between individuals, groups, and organizations. North (1990), pp. 3-10. Also, I use the terms "institutions" and "policies" in this paper more or less interchangeably. I consider them to be different degrees of the same concept (or at least as overlapping concepts) with the former being greater in scope, depth, longevity, and/or inertia than the latter. More specifically, my intention is explicitly *not* to play a game of semantics in which I criticize "institutions" explanations, but am silent on or allow exception for "policy" explanations.

makes good sense, at least *prima facie*. But then, so do many of the alternatives listed above. They too vary across countries and offer rewards and incentives for or against innovation, albeit less proximately or consciously than institutions.

Rather, the debate's fixation on domestic institutions seems not to result from a series of well-tested hypotheses, but from advances in economic theory, specifically in the economics of science and in formal economic growth theory. In these subfields, economists have come to believe that certain domestic institutions are necessary to address the obstacles which prevent or slow innovation. For example, some innovation scholars highlight the non-rival and non-excludable aspects of inventive activity, thus casting innovation as a public goods problem.[8] Other scholars emphasize the high levels of uncertainty, risk, high transactions costs, and incomplete information associated with innovation.[9] 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.[10]

Theoretically, domestic institutions help solve each 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 whom might oppose technological change. Thus domestic institutions have come to play a determining causal role in theories of national innovation rates.

But exactly which institutions matter? This is where the theoretical trail breaks down. Domestic institutions theories of innovation take myriad forms and employ different levels of analysis. Elements of a state-level domestic institutions theory of technological change can be recognized as early as the 1791 *Report on Manufactures* by Alexander Hamilton and Tench Coxe, and certainly in the writings of German

[8] Arrow 1962; Romer 1990; Hall & Jones 1999; Aghion & Howitt 1998
[9] Nelson 1959; North 1990
[10] Mokyr 1990; Acemoglu, Johnson, & Robinson 2005

political-economist Friedrich List.[11] But many early theorists who focused on the institutions-innovation relationship failed to specify their independent variable. Indeed, even prominent economists who have attempted to deal systematically with technological change (including Smith, Marx,[12] Solow, and even Schumpeter) have generally regarded science and technology as "black boxes" proceeding according to their own internal processes largely independent of political or economic forces; they therefore tended to omit its causality from their analysis.

This changed with the Cold War, when the economics of science and modern economic growth theory were born. As discussed above, theorists in these subfields began to endogenize technological change, and attempted to identify specific institutions which should affect it. Unfortunately, much of the empirical evidence they used to substantiate, or generate, these hypotheses was either equivocal, based on anecdotal evidence, or on non-generalizeable case studies. Finally, in the late-1980s, a new research program was created to address these problems. It employed a comprehensive cross-national empirical approach designed to identify the specific domestic institutions responsible for differences in national innovation rates. This effort was termed the "National Innovation Systems" (NIS) research program and, though it changed the practice of innovation research, the next section will show that it has not produced any general hypotheses.

II. National Innovation Systems: Empirically Rich, Theory Poor

NIS research was originally designed to be the empirical solution to a theory-laden debate over innovation rates. Ironically, NIS has created the opposite situation: a library full of excellent empirical case-studies of domestic institutions and policies, but no general theory of national innovation rates.

NIS was perhaps the first systematic cross-national approach to studying innovation rates.[13] It arose in response to empirical puzzles posed by radical and unexpected changes in national innovation

[11] Granted, these men did not seek to explain technological innovation per se. Instead they argued for the creation of what today might be called "industrial policy": a combination of trade, finance, budgetary, procurement, and regulatory policies (and the formal government institutions necessary to support them) which would foster growth and improvement in their nations' domestic industrial base. Throughout the following two centuries, these ideas were taken up with great enthusiasm by policymakers in developing Germany, Japan, and other states in Europe, Asia, and even Latin America. Hamilton 1791; List 1841.

[12] For an alternative view of Marx, see Bimber 1994.

rates during the 1970s and 1980s. These unexpected changes included the 1) apparent decline of established technological leaders such as the US and Great Britain, 2) the rapid rise to technological power of Japan, and 3) the sudden appearance of Taiwan, South Korea and other newly industrialized countries at or near the technological frontier. None of these phenomena were easily explained by existing theories of innovation in politics or economics. Moreover, the flurry of anecdote-driven research which attempted to explain these anomalies created instead a confusing array of conflicting theories and policy prescriptions. In response, political economists in the United States and Europe initiated NIS, which took a more holistic and empirical approach to studying the effects of domestic institutions on innovation rates. And since its inception, NIS has become one of the dominant paradigms within the subfield of innovation research.

The NIS approach to explaining national innovation rates starts with the recognition that innovation, be it performed by firms or individuals, occurs within the context of broader political and economic institutions and policies. NIS further posits that these institutions and policies together form a "system" which determines a country's rate and direction of technological "innovation". And since these institutions and policies differ from nation to nation, and in fact define nations to some extent, they therefore constitute "national innovation systems". Of course, NIS scholars recognized that this view of technological change was not entirely new, but was reminiscent of Hamilton and List.[14]

What *was* new in the NIS research program was the empirical depth and thoroughness with which its proponents approached the subject. Generally using a case study approach, NIS scholars focused their research on identifying and probing the roles of dozens of specific national institutions and policies which affect innovation. Pioneered by economists Christopher Freeman, Bengt-Ake Lundvall, Richard Nelson, and Charles Edquist,[15] NIS scholars examined the interactions and effects on innovation of different educational institutions, science policies, trade regimes, legal frameworks, financial institutions, anti-trust laws, etc. They also took care to observe these domestic institutions across a wide spectrum of nations,

[13] Nelson 1993; Lundvall 1992; Edquist 1997.
[14] Lundvall 1992; Freeman 1995.

many of which had been little studied in previous research on innovation. For instance, in Nelson's seminal publication, NIS scholars analyzed large, wealthy, frontier innovators (Japan, US, Germany), small wealthy but innovsative states (Denmark, Canada, Sweden), and lesser developed countries both innovative (Israel, Taiwan) and not (Argentina, Brazil). Since then, other researchers have gone on to apply the NIS methodology to a variety of disparate states from Finland to China, Slovakia to Algeria, Hungary to Argentina.[16]

But while the NIS research program has made major empirical contributions to the debate, a problem with generalizability soon emerged. Taken as a whole, the separate NIS case studies suggest some 20-30 major independent variables (policies and institutions), each of which may play a role in technological innovation depending on its configuration vis-à-vis the other variables. Thus NIS has brought to light the complexity of the innovation process and the diversity of factors involved in it; but has failed to produce any general theory.

For example, in the case of the U.S., NIS scholars contend that the key drivers of technological progress since World War II include military procurement, timely and strong anti-trust actions, small firms, and universities.[17] Yet none of these variables figure significantly in Japan's national innovation system. Rather, Japan's innovative strength during the post-war period emanates from tight government control over trade and investment, cooperative industry-labor relations, and specific corporate management techniques, each of which are missing from the U.S. case.[18] Studies of the UK, Germany, France, Korea, and Taiwan similarly expand the list of variables.[19] Furthermore, since the successful operation of each NIS variable often depends upon its context, we find ourselves with a rapid proliferation of viable national innovation systems. So while the relatively strong American anti-trust regime helps innovation, it does so in the context of free trade and capital mobility; conversely, Japan's relatively weak anti-trust enforcement seems to aid innovation when configured with its system of

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[15] Nelson 1993; Lundvall; 1992; Edquist 1997.
[16] Oinas 2005; Sun 2002; Balaz 2005; Saad & Zawdie 2005; De Tournemine & Muller 1996; Correa 1998.
[17] Mowrey & Rosenberg 1993.
[18] Odagiri & Goto 1993.
[19] Nelson 1993; see also Kim & Nelson 2000.

industrial policy and captive finance. Hence, in addition to a large number of variables, the NIS approach produces an exponentially greater number of possible combinations of these variables, each of which may promote or hinder innovation. This lack of parsimony poses a problem for both theorizing and testing, especially in cases where the *same* independent variable is attributed with *different* effects on innovation rates in different countries.[20]

Thus, after twenty years of research NIS scholars have yet to produce any general hypotheses to explain differences in national innovation rates. That is, while they have achieved their empirical goal of increasing the set of datapoints and potential relationships between them, NIS scholars have yet to fit a theory to them. I am perhaps overly emphatic on this point because a common occurrence in innovation debates is for audience members, article reviewers, or casual observers to bring up policy or institution "X" as the solution to the institutions-innovation puzzle. Often these claimants are experts in a particular region, country, industry, or time-period; and institution "X" may full well seem to explain innovation rates in their particular area of study. But often these claimants are unaware of the NIS literature, which has usually studied their particular "X" in multiple industries, countries, and time-periods, and failed to find consistent outcomes.

Certainly, additional research may yet identify a particular institution, policy, or combination thereof that *does* provide a generalizeable explanation of innovation rates. But to date, NIS research has been of such high quality and thoroughness that I and others feel that new approaches should be taken, and new variables considered. Amongst those who agree with this pessimism are Varieties of Capitalism researchers who have generated an exciting new line of research, which is the subject of the next section.

[20] While I critique NIS here for its lack of strong theoretical foundations, it is important to note that its atheoretical approach was a strategic choice by some of its founders, not a product of bad research design. For example, the 1993 case studies coordinated by NIS pioneer Richard Nelson were written in direct response to the inability of innovation theory to predict empirical reality. While endogenous growth theorists had made enormous contributions to economists' understanding of innovation, Nelson critiqued them for neglecting or mis-specifying many important independent variables and causal relationships. He recommended that empirical research, in the form of in-depth qualitative case studies, was necessary to capture the causal factors missed by grand theory (Nelson 1997). However, much of the existing empirical research of the sort suggested by Nelson was based on just a single country (often Japan). Hence, the idea behind the NIS movement was to increase "the number of 'points' that a causal theory had to 'fit'"(Nelson 1993).

III. Varieties of Capitalism: Theoretically Rich, But Selects on the Dependent Variable

Recently, there have since been several attempts to explain why NIS institutions and policies are unable to explain innovation rates in the aggregate. Most of these arguments imply that NIS 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.

One prominent school of thought along these lines is "Varieties of Capitalism" (VOC) theory. VOC scholars, in part, seek to fill the gap between endogenous growth theory and the NIS research program. They agree with both schools of thought that domestic institutions best explain national innovation rates. However, they critique the NIS approach for its lack of theory and parsimony. They also fault endogenous growth theory for its failure to adequately consider non-market relationships between economic actors. VOC theory is an attempt to address both sets of weaknesses.

As put forward by Peter Hall & David Soskice (2001), VOC theory argues that the behavior of a country's NIS institutions and its innovators are both endogenous to markets.[21] 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. This is admittedly a highly condensed version of a nuanced and sophisticated theory, but it is accurate for the purposes of our discussion.

Overall, the VOC causal explanation is both theoretically appealing and dovetails with some widely held stereotypes about national differences in innovation; however, little empirical data was produced to support its central claim. The evidence offered by Hall & Soskice consisted of only four years of patent data from the European Patent Office (EPO) which shows that Germany and the US concentrate their patenting as predicted by VOC theory. Specifically, Hall & Soskice examined patenting activity by Germany (a coordinated market economy, or "CME") and the US (a liberal market economy,

[21] Hall and Soskice 2001.

or "LME") in 30 technology classes during 1983-84 and 1993-94 (Figure 1 below). They found that Germany's patent specialization was almost equal and opposite that of the US in both time periods. More specifically, the Germans were found to be more active innovators in industries which Hall & Soskice characterize as dominated by incremental innovation (such as mechanical engineering, product handling, transport, consumer durables, and machine tools); meanwhile, firms in the US innovated disproportionately in industries which the authors perceive as more radically innovative (including medical engineering, biotechnology, semiconductors, and telecommunications).

Several possible problems exist with this approach, but the main concerns are with selection bias and measurement error.[22] First, the VOC scholars compare only 4 years worth of data from only 2 countries. Second, the country chosen to represent liberal market economies (LMEs) is the United States, a technological innovation outlier by almost any measure. Third, they use patent counts as their measure of innovation rates. But simply counting up a nation's patents does not provide a good measure of innovative output since it treats trivial inventions the same as major ones (research has shown that it corresponds better with innovative inputs [e.g. R&D spending, sci-tech labor, etc.]).[23] As a solution, innovation scholars weight patents by forward citations in order to control for patent quality. A more complete discussion of innovation measurement and the appropriate use of patent data can be found in the Appendix below.

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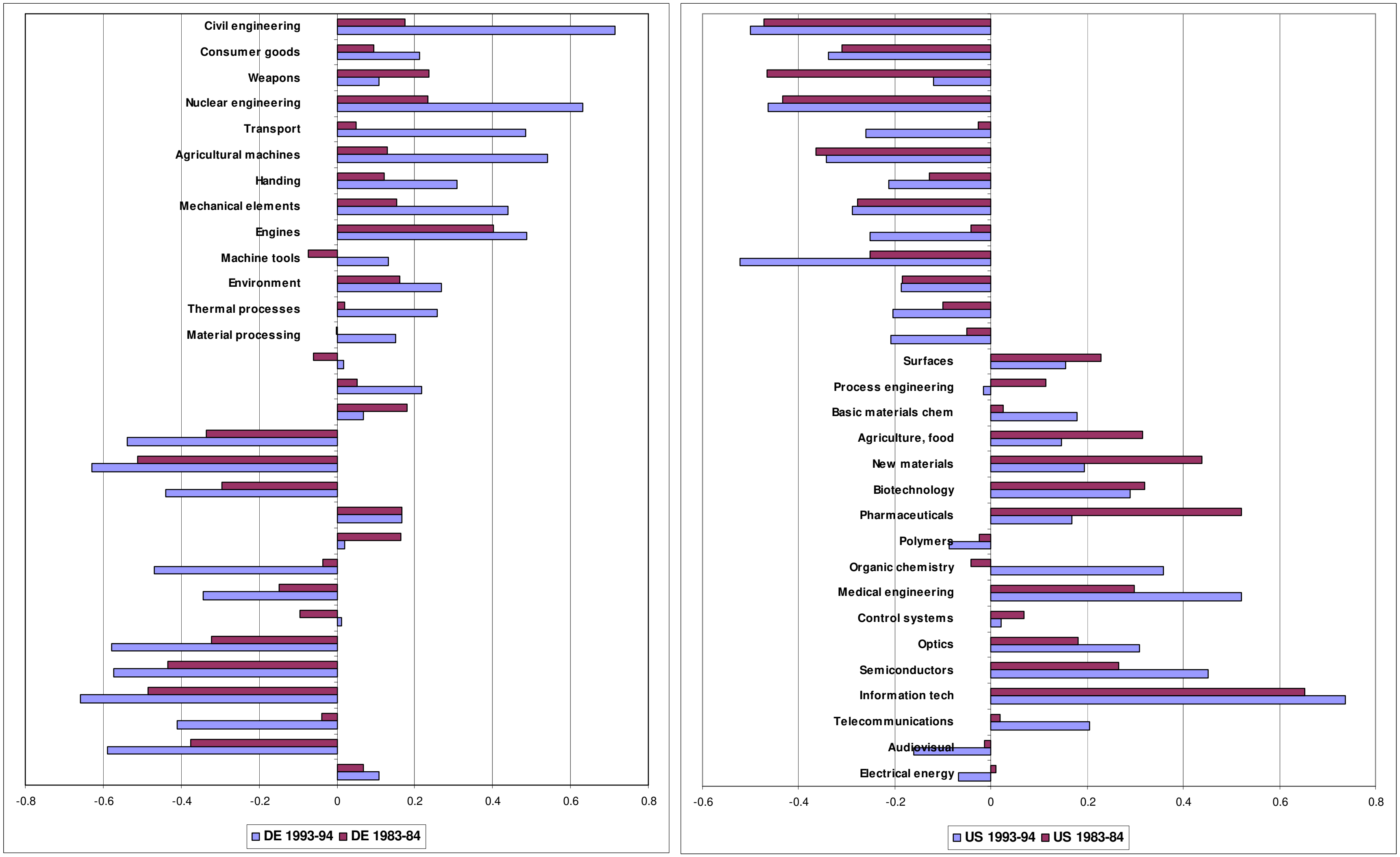
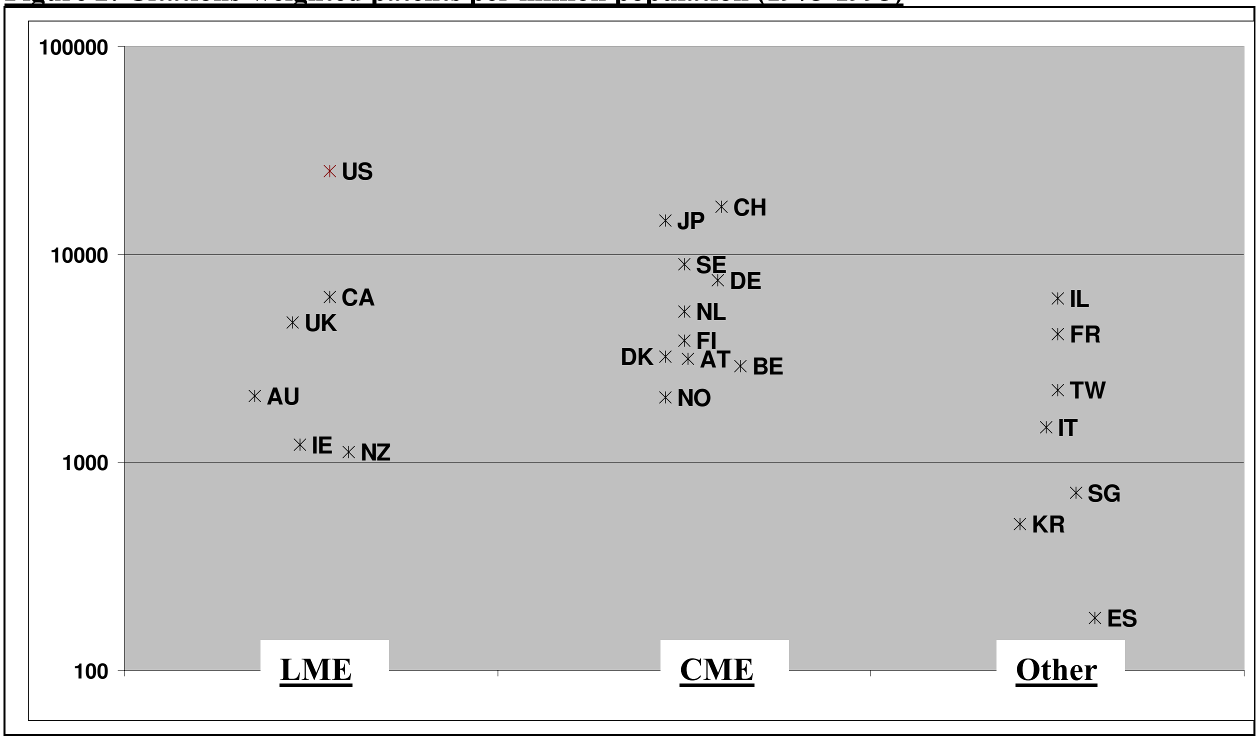
[22] For example, simple patent counts do not provide a good measure of innovative output since they treat trivial inventions the same as major ones. As a solution, innovation scholars weight patents by forward citations in order to control for patent quality. They also triangulate datasets by using other innovation measures, such as science & engineering research publications, and high-tech exports. Also, VOC's theory assumes that some industries are inherently more innovative than others, a description not born out by the historical record, though probably not problematic during the time period considered by Hall & Soskice 2001.
[23] Griliches 1984, 1990. See Appendix.

Figure 1: Patent Specialization by Technology Class in Germany and The U.S.



Note: Higher scores indicate greater specialization in innovation in that particular type of technology.
Source: Charts reproduced here with data obtained through the cooperation of Thomas Cusack, David Soskice, and Peter Hall. See also Hall & Soskice 2001, pp 42-43.

Figure 2: Citations-weighted patents per million population (1975-1995)



Source: NBER Patent Dataset, World Bank Development Indicators

A more thorough analysis using twenty years of citations-weighted patents for *all* of the LME and CME countries paints a distinctly different picture. Figure 2 (above) presents a simplified version of the main results.[24] As the chart shows, VOC theory does not accurately predict innovative behavior over time and space: LME and CME countries innovate at about the same rates. The LME's have greater variance, but their mean is more or less the same as the CME's. If one uses individual patents as the unit of analysis, a similar result is produced: LME patents are no more radically innovative than CME patents, especially if you exclude the US data. This picture is further corroborated by data on scientific publications: scientists in the LME's are no more radically innovative, do not concentrate in more cutting-edge subfields, than those in CME's.

IV. Political Decentralization: Theoretically Over-determined, Anecdotally Rich, But Aggregately Insignificant

[24] Additional data, regression analysis, and technical discussions can be found in Taylor 2004

Political decentralization offers another route to high innovation rates; one which might also explain the weak explanatory power of NIS and VOC research. Indeed, political decentralization is one of the most theoretically over-determined explanations for national innovation rates. Decentralized governments are widely seen as agile, competitive, and well structured to adapt to innovation's gale of creative destruction. Meanwhile centralized organizations of all sizes, from firms to nation-states, have come to be viewed as rigid and thus either hostile to the risks, costs, and change associated with new technology, or prone to cling too long to fool-hearty or outdated technological projects. These sentiments are in fact so pervasive that they can be found both in the popular press[25] and throughout the academic literature[26] But like the two research programs discussed in the previous sections, while the popular association between political decentralization and innovation is strong, the empirical evidence consists mostly of anecdotal observations and stylized case studies. A more rigorous and comprehensive analysis tells a more equivocal story about the advantages of decentralization for innovators.

Political decentralization proponents emphasize four primary mechanisms by which government structure should affect national innovation rates. First, they argue that both horizontal and vertical decentralization increase the number of political and economic units participating in, funding, and demanding innovative activities. This not only multiplies technological search and experimentation efforts,[27] but can also increase the diversity of these research efforts and the information acquired through them.[28]

Second, scholars assert that, by increasing the number of units, decentralization increases competition, thus increasing the incentives for innovation. This theme is perhaps best specified by federalism scholars, who point out that decentralization can result in a "Delaware effect" in which sub-national governments compete with one another to attract business investment, and therefore constantly improve the legal, tax, and regulatory environments for innovators.[29] This concept has evolved into

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[25] Suroweicki, 2004
[26] Rosenberg & Birdzell, 1985; Mokyr 1990, 2002; Drezner 2001, Acemoglu et. al., 2006
[27] Drezner, 2001; Mokyr 1990, 2002; Weingast, 1995; Nelson, 2005; Acemoglu, Johnson, & Robinson, 2005
[28] Drezner, 2001; Mokyr 1990, 2002; Rosenberg & Birdzell, 1985; Suroweicki, 2004; Acemoglu et. al. 2005
[29] Cary, 1974; Oates 1972

Weingast's "market-preserving federalism", in which federalism can prevent government from acting in a predatory manner toward innovators, and allow credible commitments to produce pro-market policies and public goods.[30]

Third, federalism theory holds that political decentralization leads to both better policy design and public goods provision at the local level. Adhering to Hayek (1945), the idea here is that local policymakers simply have superior information concerning local conditions than do distant national legislators or bureaucrats, and can therefore design better policy for the local environment. Better policy should in turn mean more efficient allocation of resources toward, and proper incentives for, local innovators. In addition, decentralized local public goods production is often better at reflecting popular preferences than is centralized national public goods production. As Tiebout (1956) put it, different sub-national governments provide a menu of different policy environments, which allows different kinds of "consumer-voters" of public goods (here innovators consuming scientific knowledge, investors looking for R&D opportunities, high-tech labor seeking employment, and so forth) to choose the environment that is right for them. So, for example, innovators in Massachusetts can use state government funding to pursue stem cell research, while Kansas' more rural and religious taxpayers can instead fund initiatives in agricultural sciences, and California's public universities can focus on alternative energy. In a unitary state, this type of public goods preference matching would not occur as systematically. Surowecki (2004) describes this as a form of decentralization-driven specialization which makes innovators more productive and efficient. It could alternately be interpreted as precisely the kind of national environment conducive to producing Richard Florida's (2002) "creative cities".

Fourth, several scholars argue that political decentralization aids national innovation rates by making the state less vulnerable to capture by status-quo interest groups.[31] Put simply, more centralized governments are more vulnerable to interest-group capture because they have fewer decision-making points and veto-players to control. Therefore, *ceteris paribus*, more capture-able centralized governments

[30] Weingast, 1995; Qian & Weingast, 1997
[31] Drezner, 2001; Mokyr 1990, 2002; Rosenberg & Birdzell, 1984; Weingast, 1995; Acemoglu et. al., 2005

are more likely to make policies which slow technological innovation. 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. A good example of this in the U.S. might be AIDS research during the 1980s when powerful interest groups exerted their influence on the federal executive branch to slow innovation in these areas. However, the federal legislature, as well as state and city governments, were able to override the objections of the executive branch and provide regulatory or budgetary support for research; while the courts served as an additional point of entry for supporters of technological progress.[32]

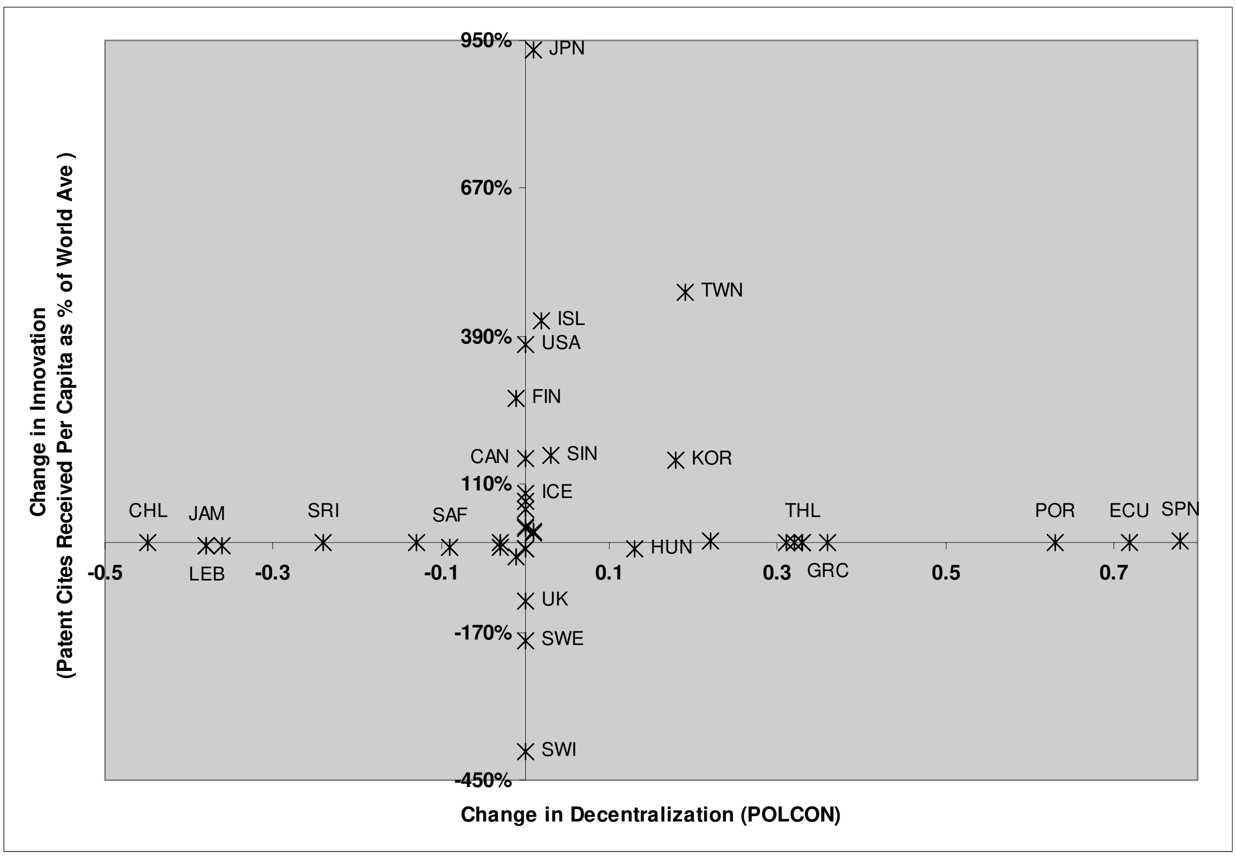
This fourth aspect of government structure might also help to explain why NIS and VOC institutional explanations have failed to generalize across different countries and time periods. According to decentralization proponents, technological innovation poses not just a public goods dilemma, it also suffers from an interest-group capture problem. Status-quo interest groups are those whose assets (e.g. skills, capital, land) are hurt by technological change. In order to obstruct threatening technological changes, these interest groups will often seek to influence or capture precisely those institutions and policies which NIS scholars use to explain innovation rates. Even the presence of markets cannot prevent this phenomena, argue Acemoglu et. al. (2005) and Drezner (2001), since markets and property rights are but institutions subject to the will of captured state apparatus.[33] Thus NIS and VOC explanations fail to generalize across time and space because the institutions & policies they prescribe are endogenous to government structure: their technological goals, and their efficiency in achieving these goals, are determined by the ability of broader state structures to resist interest-group capture.

[32] Shilts, 1987

[33] But what if a centralized government is strongly pro-technology or captured by pro-technology interest-groups? After all, centralized government can better solve coordination dilemmas that inhibit technological progress, and marshal the economic resources necessary for massive projects such as late-industrialization, space flight, or atomic weaponry. Therefore more centralized government should be good for innovation when powerful interest-groups favor it. Yet Drezner (2001) points out that, even in these cases, decentralized states still have an advantage because the sub-national provinces can act as experimental test beds for different kinds of policies and innovations. Over time, the vulnerability of centralized states to interest-group capture will outweigh any benefits, as new innovations rapidly evolve into status-quo interests and thus a drag on further technological progress.

Ideally, in order to test the political decentralization thesis, one would want to perform a natural experiment, in which observed changes in government structure can be followed by observations of changes in innovative activity, with all other factors held constant. While no empirical situation fits this ideal, we do have a number of cases in which governments have decentralized over time, and where we can also collect some quantitative data on innovative outputs. These are presented in Figure 3 (below). This graph plots changes in decentralization versus changes in innovation in the twenty-nine countries which underwent the largest changes in government decentralization from 1975-95. In addition, I also plotted the results for the twenty-five countries with the largest changes in relative innovation rates.[34] The measure of innovation used is citations-weighted patents per capita (see Appendix), but similar graphs can be made for science-engineering publications, or other measures of technological capability.

Figure 3: Innovation vs. Decentralization in 45 Countries (1975-95)



Source: United States Patent & Trademark Office, NBER (2001)

[34] Overlap between the two sets of countries and missing POLCON data for Hong Kong and the Bahamas brings the total number of countries to forty-five.

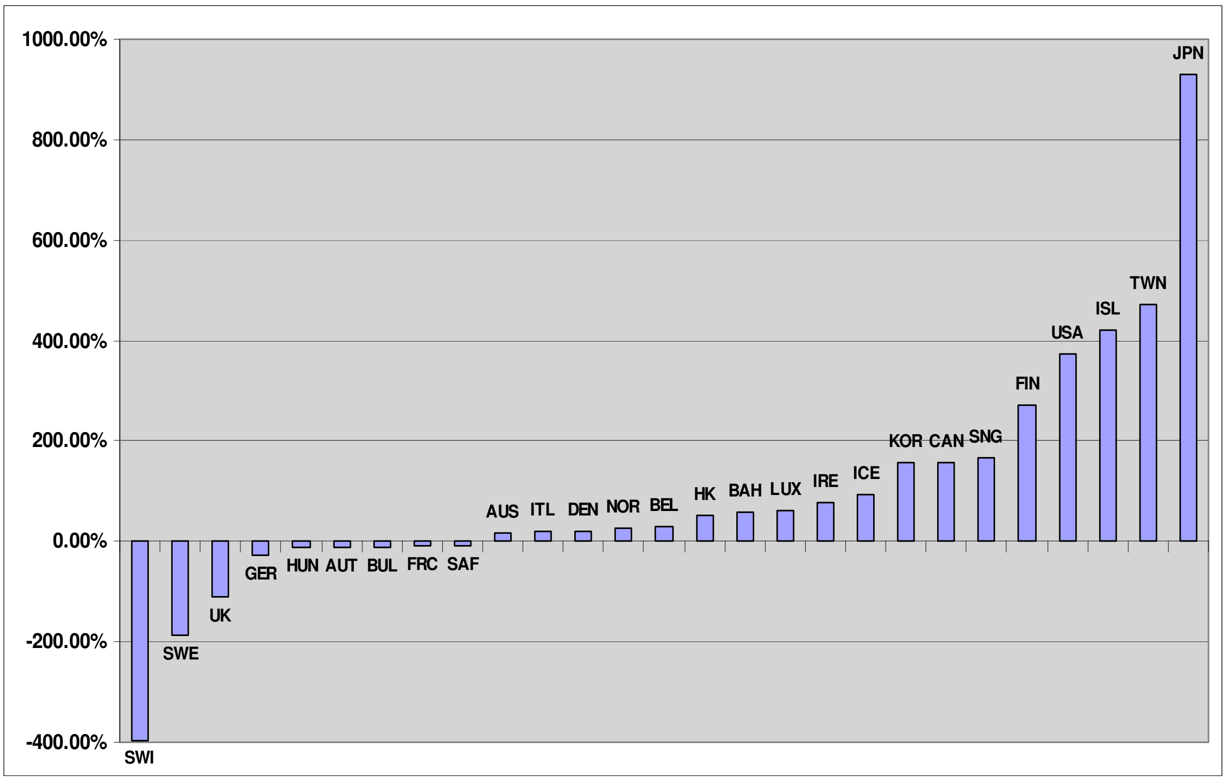
As my measure of overall decentralization in this graph, I employ the POLCON Index developed by Witold Henisz (U. Penn).[35] The POLCON Index is a 0-1 measure which takes into account the number of independent branches of government with veto power over policy, modified by the extent of party alignment across branches of government and the extent of preference heterogeneity within each legislative branch. The inclusion of party alignment and legislative preferences means that POLCON is not a pure measure of structural decentralization. However, unlike measures which rely purely on formal institutional structure, the POLCON measure allows me to control for states which may be formally decentralized but which may suffer ineffective *de facto* checks and balances. It also provides a finer gauge than the traditional technique of using "dummies". Moreover, 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.[36]

If decentralization is as overwhelming an influence on innovation as is assumed in the literature, then those states which have decentralized the most should enjoy significant improvements in innovation rates. That is, we should see a clear diagonal line of points stretching upwards across the graph above. However, as Figure 3 reveals, only Taiwan and South Korea appear have experienced significant increases in both variables. Otherwise, the countries that decentralized most (Spain, Ecuador, Portugal, Greece, and Thailand), experienced little change in innovation rates; while the countries which had major shifts in innovative performance (Japan, Israel, Switzerland, US, Finland) underwent little change in government structure. Of course, "decentralization" in many of these countries was more horizontal and informal, and is perhaps better described as a move from autocracy or single-party government towards genuine multi-party democracy. But this is precisely the point: even using the broadest definition and least formal measure of decentralization, it is difficult to find a correlation with innovation.

[35] Henisz 2000.
[36] Delios and Henisz. 2000; Henisz 2002; Henisz & Zelner. 2001.

Using the same measure of innovation, Figure 4 (below) selects out those countries with the largest increases in relative innovation rates from 1975-95. The first thing that should strike us here is how little change in relative innovation rates there is at all. Few of the 74 countries sampled registered any significant shift in their relative rankings, and those with less than a 7.5 percent change have been left off of the graph altogether. Secondly, even a cursory examination reveals that the decentralized states

Figure 4: Change in Per Capita Patent Cites Received as Percent of World Ave. (1970-75 vs. 1990-95)



Note: n=74, countries not shown had a change of <7.5%. Source: United States Patent & Trademark Office, NBER (2001). Countries shown: Switzerland, Sweden, Great Britain, Germany, Hungary, Austria, Bulgaria, France, South Africa, Australia, Italy, Denmark, Norway, Belgium, Hong Kong, Bahamas, Luxembourg, Ireland, Iceland, South Korea, Canada, Singapore, Finland, United States, Israel, Taiwan, Japan.

appear to have had little innovative advantage over other states, regardless of size or wealth. The decentralized US and Canada both experienced large relative gains in forward patent cites per capita; meanwhile the federalist states of Germany and Switzerland suffered significant relative declines. Amongst the biggest gainers are countries like Japan, Taiwan, Israel, Singapore and South Korea, all relatively centralized states. One major new innovator, Finland, even marginally increased its centralization (as measured by POLCON). But before we credit centralization with this achievement, we must also note that three of the most centralized European states (France, Great Britain, and Sweden) are amongst the largest decliners in relative innovation rates. More interesting is the nation that does not appear in Figure 4, Spain, which significantly decentralized by almost any measure one can calculate. Spain's negative change in relative innovative performance (a mere -0.01 percent) is too small to register on this graph, despite the fact that its government continuously decentralized, both horizontally and vertically, formally and informally, throughout the entire time period sampled. Hence, even if I "cheat" by selecting on the dependent variable, I cannot substantiate a relationship between structure and innovation!

Of course, these simple statistical tests do not allow us to simultaneously control for important conditional variables which might also affect innovation rates. Certainly when one controls for economic development, democracy, education, etc., then the causal strengths of political decentralization should become apparent? In Taylor (2007a), I conduct quantitative analyses along these lines, the results of which I briefly summarize here. Surprisingly, with but a single exception, no regression yielded a significant coefficient for any measure of decentralization used in any combination with any of the innovation measures or conditional variables. The results were triangulated using 3 distinct and independent measures of national innovation rates, 4 different measures of political decentralization (both vertical and horizontal), and over a dozen different control variables (Figure 5). These control variables were not run altogether in a "kitchen-sink" regression, but were modeled according to theory and critique in a back-and-forth manner between author, critics (such as talks & conference venues like this), and reviewers. The lone case in which the null hypothesis could be rejected occurred when countries were sub-divided by wealth; but here the effect was fairly small, only applied to the wealthiest subset of nations, and was not consistent across different measures of decentralization. This is not what one would expect from such a well theorized and widely accepted causal relationship.

Figure 5: Summary of Decentralization-Innovation Regressions

Different Measures of Decentralization	Various Control Variables	Different Measures of Innovation
Federalism Dummies (Watts 1999)	Econ Development: -electriciy consmptn/capita -GDP/capita -lagged DV	Patents (citations-weighted, per capita)
Federalism (Lijphart scale)	Size: -population -GDP	Science-Engineering Research Publications (citations-weighted, per capita)
Horizontl Decntrlztn (Lijphart scale)	Democracy (Polity IV)	High Tech Exports (per GDP)
Veto Players (Henitz POLCON)	Trade Openness (% of GDP)	
	Military Spending (% of GDP)	
	Natural Resource Curse: -arable land (% of total) -fuel exports (% of total) -metal/ore exports (% of total)	
	Education: -Literacy -Science/Eng undergrads -Education spending (% total)	
	R&D Spending (% GNP)	
	US Dummy	
	OECD Member Dummy	
	High v. Low GDP/capita Dummy	

Of course, statistical analysis has its weaknesses and limitations; therefore, given the strength of decentralization theory, a subsequent set of comparative case studies was performed (Taylor 2006) to corroborate the quantitative analysis above. This qualitative approach adds value because it allows us to better (dis)confirm causal mechanisms, expose potential issues with endogeneity, and can reveal model specification errors (omitted variable bias is of particular concern in this case). To that end, the case studies examined innovation in two drastically different technologies and time periods (blood products 1981-1987 and electric power 1879-1914) across five countries (France, Germany, Japan, UK, US) for each. The case studies generally corroborated the statistical findings. In neither technology did government structure appear to have a significant or systematic effect on innovation rates.

However, the case studies did find that technologies in both sectors and time periods consistently diffused more slowly in the centralized states than in the decentralized states.[37] This might explain the perception that innovation also occurs more rapidly in these countries. That is, since both innovation and

[37] This is not a new or original finding, but merely confirms a prediction made in prior research. See Rogers 1995; Walker. 1969.

diffusion manifest themselves in the appearance of new technology, the two phenomena can be easily mistaken for one another at a superficial level. And given that the much of the existing evidence for a decentralization-innovation thesis involves stylized facts and anecdotal case studies, it is possible that the empirical observations reported in prior research are actually instances of political decentralization aiding diffusion which were misidentified as innovation.

Regardless, we are still left without a convincing domestic institutions explanation for differences in national innovation rates. Moreover, as with VOC, the failure of the aggregate empirical evidence to support such a well-theorized explanation is surprising. This should force us to question even our most axiomatic institutional causal variables. In the next section, I shall do just that; I will show that even the institutions of democracy and free markets are not as powerful causal agents as previously assumed.

V. North-Acemoglu Institutions: Theoretically Broad & Compelling, Still Empirically Problematic

The current state of the innovation 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 (1973), who used historical analysis to suggest that technological change is endogenous to them.[38] At first, this might appear to confound innovation with investment and economic growth. But in order to explain differences in national innovation rates, research must draw somewhat on the economic growth literature because a) research has consistently shown that technological change is the main driver of modern, long-run economic growth; and therefore, b) economic growth scholars are producing the most often discussed theories, tests, and evidence on this subject.

North & Thomas implied that "good" institutions are necessary for technology-based industrialization, modernization, and economic competitiveness. The institutions they focused on were property rights and efficient markets for trading them, and for motivating the investment and risk-taking necessary for innovation.[39] Of course, the specification and enforcement of property rights and markets are political issues, therefore North later noted that political institutions need also be efficient and

[38] North & Thomas. 1973.

therefore democratic.[40] 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).[41] They repeatedly assert or imply that these Northian institutions are the essential institutional requirements for technology-driven long-run economic growth.

But is this what we see in the innovation data? Figures 6a-6c (below) graph the national innovation rates for twenty-one currently industrialized democracies over the 1975-1995 period. The measure of innovation used is citations-weighted patents per capita (see Appendix), but similar graphs can be made for science-engineering publications, or other measures of technological capability. Since the United States is by far the most innovative country in the world during this time period, the data has been normalized to show each country's innovation rate relative to that of the United States. The top graph presents data on those countries that are consistently the world's most innovative nations, the middle graph shows the mid-level innovators, and the bottom graph highlights those countries which have had the most significant increases in innovation rates during the twenty year period.[42] Note that each of the graphs uses the same vertical scale, and hence can be compared against one another. With this aggregate data in hand, we can begin to make some initial judgments about the plausibility of various common assumptions about national innovation patterns.

What does Figure 6 tell us about Northian institutions? First, notice that there are no African, Latin American, or ex-communist bloc nations tracked in the graphs since most countries in these regions barely register on the vertical scale. Countries in these regions are indeed typified by low levels of

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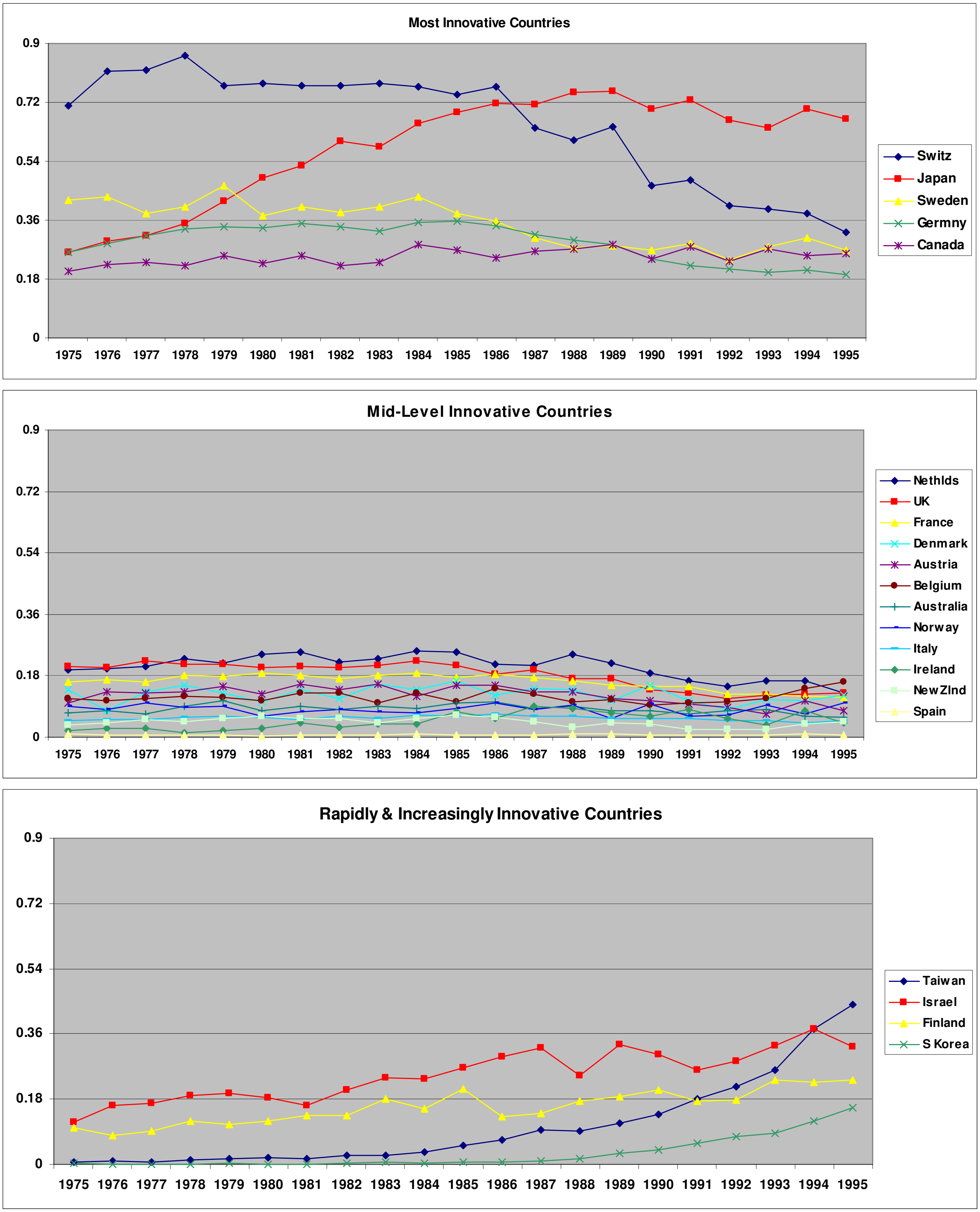
[39] North & Thomas 1973.
[40] North 1981, 1990.
[41] Acemoglu, Johnson, & Robinson. 2005; Acemoglu & Robinson. 2000; Acemoglu 2003.
[42] The term "mid-level" is used here to remind us that there are approximately one hundred countries that produced little or no patented innovation during this period (defined as 10 or fewer patents). The only other countries not included in Figure 1 that innovated at a comparable level to those graphed are the USSR/Russia, South Africa, Hungary, and Hong Kong, each of which would be in the mid-level group. These were omitted since they are generally not considered to be amongst the industrialized democratic nations.

Figure 6a-c: Total Citations-Weighted Patents per Capita (US = 1.00) [*Best viewed in color*]



Source: National Bureau of Economic Research (2001) democracy, poorly functioning markets, loosely enforced property rights, and high levels of corruption. Hence Northian institutions seem like a good candidate for a causal explanation for their absence.

Second, note the appearance of Taiwan and South Korea as two rapidly and increasingly innovative countries in Fig 6c. But recall that Taiwan was until recently an authoritarian state, remaining under martial law for four decades until 1987, and one-party rule until 1991 when President Chiang Ching-kuo gradually liberalized and democratized the system. Meanwhile South Korea was ruled by various autocrats and military dictators until its first democratic elections in 1987. Hence both Taiwan and South Korea democratized *after* their surge in innovation rates had begun, not before. What about market institutions? Israel is instructive here. Israel has always had a high level of democracy, but from 1970-1980 its economic market institutions suffered from an increase in non-market government coordination, subsidies, and transfers. Yet Israel's innovation rate increased despite this move towards what Hall & Soskice might call a coordinated market economy.[43] 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. Hence neither a strong democracy nor strong markets seem to have been a prerequisite for high levels of innovation in these countries. Finally, note that there are fairly large difference in innovation rates amongst the top & mid-level innovators, yet most of them share similar institutions, with relatively strong and well enforced property rights, democracies, and markets. Indeed there are several countries (e.g. New Zealand, Portugal, Greece, Brazil, Costa Rica, etc.) which have decades of good or improving domestic institutions but little corresponding improvement in national innovation rates. Indeed, if domestic institutions are so powerful, then how can we explain Spain? Spain has been institutionally transformed from a socialist military dictatorship into a market-oriented, competitive, decentralized democracy but as yet without any apparent change in innovation rates!

It is important to restate here that I am *not* arguing that democracy and free markets have no causal effects on innovation rates. Rather, I contend that existing theories which put these institutions at their core as necessary or sufficient for sustained technological innovation have been over-stated, over-simplified, and need to be re-examined. They simply do not have the predictive or explanatory power we assume them to have.

So where do we stand? The NIS scholars have found that: pick your favorite policy or mid-level institution (financial system, anti-trust regime, education policy, etc.), and you can find both highly innovative *and* lowly innovative states which employ it. The innovation devil may yet be in the policy details, but twenty years of research have yet to identify him. VOC scholars attempted to explain this by arguing that both NIS institutions and innovative behavior are endogenous to markets, but the empirical data fails to show any aggregate effect of a nation's "variety of capitalism" on innovation rates. Political decentralization theory can then be brought in to argue that both NIS institutions and a nation's variety of capitalism are endogenous to government structure. But decades of technology patents, science-engineering publications, and high tech export data fail to substantiate any of these hypotheses. Finally, even the broadest of domestic institutions (democracy and economic freedom) do not seem to be necessary or sufficient to explain national innovation rates. What's going on?

I argue in the next section that what's going on is omitted variable bias. Specifically, I will suggest 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. These relationships are generally overlooked in the debates over domestic institutions, and often go unaccounted for. I will show that when controlled for, a country's international relationships with the lead innovator do a better job of explaining innovation rates than institutions alone.

VI. International Relationships: A Case of Omitted Variable Bias

Why should international relationships matter? Theoretically, the causal mechanisms are diverse: 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 (see Taylor 2007b for full discussion). But most immediately, an interest in international relationships as an alternate explanation for differences in national innovation rates also emerges out of

[43] Hall and Soskice. 2001.

the research on domestic institutions. For example, we saw above that statistical analysis of the VOC theory of technological innovation consistently points to the United States as an important outlier in global patterns of innovation. We can also observe 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, such as Japan, Canada, the UK, Israel, South Korea, 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.[44] 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.[45] 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 NIS 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.[46] 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.[47] 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.[48]

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[44] Taylor, 1995
[45] Amsden 1989, 2001; Yamashita 1991
[46] Kim and Nelson 2000.
[47] Jeremy 1991;Cowan 1997.
[48] Keller 2004; Cantwell 1995.

It is also interesting that many of the countries which suffer from low innovation rates also appear to have poor international relationships with the world's lead innovators. For example, the poorly innovating African, Latin American, and ex-communist bloc nations discussed in the previous section (and missing from Figure 6) are typified by *both* bad institutions *and* fewer and shallower international relationships with the lead innovators. Meanwhile, each of highly innovative South Korea, Taiwan, Israel, and Japan had relatively bad institutions by Northian standards, *but* was 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 the possibility of omitted variable bias in the innovation debate. They suggest 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. This is not to argue that domestic institutions are insignificant, but that factors such as those listed below in Figure 7 between the lead innovator and other countries should be examined for their effects on innovation.

Figure 7: 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**

If the international relationships listed in Figure 7 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*.

How can we probe for this? Unfortunately, there is no single variable which captures the myriad international relationships listed in Figure 7. Also, different countries have different combinations of these international relationships depending on their availability, costs, benefits, and historical experience. 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 7, and are restricted to relationships with the US,[49] therefore the results should be interpreted as an initial step in a larger research program. But they do serve the purpose of an exploratory probe.

The best way to simultaneously control for multiple independent variables in a generalizeable manner is through regression analysis. Therefore, let me briefly report the regression results, which the interested reader can inspect more thoroughly for rigor and specification in Taylor (2007b). In these regressions, I took a slightly different approach than used previously. Rather than merely testing whether or not institution or relationship X was significant, I controlled for them simultaneously. This allows us to ask whether international relationships matter even if you control for domestic institutions, and vice versa. Despite its simplicity, this type of testing appears not to have yet been done. Using factor analysis, I combined data on international relationships into a single IR-factor, which I then used as a regressor alongside the usual measures of Northian institutions.

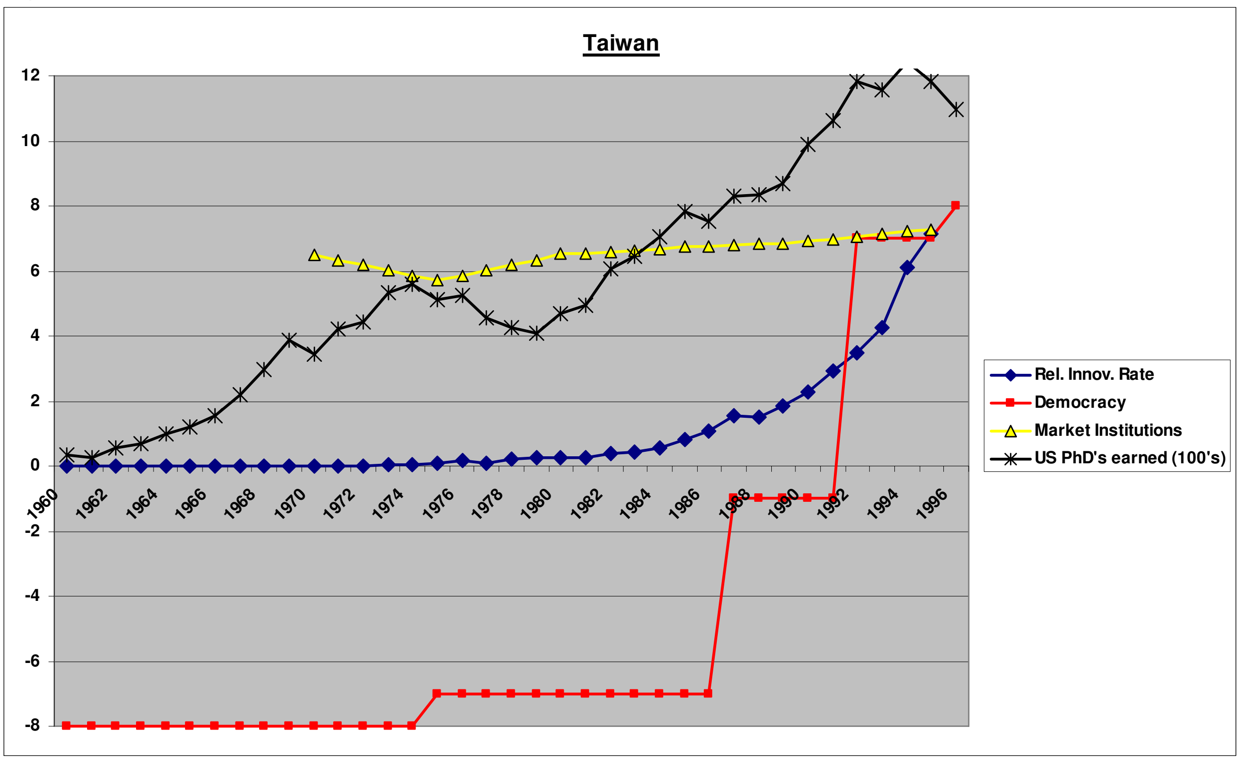
[49] Each of these measures focuses specifically on countries' relationships with the lead innovator, the United States. Although this is done primarily for purposes of data availability and cost, it also has several desirable properties. First, the international relationships described in the last section 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.

The first and most important finding of the regressions was 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). How do we know that international relationships affect innovation rates, rather than the reverse? I attempted to answer this question in several ways: by running time-series cross-section regressions, by using increasing time lags between the independent and dependent variables, and by using a lagged DV. In all cases, I found that the coefficients for the IR Factor are consistently positive and significant. The second, and perhaps more interesting, result is that the coefficients for domestic institutions were generally small and often insignificant. This occurred for several measures of democracy (Polity II, Freedom House, POLCON); while the coefficients for the Fraiser Index of economic freedom were somewhat larger, though often insignificant. Interestingly, neither the strength of international relationships nor the relative weakness of the domestic institutions measures was much affected by each other's presence or absence in the regression models. That is, the regression results were fairly robust to changes in the model and reveal that we do not need to hold domestic institutions constant in order for international relationships to reveal their effects.

But we do not need regressions to illustrate these findings; many of them can be clearly seen in the following two simple charts. Figure 8a traces technological innovation, Northian institutions, and a single type of international relationship in Taiwan (a rapidly innovative country). Figure 8b does so in Portugal (a slowly innovative country). These two countries are not outliers, similar comparisons could be made for a number of country pairs (indeed including Spain's would have been a far more dramatic comparison). The numbers on the vertical scale indicate the levels of democracy (Polity II score), economic market freedom (Fraiser Index), and the quantity of science-engineering graduates students sent to study in US universities. The national innovate rate has simply been scaled for time-series comparison and has no relationship with the numbers on Y-axis.

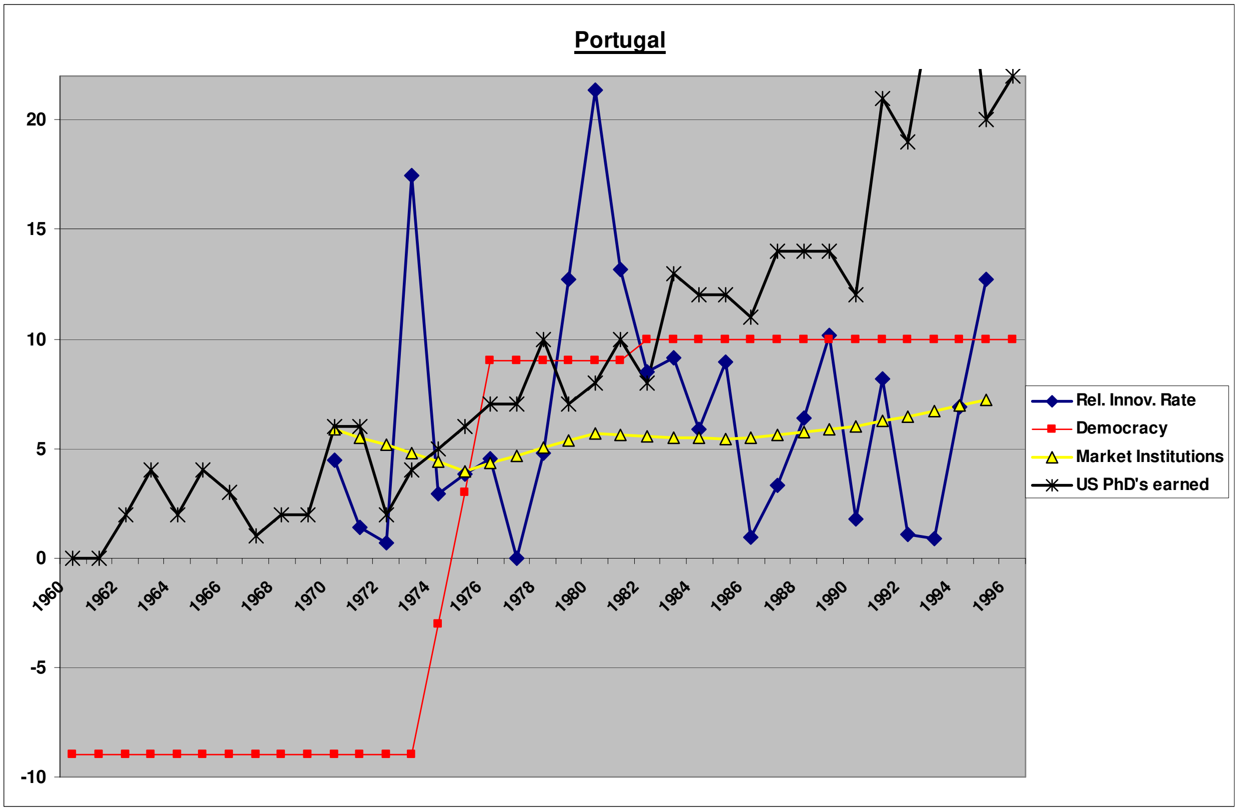
Figure 8a illustrates what we already know: that Taiwan's innovative "take-off" occurred long before its institutional reforms. While some might posit that Taiwan's seeds of democracy were planted prior to this, it is simply hard to argue that Taiwan was functionally democratic or free market prior to 1991, or at least not according to the standards laid down by the theories of North or Acemoglu. But what *did* change for Taiwan was that its relationships with lead innovators increased in scope and depth. One measure of this is the number of students, first hundreds and later thousands, students sent to US universities to earn science & engineering PhD's. Their training abroad precedes and matches Taiwan's innovation spurt. Similarly major increases can be found in many of Taiwan's other international relationships listed in Figure 7. A more thorough discussion of how Taiwan linked with the United States to forge its innovative capabilities can be found in Breznitz (2007).

Figure 8a [*Best viewed in color*]



Now examine Portugal's transition to democracy during the mid-1970s and its attendant increase in economic market freedoms (Figure 8b). These were major and pervasive institutional changes, sweeping the entire political-economy of Portugal. And yet despite these dramatic transformations, we observe no attendant change in Portugal's national innovation rate. It remained essentially flat during the 1970-1995 period. Portugal did increase its level of PhDs sent to study science or engineering in the US, but only from ~5 to ~25 individuals. Similarly minor increases can be shown for Portugal's other international relationships listed in Figure 7.

Figure 8b [*Best viewed in color*]



VII. Alternate Explanations

There several possible alternate explanations for the findings above. First and foremost, it may be that Northian institutions 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

[50] Henisz 2000; Rodrik 2000; Jensen 2003.
[51] Braun 2006; Harms & Ursprung 2002.

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.

On the quantitative side, I tried to 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. Nor did regressions of the IR-factor on domestic institutions reveal a strong linear relationship between the two: the coefficients were significant but small, sensitive to time-period and level of development, and the R^2's were low. 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

[52] Gallagher 2002; Busse 2004; Archer, Biglaiser & DeRouen 2007.
[53] Li & Resnick 2003; Egger and Winner 2004; Biglaiser and Derouen 2006.

the evidence that national innovation rates present an anomaly which deserves greater attention, and cannot be explained away as a simple statistical error.

As another 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 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. (Readers are encouraged to read the Appendix on innovation measurement and the strengths/weaknesses of patent measures). 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 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. Discussions of other alternatives can be found in Taylor (2007b)

VIII Conclusions and Implications

The point of this paper is not to argue that domestic institutions have no effect on national innovation rates, but rather to defuse some widely accepted, but unsubstantiated, generalizations about the sources of technological innovation. The domestic institutions discussed above are frequently paraded out as “accepted wisdom” during discussions of national innovation rates. And certainly some of them might make sense when used to explain a particular country’s innovation rate at a specific point in time. Yet on closer consideration, we find that not one of them can be consistently applied across time and space to explain the world's most innovative countries. Thus I am not contending that institutions do not matter at all; 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.

Thus, the research reviewed here suggests a change in the debate over national innovation rates. It suggests that a single-minded focus on finding an institutional explanation can blind scholars to important political variables that play powerful roles in affecting technological change. Along these lines, this paper has suggested that international relationships may be the solution to the innovation rate puzzle. International relationships are often overlooked in the search for the "right" institutions to explain nations' technological performance. But the empirical evidence suggests that certain kinds of international relations 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. But we cannot properly develop this avenue of research if we refuse to travel down it or to allow into the debate those who have.

Appendix: Measuring Nationnal Innovation Rates

The most frequently used measure of innovation is patents. The debate over the proper use of patent data has proceeded vigorously and with increasing sophistication over the past several decades. The current consensus holds that patent 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 not appropriate when used as a measure of micro-level innovation (to compare the innovativeness of individual firms or specific industries from year to year). And while this debate is ongoing and is better recounted elsewhere, this section will address some of the more pressing issues surrounding patent measures and their use in testing.[54]

Strictly speaking, a patent is a temporary legal monopoly granted by the government to an inventor for the commercial use of her invention, where the invention can take the form of a process, machine, article of manufacture, or compositions of matters, or any new useful improvement thereof. (USPTO)[55] A patent is a specific property right which is granted only after formal examination of the invention has revealed it to be nontrivial (i.e. it would not appear obvious to a skilled user of the relevant technology), useful (i.e. it has potential commercial value), and novel (i.e. it is significantly different than existing technology). As such, patents have characteristics which make them a potentially useful tool for the quantification of inventive activity. First, patents are by definition related to innovation, each representing a "quantum of invention" that has passed the scrutiny of a trained specialist and gained the support of investors and researchers who must dedicate time, effort, and often significant resources for its physical development and subsequent legal protection. Second, patent data are widely available, and are perhaps the only observable result of inventive activity which covers almost every field of invention in most developed countries over long periods of time. Third, the granting of patents is based on relatively objective and slowly changing standards. Finally, the United States Patent and Trademark Office and the European Patent Office provide researchers with centralized patenting institutions for the two largest markets for new technology. In practical terms, this allows researchers to get around the issue of national differences in patenting laws as well as providing two separate and fairly independent data pools.

Given these qualities, patents have been used as a basis for the economic analysis of innovative activity for over thirty-five years. Current use began with the pioneering work of Frederic Scherer and Jacob Schmookler who used patent statistics to investigate the demand-side determinants of innovation.[56] However, the labor intensive nature of patent analysis, which used to involve the manual location and coding of thousands of patent documents, severely limited the extent (or at least the appeal) of their use in political and economic research. These limitations were eased somewhat during the 1970s when the advent of machine-readable patent data sparked a wave of econometric analysis.[57] In the late 1980s, the

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[54] For a review of the debate see Griliches, Zvi. 1990. "Patents Statistics as Economic Indicators: A Survey". *Journal of Economic Literature* 28 (4):1661-1707; Trajtenberg, Manuel. 1990. "A Penny for Your Quotes: Patent Citations and the Value of Innovations" *The RAND Journal of Economics* 21 (1):172-187; Archibugi, D. and M. Pianta. 1996. "Measuring Technological Change Through Patents and Innovation Surveys" *Technovation* 16 (9):451-468; Harhoff, Dietmar, Francis Narin, FM Scherer, and Katrin Vopel. 1999. "Citation Frequency and the Value of Patented Inventories" *The Review of Economics and Statistics* 81 (3):511-515; Eaton, J. and S. Kortum. 1999. "International Technology Diffusion: Theory and Measurement" *International Economic Review* 40 (3):537-570; Jaffe, Adam B., Adam, Manuel Trajtenberg, and Michael Fogarty. 2000. "The Meaning of Patent Citations: Report of the NBER/Case Western Reserve Survey of Patentees" Working Paper, 7631. Cambridge, MA: National Bureau of Economic Research; Hall, Bronwyn H., Adam Jaffe, and Manuel Trajtenberg. 2000. "Market Value and Patent Citations: A First Look" Working Paper, 7741. Cambridge, MA: National Bureau of Economic Research.

[55] Designs and plant life can also be patented, however most econometric analysis of patent data is confined to utility patents granted for inventions such as those listed above. For a fuller description of patents and patent laws, classifications, and the application process see http://www.uspto.gov/main/patents.htm.

[56] Scherer, Frederic M. 1965. "Firm Size, Market Structure, Opportunity, and the Output of Patented Innovations" *American Economic Review* 55 (5):1097-1125; Schmookler, Jacob. 1966. *Invention and Economic Growth*. Cambridge, MA: Harvard University Press.

[57] Summaries of which can be found in Griliches, Zvi ed. 1984. *R&D, Patents, and Productivity*. Chicago, IL: University of Chicago Press; Pakes, Ariel. 1986. "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks" *Econometrica* 54 (4):755-784; Griliches, Zvi, Bronwyn H. Hall, and Ariel Pakes. 1987. "The Value of Patents as Indicators of

use of patent data was further facilitated by computerization, which increased the practical size of patent datasets into millions of observations. Most recently, Hall, Jaffe, & Trajtenberg at the NBER have compiled a statistical database of several million patents complete with geographic, industry, and citation information, which I use in Figures 1-8 above.[58]

However, patents do have significant drawbacks which somewhat restrict, but by no means eliminate, their usage as an index of innovation. First, there is the classification problem, in that it is difficult to assign a particular industry to a patent, especially since the industry of invention may not be the industry of eventual production or the industry of use or benefit. I address this issue, where possible, by using two different patent datasets with assorted systems and levels of patent classification. Second, it is not yet clear what fraction of the universe of innovation is represented by patents, since not all inventions are patentable and not all patentable inventions are patented. This problem is exacerbated when attempting comparative research since different industries and different countries may exhibit significant variance in their propensity to patent. One can address these concerns by using publications data in addition to patents. And although patents and publications both may be imprecise measures of innovation, as long as this measurement error is random and uncorrelated with the explanatory variables, then regressions using this data should produce unbiased estimates of the coefficients (and generally with inflated standard errors).

Finally, some critics point out that patents vary widely in their technical and economic significance: most are for minor inventions, while a few represent extremely valuable and far-reaching innovations. Moreover, it has been found that simple patent counts do *not* provide a good measure of the radical-ness, importance, or "size" of an innovation. Simple patents counts correlate well with innovation inputs such as R&D outlays, but they are too noisy to serve as anything but a very rough measure of innovation output.[59] Therefore I use patent counts which have been weighted by forward citations. Forward citations on patents have been found to be a good indicator of the importance or value of an innovation, just as scholarly journal articles are often valuated by the number of times they are cited. The idea here is that minor or incremental innovations receive few if any citations, and revolutionary innovations receive tens or hundreds. 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.[60]

A final potential weakness is that it is often unclear what fraction of a nation's innovation is actually patented, or to what degree selection bias exists in any given set of patent data. This problem is exacerbated when we consider that different countries may exhibit significant variance in their propensity to patent. However, at the national level, patents have also been found to correlate highly with other measures which we generally associate with aggregate innovation rates, including GDP growth, manufacturing growth, exports of capital goods, R&D spending, capital formation, Nobel Prize winners, etc.[61] 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. Therefore, although citations-weighted patents

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Inventive Activity" in *Economic Policy and Technological Performance* edited by Partha Dasgupta and Paul Stoneman, 68-103. New York, NY: Cambridge University Press.

[58] 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.

[59] Griliches (1984).

[60] Trajtenberg (1990); Hall, Jaffe, and Trajtenberg (2000); 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. 1999. "The Quality of Ideas: Measuring Innovation with Multiple Indicators" Working Paper, 7345. Cambridge, MA: National Bureau of Economic Research; Jaffe, Trajtenberg, and Fogarty (2000).

[61] Amsden, Alice H. and Mona Mourshed. 1997. "Scientific Publications, Patents and Technological Capabilities in Late-Industrializing Countries" *Technology Analysis and Strategic Management* 9(3).

are by no means a perfect measure of innovation, and should always be corroborated by other measures wherever possible, they can be used with some confidence to judge the relative innovative performance of different countries. 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.

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