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Political Decentralization and Technological Innovation: Testing The Innovative Advantages of Decentralized States

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ABSTRACT

Although never rigorously tested, it has become a sort of accepted wisdom amongst social scientists that government decentralization offers key advantages for innovators. Decentralized governments are widely seen as agile, competitive, and well structured to adapt to innovation's gale of creative destruction. Meanwhile, centralized states, even when democratic, have come to be viewed as rigid and thus hostile to the risks, costs, and change associated with new technology; or are subject to capture by status-quo interest groups which use their influence to promote policies which ultimately restrict technological change. Therefore decentralized government is often perceived as a necessary institutional foundation for encouraging long-run technological innovation. In the following article, this wisdom is tested using data on international patent activity, scientific publications, and high-technology exports. The results suggest that the supposed technological advantages of decentralized states are a fiction, and that international pressures may be more important.

KEYWORDS: Innovation, Technology, Government, Decentralization, Federalism

1. Introduction

1.1. Research Summary

Why are some countries more technologically innovative than others? Technological innovation is a vital component of every state's long-run economic growth, international comparative advantage, and relative military power. In recognition of this, almost every society expends a considerable share of its resources on the pursuit of technological advance. However, despite the random nature of innovation, and the seemingly clear requirements for promoting innovative behavior, some countries are consistently more successful than others at technological progress, even amongst the industrialized democracies.

When observed over the long-run, one apparent trend is the ability of decentralized states to maintain their places at the technological frontier. Decentralized governments are widely seen as agile, competitive, and well structured to adapt to innovation's gale of creative destruction. Meanwhile centralized states, even when democratic, seem either unable to achieve high rates of innovation or to maintain technological leadership if achieved. Over time this observation has evolved into conventional wisdom: 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-hardy or outdated technological projects.¹ These sentiments can be found both in the popular press² and throughout the academic literature. In the latter, a number of prominent economists and political scientists have applied various forms of the political decentralization hypothesis to explain differences in national innovation rates. These efforts include works by Nathan Rosenberg & L.E. Birdzell Jr., Joel Mokyr, Daron Acemoglu, and Daniel Drezner; or can be inferred from the writings of scholars in evolutionary economics such as Richard Nelson, Sydney Winter, and Walter Vincenti (citations below).

This article therefore asks a simple empirical question: is there any aggregate evidence for a general relationship between government structure and long-run technological innovation? Despite broad theoretical support, a correlation between political decentralization and technological innovation has yet to be rigorously established by social scientists. While the popular association between the two phenomena is strong, the empirical evidence consists entirely of anecdotal observations and stylized case studies. In an attempt to answer this question, this paper examines several datasets of international patent activity, science and engineering research publications, and high-technology exports. Using a variety of different statistical approaches and controls, it will be shown that no matter how one treats the data, little evidence can be produced to support the decentralization-innovation hypothesis: innovators in decentralized states are empirically no more technologically innovative than those in more centralized states. The conventional wisdom is therefore in need of deep revision, and indications of more fruitful avenues of research will be inferred from the data. Thus this paper reports a negative finding; but it is one of such strong and consistent disconfirming evidence for a relationship so relatively well accepted, that it merits entry into the scientific debate over national innovation rates.

1.2. Justification

This question of whether decentralized states are more technologically innovative than others should interest scholars of comparative politics and international relations for reasons beyond that of national technological capability. First and foremost, political power is currently in the process of being redistributed throughout states around the world, not only via a global shift towards greater democracy, but with traditionally centralized polities in Asia, the Americas, and Europe either now decentralized or on their way to decentralization. And even while the European Union's members are engaged in a process of agglomeration in order to reap the benefits of size and the economies of scale, there is also a concurrent commitment in Europe to decentralizing their

massive new political organization. While the politics of local autonomy and ethno-cultural divisions certainly play a role in the move to decentralize government in some states, part of the motivation behind this global movement is also this belief that decentralized states have a long-run competitive advantage over centralized states in promoting technological progress and in sustaining innovation-driven economic growth.³

Second, scholars of federalism also have an obvious interest in the outcome of this debate, especially since the theoretical consensus on the macroeconomic effects of federalism has recently broken down. A long tradition of federalism research credits decentralized political systems with everything from fiscal restraint to efficient government to preserving markets.⁴ But more recently, a critical line of research has attacked this view and pointed out the detrimental affects of federalism on fiscal & monetary policy, exchange rate management, and privatization programs.⁵ In an attempt at synthesis, still other scholars have criticized this dichotomy as a fallacy based upon abstract models and individual case studies. Instead, they use empirical data to show that federalism and its effects are better understood as varying along a spectrum.⁶ Since most of these arguments concern the consequences of decentralization for long-run macroeconomic management and performance, and since technological innovation is both affected by, and is an important component of, the macroeconomy, it makes sense to link these research programs. That is, it is logical to ask whether the macroeconomic benefits, or costs, of decentralization identified by federalism scholars also affect technological innovation.

2. Theoretical and Empirical Framework

2.1 Definition

Political decentralization (a.k.a. government decentralization) is defined here as an increase in both the number and equality of centers of political power and policy-making. For many scholars, “decentralization” simply means federalism. However, as will be shown below, existing theories

about government structure and technological change demand that I be more flexible in my definition, and allow decentralization to be either vertical or horizontal. In vertically decentralized states, authority has been shifted away from the central government and towards local governments, the classic example being federalism.⁷ In horizontally decentralized states, authority is shared between an executive, legislature, judiciary, and in some cases even a powerful bureaucracy or autonomous military.⁸ In practice, many states decentralize even further, with power formally divided between different houses of the legislature, competing bureaucracies, or branches of the armed forces. Finally, as will be further discussed below, when measuring the degree of decentralization it is also important to consider that government structure can have both formal *de jure* components (those expressed in law or constitution) and informal *de facto* components (e.g. the extent of party alignment across different branches of government, or the extent of preference heterogeneity within each legislative branch).

2.2 Theory

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,⁹ but can also increase the diversity of these research efforts and the scientific-technical knowledge acquired through them.¹⁰

Second, scholars assert that, by increasing the number of units, decentralization increases competition, thus increasing the incentives for innovation. This theme recurs throughout much of the innovation literature, but is perhaps best specified in the federalism literature. Federalism scholars points 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.¹¹ This concept has evolved into Weingast's "market-preserving federalism", in which federalism can prevent government from acting in a predatory manner towards innovators, and allow credible commitments to produce pro-market policies and public goods.¹²

Third, it is also argued that decentralization provides superior information for both policymakers and innovators.¹³ Hayek observed that much information which is helpful for economic activity cannot be usefully centralized (e.g. tacit knowledge).¹⁴ Although Hayek wrote about the merits of decentralized markets over central economic planning, the implications for political decentralization are clear: local policymakers simply have superior information about local conditions than do distant national legislators or bureaucrats, and can therefore design better policy for the local environment. And better policy should mean more efficient allocation of resources towards, and proper incentives for, local innovators. This does not mean that centralized political coordination of any kind is always bad for technological innovation; but as Tiebout has shown, decentralized local public goods production is generally better at reflecting popular preferences than is centralized national public goods production.¹⁵ Hence in Tiebout's economy, 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, etc.) to choose the environment that's 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. Surowiecki describes this as a form of decentralization-driven specialization which makes innovators more productive and efficient.¹⁶

Fourth, several scholars argue that political decentralization aids national innovation rates by making the state less vulnerable to capture by status-quo interest groups.¹⁷ 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 are more likely to make policies which slow technological innovation.¹⁸ And once made, such policies will be imposed across the entire nation due to the centralized nature of government in these states. But 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 US 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.¹⁹

This fourth mechanism might also help to explain why other institutional explanations have failed to generalize across different countries and time periods. For example, national systems of innovation (NSI) scholars have long probed the effects of dozens of national institutions and policies on the innovation rates of a wide spectrum of nations, but with few generalizable results.²⁰ NSI's approach has been to use case-studies to identify the domestic institutions and policies which best solve the extraordinary public goods problems associated with technological innovation.²¹ NSI scholars have therefore examined the interactions and effects on innovation rates of different education policies, science policies, trade regimes, legal frameworks, financial institutions, anti-trust laws, etc. However after almost twenty years of research, NSI scholars have failed to produce any general theory of national innovation rates. That is, institution or policy "X" might explain a

certain country's innovation rate at a specific point in time, but not over time and not in other countries.

Government decentralization offers a possible explanation for this conundrum. 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 (skills, capital, land, etc.) are hurt by technological change. And in order to obstruct threatening technological changes, these interest groups will often seek to influence or capture precisely those institutions and policies which NSI scholars use to explain innovation rates. Even the presence of markets cannot prevent this phenomena, argue Acemoglu et. al. and Drezner, since markets and property rights are but institutions subject to the will of captured state apparatus.²² Thus NSI explanations fail to generalize across time and space because the mid-level 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.

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 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.²³ And 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.

Finally, the arguments posited above should be qualified in that scholars differ in the degree to which they believe political decentralization matters, relative to other causal variables, for innovation. At one extreme, evolutionary economics suggests the possibility that, at least in the long-run, government decentralization alone might do much of the work towards fostering innovation. In evolutionary theory, variation (i.e. search efforts) and selection (i.e. competition for limited resources) are necessary and sufficient for sustained technological change.²⁴ And since decentralization is both necessary for competition and fosters variation, in the very long-run it could be a primary causal factor for technological change. Granted, evolutionary economists generally theorize about firms fostering innovation within an industry, but there is no reason why this dynamic should not operate in other institutional setting. For example, the literature on why Europe innovated rapidly during the last half-millennium, while Asia stagnated, often posits this stronger evolutionary version of the decentralization hypothesis.²⁵ It is therefore not a major leap to suggest that subnational units fostering innovation within a national system might also obey an evolutionary dynamic, and therefore be strongly affected by political decentralization. A somewhat weaker version of the decentralization hypothesis is exemplified by Drezner who argues that decentralization is necessary, but not sufficient, for innovation.²⁶ While Drezner sees government decentralization as being generally helpful, he also invokes conditional variables such as factor endowments, level of development, size, and just plain luck, in order to explain outlier cases. Yet, perhaps the weakest version of the decentralization argument is made by Mokyr, who states that decentralization is neither necessary nor sufficient for innovation. He notes that when political decentralization manifests itself as severe fragmentation and Balkanization, it can lead to a complete lack of cooperation, violent competition, and physical conflict.²⁷ Thus government decentralization should hurt innovation as it approaches the extremes of breaking apart a nation or causing civil war.

In sum, however, despite all the conditions put forward by different theorists, and regardless of the specific mechanism emphasized, the core of the decentralization argument remains. Or as Mokyr puts it, after a thorough discussion of caveats and provisos:

All the same, some measure of decentralization is probably desirable...it seems that too much coordination can be unhealthy. The need to retain some political diversity, coupled with openness and freedom of both ideas and the people in which they are embedded, seems to be undiminished even as knowledge itself has become more mobile...²⁸

2.3 Scant Empirical Evidence

The causal mechanisms outlined above dovetail with some widely held stereotypes about national differences in innovation rates. However, little empirical data has yet been produced to verify the assumption that decentralized states have some sort of comparative institutional advantage that promotes technological innovation. And the empirical data which does exist is either limited to anecdotal evidence and stylized facts, or does not directly bear on the question of innovation rates. Therefore it is unclear whether any government structure-innovation relationship exists in the first place, either in the aggregate or over the long-run.

In fact, few scholars have attempted to build an empirical case for the decentralization-innovation hypothesis. In separate research programs, Colleen Dunlavy, Peter Hall, and T.J. Pempel have each tied state structure with technological progress in different case studies.²⁹ However their linkages are sometimes implicit or indirect, and none of them directly credit decentralization with any specific innovative advantages. Historian William McNeill has attributed China's failed brush with industrialization in the fourteenth century to its centralized governmental command structure.³⁰ McNeill describes how pockets of market activity developed within the ancient Chinese economy, leading first to rapid technological change and later to entrepreneurial-based challenges to Imperial political authority. In response, the Chinese political establishment increasingly used its unified command structure to put down these threats, and redirect China's

resources away from technological innovation. Although McNeill's brief sketch sounds supportive of the decentralization thesis discussed above, the historical research on this period in Chinese history is too sparse to eliminate competing hypotheses, nor does a single case prove a theory.

Perhaps the only direct empirical test of a structure-innovation relationship is that performed by Drezner, who investigates two bilateral rivalries for technological leadership (UK vs. Germany, Japan vs. US) in separate time periods. Drezner points out that, in both cases, the state with the more centralized government structure fell behind the technological leader, even despite initial success.³¹ However, Drezner's number of observations is too small to produce generalizable conclusions. Nor does he explain why decentralized states such as Australia, Austria, or India have not enjoyed similar technological success to the US or Germany, while many centralized states (e.g. France, Sweden, Israel, and Finland) innovate at or near the technological frontier.

3. Statistical Tests

The purpose of the remainder of this article is to ask a fundamental empirical question: is there any evidence to support a general relationship between government structure and technological innovation? Note that I am not testing here for the presence of a specific causal mechanism. This is because decentralization scholars collectively, and sometimes individually, describe multiple causal mechanisms by which decentralized government should affect innovation. And different researchers posit different combinations of mechanisms. Therefore I will test only for the presence of a general correlation. In so doing, my approach is similar to that used by researchers who have sought to test for general correlations between smoking and cancer, or industrialization and climate change, but did not know the precise causal mechanism involved.³² That is, no matter which mechanism is in operation (i.e. increased competition, superior information, greater experimentation, limitations on status-quo interests), or even if the specific mechanism(s) remains unidentified, the regression models employed below should reveal a correlation between

decentralization and innovation if a causal relationship actually exists. Hence my regressions constitute a Van Everan “hoop” test: flunking the test provides strong evidence *against* the hypothesized relationship, though passing test may only produce little support for it.³³ This empirical section of this paper will suggest that the political decentralization hypothesis flunks such a “hoop” test.

3.1. Simple Bivariate Tests

One fairly straightforward and traditional way to test for the strongest version of a decentralization-innovation relationship is to simply compare national patent rates. The results of such a test are presented below in Figure 1. Here, using seventeen years of international patent data from the European Patent Office (EPO), the combined per capita patenting activity of the five of the most decentralized industrialized democracies (Australia, Canada, Germany, Switzerland, and the United States) has been plotted alongside that of the five of the most centralized industrialized democracies (Finland, France, Great Britain, New Zealand, Sweden). I do not use any formal measure of decentralization in these comparisons, but have instead selected those political systems which are widely characterized throughout the literature as being either highly decentralized or highly centralized. Between 1978-88, the graph reveals no clear innovative advantages to either type of government structure; but from 1989-95 the decentralized states do indeed patent more than the centralized states. However, the gap between the two groups is always less than 10 percent and shows a pattern of reversing itself repeatedly over time, hence there is no way to tell if this apparent patenting superiority of decentralized states is a significant long-run phenomena. Given the prevalence of the “accepted wisdom” about the benefits decentralization for innovation, one would not expect such mild and transitory results.

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

Ideally, 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 reported in Figure 2 (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

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

For my measure of innovation in Figure 2, I look at changes in relative innovation rates. Specifically, my measure is a country’s change in patent citations received (per capita) as a share of the world average, based on international patent data from the United States Patent & Trademark Office (USPTO).³⁷ This second database of patents adds value in two ways. First, it provides a separate and independent set of patent data by which to index innovation.³⁸ Second, forward

citations data are available for all USPTO patents granted between 1975-99. Simple patent counts only measure how much innovation is being produced, but weighting patents by their forward citations allow us to control somewhat for the quality, as well as the quantity, of the innovations being patented. The use of citations-weighted patents as a measure of innovation is discussed at greater length in the next section.

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. However, as Figure 2 reveals, only Taiwan and South Korea appear to 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 only strengthens the claim being made here: even using the broadest definition and least formal measure of decentralization, it is difficult to find a correlation with innovation.

***** FIGURE 2 ABOUT HERE *****

Using the same measure of innovation, Figure 3 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 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 3, 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 the strongest version of the decentralization hypothesis.

[* FIGURE 3 ABOUT HERE ***]**

Of course, these simple bivariate tests do not allow us to control for additional control variables invoked by weaker versions of the decentralization hypothesis. According to Drezner, Mokyr, and others, these conditional variables should include such factors as democracy, overall economic resources, base level of technical development, factor endowments, military spending, and openness to trade. These control variables will be considered in greater detail in the regressions below.

3.2. Multivariate Statistical Tests

3.2.1. Methods & Data

In order to test weaker versions of the decentralization-innovation hypothesis, I turn in this section to multivariate regressions. I conduct cross-sectional statistical analysis of innovation rates across some 70 countries during the 1975-95 period.³⁹ Although time-series cross-sectional regressions would be ideal here, the presence of rarely changing independent variables over time creates multicollinearity issues, especially when used with country fixed effects. Therefore I stick

with ordinary least squares (OLS), with Huber-White estimates of the standard errors. But since there are significant changes in some of the independent variables during these two decades, I later split the dataset into four consecutive five-year sub-periods and test each separately. And since a lag likely occurs between the activity of innovation and the patent application, I lag the independent variables 1, 5, and 10 years in separate regressions wherever possible.

3.2.2. Dependent Variable: Innovation

In order to triangulate on the dependent variable, I use three independent and distinct measures of innovation: citations-weighted patents (per capita), citations-weighted scientific publications (per capita), and high-technology exports (per GDP). By far, the most frequently used quantitative measure of national innovation rates is patents. Patents are by definition related to innovation. Each patent represents an individual “quantum” of invention which has passed the scrutiny of trained specialists, and gained the support of investors and researchers who must dedicate time, effort, and significant resources to research and legal protection. Given these qualities, patents have been used as a basis for the economic analysis of innovative activity for forty years, starting with the pioneering work of economists Frederic Scherer and Jacob Schmookler who used patent statistics to investigate the demand-side determinants of innovation.⁴⁰

Of course, patents do have weaknesses as a quantitative measure of innovation. First, simply adding up patents does not take into consideration that most are for minor innovations, while a few represent extremely valuable and far-reaching innovations. Also, simple patents counts have been found empirically to correlate well with innovation inputs (e.g. R&D spending), but they are too noisy to serve as anything but a very rough measure of innovation output.⁴¹ I address these issues by weighting patents by their forward citations. The idea here is that minor 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.⁴²

A second 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, citations-weighted 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.⁴³ Thus, even though patents do not capture all technological innovation, they do appear to capture a representative sample of it when weighted by forward citations and used in large aggregates.

Still, in order to increase confidence in my results, and to accommodate different perspectives on the phenomena and measurement of technological innovation, I corroborate the regressions of citations-weighted patent data (per capita) with similar regressions of two additional measures of innovation: scientific publications weighted by forward citations (per capita), and high-technology exports as a percentage of GDP. Scholarly scientific publications offer advantages similar to those of patents, with each journal article representing a discrete piece of research innovation which must pass independent review and which tends to be cited in proportion to its innovative impact. More importantly, scholarly publications data are completely independent of patents: they are generally produced by a different set of innovators, affected by different incentives, and judged according to different institutional standards.⁴⁴ High-technology exports as a share of GDP is a measure that allows me to better get at undocumented innovation, while further stressing economically valuable innovative capacity. Of course, some high-technology exports can represent purely locational moves by high-technology firms into low-cost labor countries, but

researchers have found this not to be the case in the aggregate or over the long-run. That is, in order for high-technology exports to constitute a significant share of a nation's GDP over several decades, the exporting country must have a meaningful and rapidly improving degree of technological capability.⁴⁵

The patent data comes from a subset of the National Bureau of Economic Research (NBER) Patents Database and includes data on over 1.7 million utility patents granted by the US Patent & Trademark Office (USPTO) to applicants from the United States and 146 other countries during 1974-95, and the 9.7 million citations made to these patents during the same time period.⁴⁶ The scientific publications data comes from a subset of the Thomson-ISI National Science Indicators database and includes data on over 9.4 million articles published in scientific journals by researchers in over 170 countries during 1981-95, and the 164.2 million citations made to these articles during the 1981-2002 period. The high-technology exports data comes from the United Nations *Comtrade* database and consists of trade data on total exports in those industry classes defined by the OECD as "high-technology". This OECD definition of "high technology industries" is based on R&D intensity, and has been used widely by academic researchers and major government institutions for almost two decades.⁴⁷ Its sectors include aircraft, spacecraft, pharmaceuticals, office machinery (includes accounting and computing), telecommunications equipment (including radio and television), and medical & scientific instruments.⁴⁸

3.2.3. Independent Variable: Government Decentralization

In order to test the decentralization-centralization hypothesis, various different measures of government structure are used alternately. The first follows the standard convention used by comparativists and consists of dummies for federal systems.⁴⁹ Federalism dummies have been used in this manner by researchers to test for links between government structure and macroeconomic performance, corruption, inflation, fiscal responsibility, etc.⁵⁰ The second measure is the index of

federalism devised by Arend Lijphart (UCSD) which ranks countries on a five point scale (Lijphart Fed).⁵¹ Note that both the dummies and Lijphart ranks are measures of vertical decentralization (federalism) and do not take into account horizontal decentralization. This should not pose a problem for those theories which attribute much or all of the innovative benefits of decentralization to federalism. However, in order to cover all the theoretically possibilities, I also want to test the relevance of horizontal decentralization (division of powers) and total combined decentralization. Again, Lijphart's indices are of use here. Specifically, I alternately sum and average Lijphart's measures of executive dominance (inverse), bicameralism, and judicial review to construct two different measures of horizontal decentralization. I further combine these newly constructed horizontal measures with Lijphart's federalism measure to construct two measures (summed and average) of total decentralization (Sum Lijphrt and Ave Lijphrt).⁵² I also experiment with the one of the constructed horizontal measures (Sum Lijphrt Horiz) separately. As a third independent measure of overall decentralization, I employ the POLCON Index discussed above.⁵³

3.2.4. Additional Control Variables

In order to test the weaker versions of the decentralization hypothesis, we also need to include controls for those variables specified by decentralization theorists as conditioning the effects of government decentralization on innovation. For example, almost universally, these researchers assume that the size of a country's economy and its level of development affect innovation rates. The idea here is that larger economies will have more resources upon which innovators can draw, and that innovators in more advanced economies should be able to draw on these resources more effectively. Hence the primary 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), and per capita electric power consumption (to control for base-level of economic development).⁵⁴ Also, since most decentralization scholars, especially Mokyr, require a certain amount of political freedom for

innovative activity, a measure of Democracy (Polity2, from the Polity IV database) is included.⁵⁵ Finally, since the United States is a technological outlier by almost any measure, a US-dummy is added.

The regressions are based on log-log specification, except for the political variables (decentralization and democracy) and those variables expressed in percentages. 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.⁵⁶ This results in a primary regression model along the following lines:

$$\begin{aligned} \text{Ln(Innovation}_{t=0 \text{ thru } 1}) = & B_0 + B_1 * (\text{Govt. Decentralization}_{t=0}) + B_2 * \text{Ln(Economic Resources}_{t=0}) \\ & + B_3 * \text{Ln(Level of Econ. Development}_{t=0}) + B_5 * (\text{Democracy}_{t=0}) \\ & + B_6 * (\text{US dummy}) \end{aligned}$$

where patenting activity in period $t=0$ through $t=1$ is a function of the independent variables at time $t=0$. The model is identical when publications are used as the measure of innovation. However, when high-technology exports per GDP is the dependent variable, the control for economic resources (log of GDP) is replaced with a control for total population (log of population). This allows me to match the per capita patents and publications regressions as closely as possible.

This model will doubtless arouse some criticism for its narrow approach. Economists, sociologists, and policy-analysts often take a more encompassing view when performing statistical analysis of innovation at the national level, and include a myriad of policy variables, financial controls, and education measures alongside the primary independent variables of interest. Given the large potential number of causal lines feeding into national innovation rates, this temptation is understandable. Why not control for, say, those factors identified by Furman, Porter, & Stern (2002) as contributing to national innovative capacity?⁵⁷ The answer is that this the decentralization hypothesis holds that such policies are either endogenous to government structure, or are overwhelmed by its causal effects. Although this may sound like an extreme interpretation of the

decentralization argument, recall that these mid-level institutions and policies are exactly those which NSI scholars have failed to generalize as causal explanations after almost two decades of research.

Take as an example the recent debate about the promotion of “intelligent design” in the United States. A decentralization theorist would argue that, if the US had a centralized government structure, then the Bush administration or a Republican controlled congress could have required US public schools to teach intelligent design as science, and even deemphasized the teaching of evolution. Depending on the extremes to which this policy were taken, private schools might also have felt a need to join this movement in order to be “competitive”, or to meet government certification requirements. However, since the US is decentralized, the decision over intelligent design was left up to the states and the local school boards. Most of these school districts opted to omit intelligent design, others chose to place warning stickers on biology textbooks, still others actively promoted the teaching of intelligent design as science. The courts then got involved to thwart the teaching of intelligent design as science in some states, while voters changed outcomes in local elections in others. Thus decentralized government, both horizontal and vertical, has arguably played an important role in virtually eliminating intelligent design, and continuing the support for teaching evolution, in science classrooms. A very different outcome might have occurred in a centralized American democracy.

Decentralization proponents argue that similar types of policy battles are regularly fought over R&D spending, science policy, education budgets, high-technology procurement, teaching & testing standards, etc. These fights take place between different interest groups at both the federal and local levels, as well as between the executive, legislative, and judicial branches. Hence, all sorts of policies important for innovation are arguably endogenous to government structure, and in very much the ways described by decentralization scholars (i.e. policy responds to competition between

different branches and levels of government; is made better by superior information available to voters and policymakers at the local level; decentralization creates a menu of different policy environments for consumers of public goods to choose from, etc). Note that we need not necessarily nor disagree with this; rather the purpose of this paper is merely to test the decentralization-innovation thesis as given.

Nonetheless, for those who are not fully convinced by the endogeneity argument, in some regressions I do experiment with four additional controls. Three of these are variables which are specifically cited by innovation and some decentralization scholars as important causal factors for innovation, and which are arguably not endogenous to government structure. First, openness to trade (defined as exports plus imports as a share of GDP) is generally considered to provide competitive motivation for long-run innovation.⁵⁸ Second, military spending is too considered by many to be a major source of technological progress, and is included in the regressions as a percentage of gross national product.⁵⁹ Third, natural resources are considered an obstacle to innovation, “cursing” otherwise innovative countries into a cycle of dependence on exports of oil, metals, raw materials, and agricultural products.⁶⁰ I therefore experiment with three alternate measures of natural resource base (as a percent of total, alternately: arable land, fuel exports, or metal/ore exports) in my regressions.⁶¹ Finally, although the importance of aggregate education is overstated according to some proponents of the decentralization hypothesis,⁶² and arguably endogenous to government structure, I experiment with its inclusion in the regressions. I alternately included controls for undergraduates in science and engineering (total and per capita), literacy (as percent of population), and government expenditure on education (as percent of total and percent of GNP).⁶³

3.2.5 Primary Regression Results

The first and most important finding of the regressions is that government decentralization is consistently insignificant. 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. This result occurred regardless of the time period tested, the measure of decentralization used, the conditional variables included, and whether patents, publications, or high-technology exports were employed as the regressand. Representative results of the main set of regressions are tabulated in Tables 1-2.

***** TABLES 1 & 2 ABOUT HERE *****

The lone case in which the null hypothesis can be rejected occurs when I sub-divide countries by wealth, but here the affect is fairly small (Table 3). In this case, regression analysis suggests that decentralization may foster innovation, but only for one measure of decentralization, and only when the dataset is constrained to a small subset of wealthy countries. Here a 0.1 increase in the POLCON scale is associated with a 33.6 percent increase in patent citations, 12.8 percent rise in publication citations (for OECD members), and a 0.003 percentage point rise in high-technology exports per GDP (for high GDP-per-capita countries). Note however that the mean POLCON score for either sub-group of wealthy countries is around 0.7, with a maximum of 0.88 and a standard deviation of ~0.25. Hence the effect of POLCON on innovation, while statistically significant, is not very large. And interestingly, neither centralization nor decentralization appeared to affect the pace of technological change in non-wealthy countries, by any measure. These results are discussed further below.

The coefficients of the other independent variables should be interpreted with caution. Since the regressions presented here were designed specifically to test the relationship between decentralization and innovation, firm conclusions cannot be drawn from them about the other independent variables. I therefore prefer to treat them as hypotheses in need of further direct testing.

One of these tentative findings is that trade matters. Trade as a percentage of GDP is significant and positive in most regressions that include it as an independent variable, and across each measure of innovation. The coefficients suggest that, cross-nationally, a 10 percent increase in trade as a percentage of GDP is associated with a 10-20 percent increase in citations-weighted patents per capita, a 7-8 percent increase in citations-weighted publications per capita, and a 0.005-0.01 percentage point increase in high-technology exports as a percent of GDP. The relatively larger effect of trade on patenting could reflect a greater concern for intellectual property protection by trading nations. Also the seemingly small effect of trade openness on high-tech exports is not quite so minor when we realize that the sample mean for high-tech exports per GDP is only 0.023 percent (with a standard deviation = 0.056 percent). Overall, this finding that trade-openness fosters innovation dovetails with much of the trade-innovation literature, and I view it as an additional piece of confirmatory evidence to that debate.⁶⁴

A second tentative finding is that level of development matters for innovation. The per capita development measure carried high levels of significance and large coefficients in every patents or publications regression which included it as an independent variable. In simple bivariate regressions with either patents or publications as the dependent variable, logged KWH per capita accounted for over 72 percent of the variance (though this dropped to 10 percent when high-technology exports was used as the measure of innovation). This makes level of development a likely suspect as a primary source of the high R^2 's in the multiple regressions of patents and publications.⁶⁵ Of course, high multicollinearity amongst the regressors might also be to blame. In order to test this, the variance inflation factors (VIF's) were calculated and the highest individual VIF is reported for each regression with an R^2 of 0.75 or above.⁶⁶ The low VIF's suggest that high multicollinearity is not a problem. Substitution of GDP per capita as the development measure yielded no significant differences in the results reported. Nor do these coefficients change

significantly across different regression models. Where high-technology exports are concerned, level of development does not seem to be significant. This could reflect both the rise of less developed innovators such as South Korea, Taiwan, and Ireland, as well as the out-sourcing of high-technology manufacturing by Western firms to Southeast Asia and Eastern Europe during the 1980s and 1990s. Hence you do appear to need to be developed in order to patent and publish, but not necessarily to make your economy a hub for high-technology exports.

Likewise GDP carried high levels of significance in many of the regressions which included it as an independent variable. However, these coefficients were at best only half as large as those for economic development. This implies that a percentage change in the size of the economy has only half the effect on innovation of a percentage change in economic development.

There are a few other results worth noting. Interestingly, democracy is significant only for a minority of the regressions, a subset of those involving patents or publications. And the coefficients for democracy are very small, implying a mere 3-13 percent increase in patents or publications for a full 1-point increase on the Polity IV scale. Second, the effect of military spending on both patents and scientific publications stands out across many of the regressions. The coefficients suggest that a 10 percent increase in military spending is associated with 70-80 percent increase in citations-weighted patents and a 50-70 percent increase in citations-weighted publications. Whether this reflects direct military research or a more nuanced correlation between security and innovation is unclear.

Also, the experiments with different measures of natural resource base produced mixed results. Arable land as a percentage of total occasionally had an unexpected positive association with innovation, but either fuel exports or metals exports (as a percentage of total exports) occasionally had a negative association with innovation. While this finding may become the subject of future research, it does not cause problems here; no measure of natural resource base affected the

significance of government structure, nor did omitting the measure altogether have any substantive affect on the regression results. Likewise, experiments with controls for science & engineering undergraduates, literacy, and education spending also failed to substantively affect the coefficients or significance levels for decentralization. These regressions suggested that, even when we control for education, government structure has little overall effect on national innovation rates.

Finally, various lagged measures of the dependent variable (citations-weighted patents citations, simple & per capita) were experimented with in each of the regressions, but with little change in the results except to drive up the variance inflation factors to more worrisome levels. And since a high correlation ($r = 0.87$) exists between lagged innovation and electric power consumption, it was felt that the latter measure sufficiently captured the control one would seek in the former. This also allows me to avoid many of the methodological and interpretational problems surrounding lagged dependent variables.⁶⁷

3.2.6 Secondary Regression Results

One possible explanation for the null results reported for government structure is that decentralization may take time to have its effect on technological innovation. After all, in order for government structure to affect the conditions and incentives for innovation, it must first alter the political, economic, and policy environments within which innovators operate. This might take several election or business cycles to be realized in full. In order to test this possibility, I used the 1974 values for my independent variables and regressed the later five-year sub-periods of innovation on them (1975-80, 1980-85, 1985-90, 1990-85). These regression results closely resemble those for the entire time period, though interestingly with generally larger coefficients for GDP and (for patents) smaller coefficients for level of development. Hence economic size seems to affect innovation more strongly over longer time-periods, development less so. Also, military spending in these regressions appears significant for both patenting and publishing across all models

tested, while arable land appears significant in many models. But each of these findings is peripheral to my main concern with decentralization. The fact remains that, even after a decade or two, government structure is still insignificant for innovation rates regardless of the model tested. This dovetails with what we saw in Figures 2 & 3 above: countries which increased their decentralization during the 1975-95 period did not appear to improve their innovative performance. Admittedly, this test only covers a 15-20 year time lag, therefore I must remain agnostic as to the effects of decentralization over longer periods of time.

A second alternate explanation for the results reported above is that government decentralization might have a bell-shaped relationship with innovation. That is, there may be diminishing returns to decentralization such that highly decentralized or highly centralized governments may hinder innovation, but that a happy medium exists. I therefore conducted tests using a “bell” constructed on the POLCON index, but they too failed to produce significant results.

A third possible explanation for the null results above is that decentralization might benefit innovation in the advanced economies, while centralization might help lesser developed countries in Gerschenkronian fashion.⁶⁸ That is, with their luxury of having the advanced economies as models, backward economies may benefit more from a powerful central authority that can force actors down a well-trodden economic path towards technological development. Conversely, this kind of centralized power might be a handicap for the advanced economies, which by nature of their position at the economic frontier must find their way forward more by experiment than by government direction. I experiment with two tests for this hypothesis, and the results merit further study. First I split the data into OECD and non-OECD subgroups and re-ran the regressions above. 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.⁶⁹ In both instances, the POLCON measure showed small but positive and significant coefficients, but not any

of the other decentralization measures. It is possible that this result is due to selection bias based on the small and overlapping samples. Alternately, it may suggest that not only does decentralization matter for wealthy countries, but that informal decentralization (which only the POLCON measure captures) may be more important than structural decentralization. In other words, structural decentralization does not matter if all actors in the structure belong to the same political party and have similar political-economic preferences. (extent of party alignment across branches of government and the extent of preference heterogeneity within each legislative branch).

***** TABLE 3 ABOUT HERE *****

3.2.7 Potential Problems

The regressions reported here do have drawbacks which somewhat restrict, but by no means eliminate, their usefulness as tests of the government structure-innovation relationship. First, a need to conserve degrees of freedom prevents me from adding country and year fixed effects. The concern over country fixed effects is somewhat ameliorated by the fact that other researchers have used pure fixed-effects models in regressions on patent data, and produced results which show no significant innovative differences between decentralized and centralized states.⁷⁰ Likewise, the separation of the dataset into temporal subperiods should mitigate some of the concerns over year fixed effects.

It is tempting to imagine that endogeneity may be at play. However there currently exists neither theoretical justification nor empirical evidence to suspect that an uncontrolled variable affects both government structure and innovation. Nor is there reason to suspect that somehow technological change affects government structure. History shows us both democratic and totalitarian states that have taken advantage of technological change to strengthen the power of central government, as well states which have used it to devolve power out to the subnational level.

Also, these regressions may resemble data-mining or seem cavalier. They are not. The inclusion of the different control variables above (trade, military spending, etc) both have solid

theoretical basis and were prompted by the specific recommendations of innovation scholars. However, so much the better if the regressions *had* been data-mining or cavalier. Data-mining is indeed problematic when it finds correlations that are then used to prove a theory; but if one goes to the extreme of data-mining and still *cannot* find a correlation between two variables, then the likelihood that a relationship exists between them becomes highly suspect, which is what I argue here. Likewise, if I had found a statistically significant relationship between decentralization and innovation, then questions about whether the regressions were overly casual and cavalier would have been an issue. But here it would only further support the argument against decentralization hypothesis. Indeed, it seems that no matter how cavalier one gets with the data, one still cannot find a relationship between decentralized government and innovation. The non-correlation is quite robust.

Another possibility is there may be changing returns to decentralization over time. The Spanish case and the subdivision into of time periods would seem to rule out this possibility. However, to be fair, one could theorize a situation whereby decentralization might result in few gains in innovation as the country initially moves to a new political-economic equilibrium, followed by a rapid increase in innovation as the new structural incentives take hold, and then diminishing returns after the new equilibrium solidifies. In other words, although the assumption of a simple linear relationship between government structure and innovation can now be seriously called into question, this does not eliminate the possibility of a more complex model, or the need to consider far longer time periods than are analyzed above.

While these issues reveal the limitations of statistical analysis in testing the government structure-innovation relationship, they do not invalidate the results reported here. Certainly, the results produced above are robust enough to allow us to question the innovative advantages of government decentralization, especially the stronger versions of the decentralization hypothesis.

They also point to the importance of case studies as the next step in research on this question. Case studies are important for confirming the statistical results produced here. They can resolve, at close range, whether there are truly no significant lines of causality between government structure and innovation, or whether wealth and government structure might interact to affect the policy environment for innovators; whether broad structural forces exist but are obscured or overwhelmed by other factors, or are conditional on some omitted variable. Case studies would also allow us to go beyond patent data, and judge with greater scrutiny the pace and degree of innovation being performed.

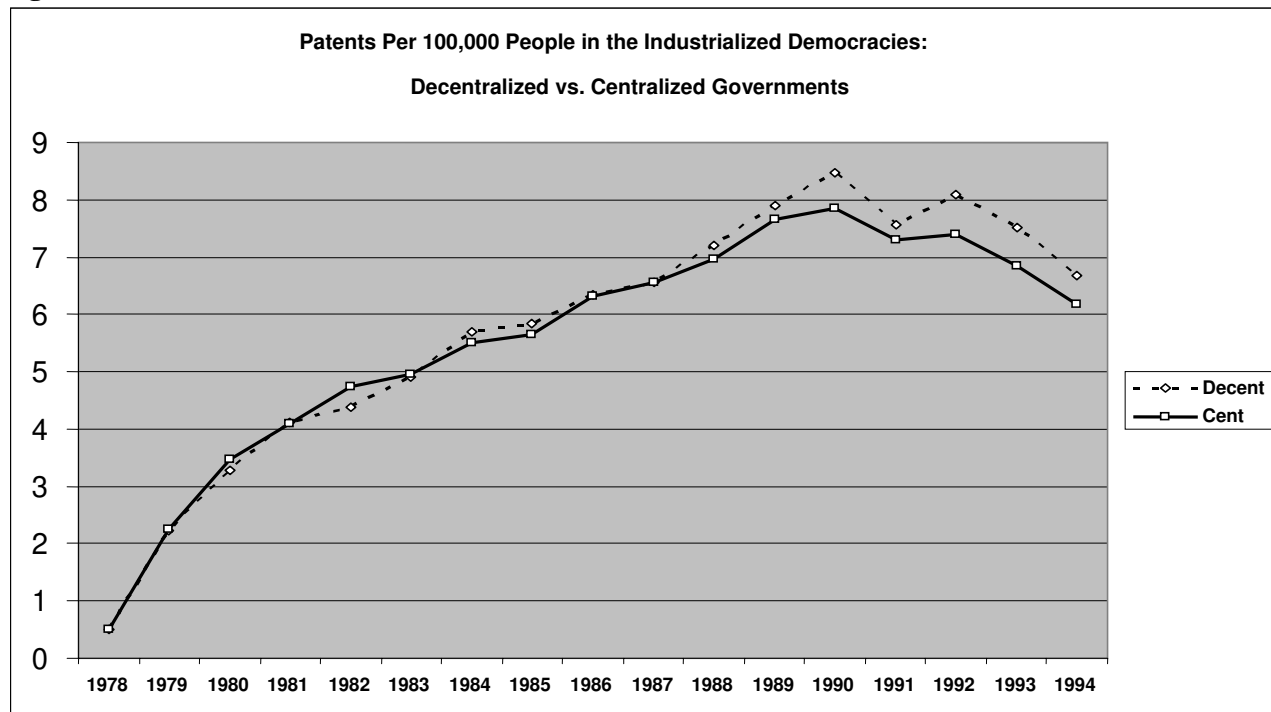
4. Conclusions and Implications

In sum, I have examined two separate sets of patent evidence, along with data on scientific publications and high-technology exports, and found that decentralized states are generally no more technologically innovative than centralized states. These findings were robust to the inclusion of several conditional variables, including controls for democracy, development, size, natural resources, military spending, trade openness, and even education. The only exception to this finding was a minor effect, which appeared only amongst a small subset of wealthy countries and only when using the broadest measure of decentralization.

The conventional wisdom is therefore incorrect. Political decentralization may have other benefits, but it appears to be neither necessary nor sufficient for explaining or predicting national innovation rates. Certainly no single statistical test or dataset is by itself conclusive, but the compounding of the several alternate measures and methods used above establishes a firm basis for questioning the assumption that government decentralization leads to higher innovation rates. And if we believe that what matters most for long-run aggregate technological change is a competitive environment, then the implication of these findings for policymaking is that government decentralization is but one way to achieve this, if at all.

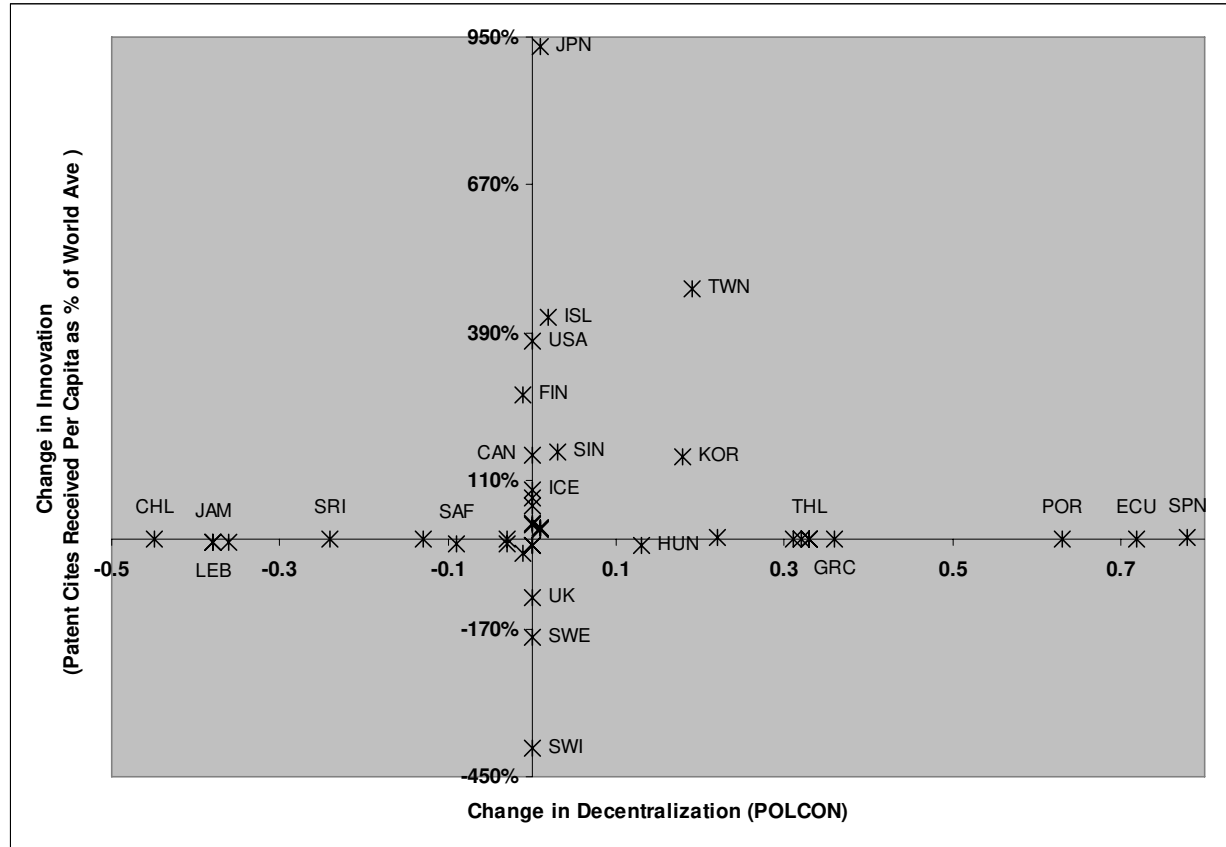
Perhaps more provocative were the secondary findings, such as the relatively minor influence of democracy, and relatively large effect of lagged military spending, on innovation over time. These results deserve some attention in future research since they contradict much of the endogenous-growth literature which puts a heavy emphasis on civilian democratic institutions for explaining long-run innovation-driven economic growth and efficiency. It suggests that, rather than being a natural product of institutional reform, innovation could instead be a rational solution to a perceived security problem. In other words, long-run technological innovation may find better explanations in international relations theory rather than comparative political institutions. This is an aspect almost totally ignored by the economists and sociologists who study innovation, and deserves greater attention from political scientists. Of course it is important not to get ahead of ourselves here, since the various tests reported here were not specifically designed to examine causal relationships between democracy and innovation. A useful next step in testing, therefore, would be for researchers to conduct in-depth qualitative analysis of individual technological case studies in order to confirm and refine each of the findings above.

Figure 1: Innovation in Advanced Democracies: Decentralized vs. Centralized States



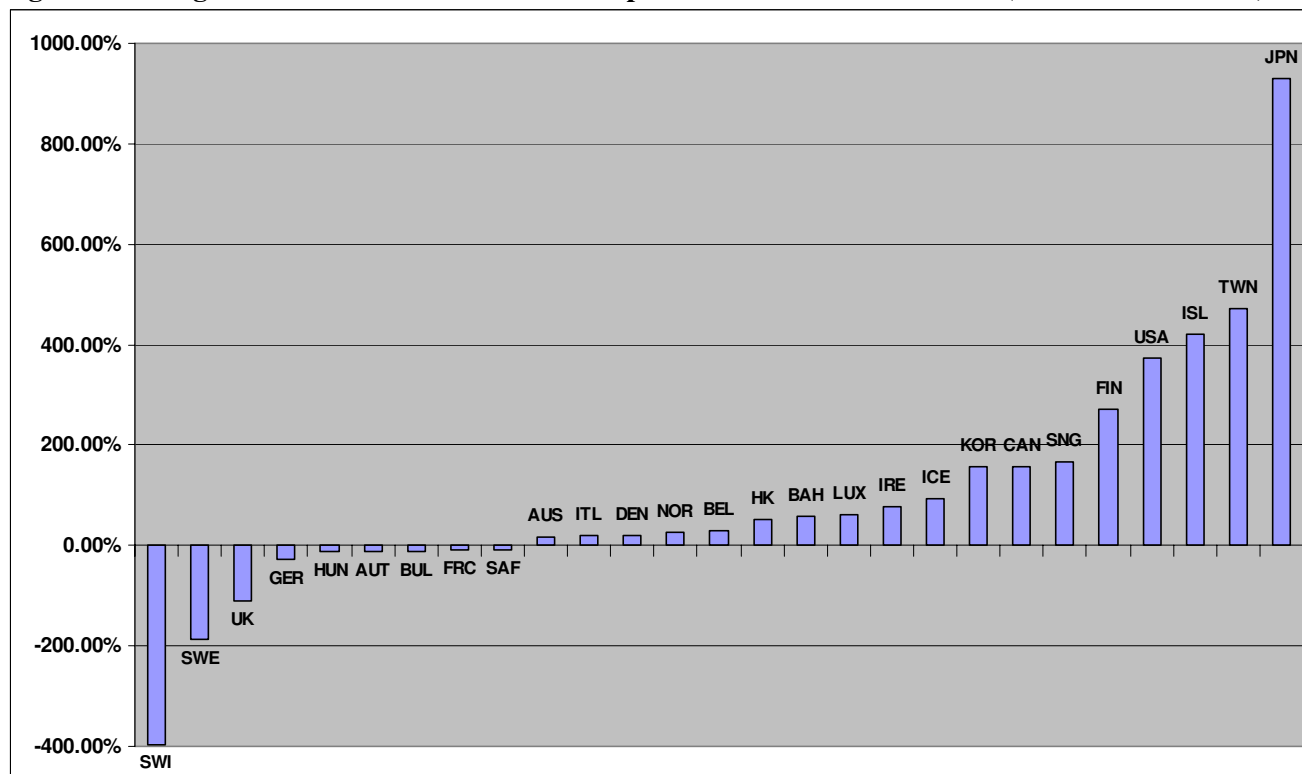
Source: European Patent Office.⁷¹

Figure 2: Innovation vs. Decentralization in 45 Countries (1975-95)



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

Figure 3: Change in Patent Cites Received Per Capita 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.

Table 1: Primary Regressions of Technological Innovation (1975-95)

	DV = Log of Patent Citations Received Per Capita					DV = Log of Pub Citations Received Per Capita					DV = High-Tech Exports as % of GDP				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Sum Lijphrt	-0.01 [0.07]					0.01 [0.06]					0.00 [0.001]				
Ave Lijphrt		-0.03 [0.27]					0.03 [0.22]					0.00 [0.004]			
Lijphrt Fed			0.06 [0.15]					0.09 [0.13]					-0.003 [0.004]		
Sum Lijphrt Horizntl			-0.06 [0.12]					-0.07 [0.09]					0.002 [0.004]		
Federalism Dummies				-0.36 [0.34]					-0.25 [0.26]					0.004 [0.01]	
POLCON					1.13 [1.07]					0.38 [0.64]					-0.02 [0.05]
Log GDP	0.42 [0.15]**	0.42 [0.15]**	0.43 [0.16]**	0.32 [0.11]**	0.29 [0.11]**	0.14 [0.12]	0.14 [0.12]	0.16 [0.12]	0.18 [0.08]*	0.16 [0.08]*					
Log Populn											-0.001 [0.003]	-0.001 [0.003]	-0.001 [0.004]	-0.003 [0.004]	-0.002 [0.003]
Log Kwh/cap	1.59 [0.31]***	1.59 [0.31]***	1.55 [0.36]***	1.33 [0.17]***	1.26 [0.19]***	1.30 [0.22]***	1.30 [0.22]***	1.25 [0.21]***	1.09 [0.09]***	1.07 [0.11]***	0.004 [0.003]	0.004 [0.003]	0.005 [0.003]	0.004 [0.003]	0.006 [0.007]
Democracy	0.13 [0.03]***	0.13 [0.03]***	0.13 [0.03]***	0.05 [0.03]	0.02 [0.04]	0.02 [0.02]	0.02 [0.02]	0.02 [0.02]	0.03 [0.02]*	0.02 [0.02]	0.001 [0.001]	0.001 [0.001]	0.001 [0.001]	0.00 [0.001]	0.001 [0.001]
US Dummy	-0.13 [0.59]	-0.13 [0.59]	0.03 [0.68]	0.98 [0.44]*	0.71 [0.42]	-0.54 [0.45]	-0.54 [0.45]	-0.33 [0.52]	-0.01 [0.32]	-0.17 [0.3]	-0.009 [0.01]	-0.009 [0.01]	-0.02 [0.01]	-0.01 [0.01]	-0.01 [0.01]
constant	-31.1 [2.51]***	-31.1 [2.51]***	-30.7 [2.74]***	-25.9 [2.36]***	-25.0 [2.34]***	-16.6 [2.23]***	-16.6 [2.23]***	-16.2 [2.45]***	-16.0 [1.76]***	-15.5 [1.83]***	0.002 [0.07]	0.002 [0.07]	-0.01 [0.06]	0.04 [0.05]	0.03 [0.04]
R-squared	0.86	0.86	0.86	0.83	0.83	0.79	0.79	0.80	0.81	0.82	0.09	0.09	0.11	0.03	0.04
max VIF	1.93	1.93	2.5	2.2	4.15	1.93	1.93	2.50	2.17	4.02					
# obs	28	28	28	70	69	28	28	28	74	73	28	28	28	78	76

Note: Analysis is by ordinary least squares (OLS), Huber-White estimates of standard errors reported in brackets. All independent variables are 1974 values, all dependent variables are overall value of the 1975-95 period. *p< .05, **p< .01, ***p<.001

Table 2: Secondary Regressions of Technological Innovation (1975-95)

	DV = Log of Patent Citations Received Per Capita					DV = Log of Pub Citations Received Per Capita					DV = High-Tech Exports as % of GDP				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Sum Lijphrt	-0.03 [0.06]					0.02 [0.05]					-0.0001 [0.001]				
Ave Lijphrt		-0.13 [0.24]					0.08 [0.19]					-0.003 [0.003]			
Lijphrt Fed			0.03 [0.12]					0.06 [0.1]					-0.003 [0.004]		
Sum Lijphrt Horizntl			-0.09 [0.13]					-0.02 [0.08]					0.001 [0.003]		
Federalism Dummies				-0.25 [0.35]					-0.08 [0.25]					0.007 [0.01]	
POLCON					1.32 [0.99]					0.93 [0.65]					-0.02 [0.03]
Log GDP	0.65 [0.20]**	0.65 [0.20]**	0.68 [0.23]**	0.38 [0.12]**	0.35 [0.12]**	0.09 [0.12]	0.09 [0.12]	0.1 [0.13]	0.2 [0.08]*	0.18 [0.08]*					
Log Populn											0.005 [0.002]*	0.005 [0.002]*	0.005 [0.003]	0.02 [0.004]***	0.02 [0.004]***
Log Kwh/cap	1.27 [0.33]**	1.27 [0.33]**	1.21 [0.40]**	1.22 [0.16]***	1.14 [0.18]***	1.38 [0.23]***	1.38 [0.23]***	1.34 [0.26]***	1.01 [0.1]***	0.94 [0.11]***	0.003 [0.003]	0.003 [0.003]	0.004 [0.003]	0.0003 [0.003]	0.002 [0.004]
Democracy	0.12 [0.03]**	0.12 [0.03]**	0.12 [0.03]**	0.05 [0.03]	0.01 [0.04]	0.03 [0.02]	0.03 [0.02]	0.03 [0.02]	0.04 [0.01]**	0.02 [0.02]	0.0005 [0.0004]	0.0005 [0.0004]	0.0005 [0.0005]	0.0004 [0.0006]	0.0009 [0.0006]
US Dummy	0.33 [0.52]	0.33 [0.52]	0.52 [0.64]	1.28 [0.49]*	1.07 [0.47]*	-0.44 [0.52]	-0.44 [0.52]	-0.32 [0.55]	0.01 [0.34]	-0.09 [0.31]	0.003 [0.01]	0.003 [0.01]	-0.003 [0.01]	0.0009 [0.01]	0.007 [0.009]
Miltry Spndng	0.08 [0.02]**	0.08 [0.02]**	0.07 [0.02]**	-0.01 [0.05]	0.003 [0.05]	0.07 [0.01]***	0.07 [0.01]***	0.07 [0.01]***	0.05 [0.025]*	0.06 [0.02]*	0.0002 [0.0005]	0.0002 [0.0005]	0.0002 [0.0004]	-0.0009 [0.0007]	-0.001 [0.0006]
Trade per GDP	0.02 [0.01]*	0.02 [0.01]*	0.02 [0.01]*	0.01 [0.003]**	0.01 [0.003]***	0.008 [0.007]	0.008 [0.007]	0.008 [0.007]	0.007 [0.003]**	0.007 [0.002]**	0.0005 [0.0002]*	0.0005 [0.0002]*	0.0005 [0.0002]*	0.001 [0.0003]***	0.001 [0.0002]***
Arable Land	-0.001 [0.01]	-0.001 [0.01]	-0.002 [0.02]	0.01 [0.01]	0.02 [0.01]	0.03 [0.01]**	0.03 [0.01]**	0.02 [0.01]**	0.01 [0.01]	0.02 [0.01]	0.0002 [0.0001]	0.0002 [0.0001]	0.0002 [0.0002]	0.00 [0.0002]	-0.0001 [0.0002]
_cons	-35.8 [3.33]***	-35.8 [3.33]***	-35.6 [3.47]***	-27.5 [2.78]***	-26.7 [2.73]***	-17.3 [2.06]***	-17.3 [2.06]***	-17.2 [2.09]***	-16.8 [1.84]***	-16.4 [1.91]***	-0.12 [0.05]*	-0.12 [0.05]*	-0.12 [0.05]*	-0.30 [0.08]***	-0.31 [0.07]***
R-squared	0.92	0.92	0.93	0.85	0.86	0.91	0.91	0.91	0.85	0.86	0.30	0.30	0.31	0.70	0.71
max VIF	4.01	4.01	4.23	2.89	4.91	4.01	4.01	4.23	2.84	4.76					
# obs	28	28	28	68	67	28	28	28	72	71	28	28	28	70	69

Note: Analysis is by ordinary least squares (OLS), Huber-White estimates of standard errors reported in brackets. All independent variables are 1974 values, all dependent variables are overall value of the 1975-95 period. *p< .05, **p< .01, ***p<.001

Table 3: Regressions of Technological Innovation in Rich Nations (1975-95)

	<i>Dependent Variable:</i>					
	<u>Pat Cites</u>	<u>Pub Cites</u>	<u>HT Exprts</u>	<u>Pat Cites</u>	<u>Pub Cites</u>	<u>HT Exprts</u>
OECD Member	X	X	X			
Wealthy Country				X	X	X
POLCON	3.36	1.28	0.05	3.36	0.95	0.03
	[0.76]***	[0.55]*	[0.028]†	[0.52]***	[1.04]	[0.009]*
Log GDP	0.46	0.23		0.58	0.45	
	[0.11]**	[0.17]		[0.12]**	[0.34]	
Log Populn			-0.003			0.0003
			[0.006]			[0.002]
Log Kwh/cap	1.14	0.75	-0.01	2.11	0.35	0.016
	[0.41]*	[0.29]*	[0.01]	[0.53]**	[0.95]	[0.007]*
Democracy‡						
US Dummy	-0.23	-0.42	0.0004	-1.52	-0.73	-0.02
	[0.47]	[0.50]	[0.017]	[0.64]*	[1.41]	[0.009]*
Constant	-29.9	-15	0.14	-40.6	-17.3	-0.14
	[4.99]***	[4.59]***	[0.17]	[6.51]***	[11.4]	[0.06]
R-squared	0.89	0.62	0.19	0.94	0.5	0.66
max VIF	1.96			1.86		
# obs	24	24	23	12	12	11

Note: Analysis is by ordinary least squares (OLS), Huber-White estimates of standard errors reported in brackets. All independent variables are 1974 values, all dependent variables are overall value of the 1990-95 period. † p<.10, *p< .05, **p< .01, ***p<.001, ‡ omitted due to high multicollinearity.

¹See for example: Carroll, Paul. 1993. *Big Blues: The Unmaking of IBM*. New York: Crown Publishers; Jennergren, L. Peter. 1981. "Decentralization in Organizations." In Nystrom, Paul C. and William H. Starbuck (eds.). *Handbook of Organizational Design Vol. II*. Oxford: Oxford University Press, p. 39-59; Acemoglu et. al. 2006. "Technology, Information, and the Decentralization of the Firm" Working Paper 12206. Cambridge, MA: National Bureau of Economic Research.

² Perhaps best exemplified by the global best-seller Surowiecki, James. 2004 *The Wisdom of Crowds: Why The Many Are Smarter Than The Few And How Collective Wisdom Shapes Business, Economies, Societies, and Nations*. New York: Doubleday.

³ European Commission. *Third European Report on Science and Technology Indicators*. 2003. Luxemborg: European Commission; Barre, Remi, Michael Gibbons, John Maddox, Ben Martin, Pierre Papon eds. 1997. *Science in Tomorrow's Europe*. Paris: Economica International; Commission on European Communities. 1988. *First Report on the State of Science and Technology in Europe*. Luxemborg: Commission on European Communities.

⁴ Oates, Wallace. 1972. *Fiscal Federalism*. New York: Harcourt Brace Jovanovich; 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.

⁵ Rodden, Jonathan. 2002. "The Dilemma of Fiscal Federalism: Grants and Fiscal Performance Around the World." *American Journal of Political Science* 44(3): 670-687; Woodruff, David. 1999. *Money Unmade: Barter and the Fate of Russian Capitalism*. Ithaca, NY: Cornell University Press; Armijo, Leslie and Prem Shankar Jah. 2000. "Centre-State Relations in India and Brazil: Privatisation of Electricity and Banking." In Satu Kahkonen and Anthony Lanyi (eds.) *Institutions, Incentives and Economic Reforms in India*. New Delhi: Sage Publications.

⁶ Rodden, Jonathan and Erik Wibbels. 2002. "Beyond the Fiction of Federalism: Macroeconomic Management in Multi-tiered Systems." *World Politics* 54(4): 494-531.

⁷ Rodden, Jonathon. 2005. *Hamilton's Paradox: The Promise and Peril of Fiscal Federalism*. Cambridge Univ. Press.

⁸ This is much the same concept as "balance of power" or "checks and balances".

⁹ Found in: Drezner, Daniel. 2001. "State Structure, Technological Leadership and the Maintenance of Hegemony" *Review of International Studies* 27(1): 3-25; Mokyr, Joel. 1990. *The Lever of Riches: Technological Creativity and Economic Progress*. Oxford Univ. Press; Mokyr, Joel. 2002. *The Gifts of Athena: Historical Origins of the Knowledge Economy*. Princeton, N.J. : Princeton University Press; 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; Nelson, Richard R. 2005. *Technology, Institutions, and Economic Growth*. Harvard University Press;; Acemoglu, Daron, Simon Johnson, and James Robinson. 2005 "Institutions as the Fundamental Cause of Long-Run Growth" in *Handbook of Economic Growth* ed. Philippe Aghion & Steve Durlauf. (Elsevier): 385-472.

¹⁰ Found in Drezner 2001; Mokyr 1990, 2002; Rosenberg, Nathan and L.E. Birdzell. 1985. *How the West Grew Rich: The Economic Transformation of the Industrial World*. New York: Basic Books; Surowiecki 2004; Nelson 2005; Acemoglu et. al. 2005.

¹¹ Cary, William L. 1974. "Federalism and Corporate Law: Reflections Upon Delaware" *Yale Law Journal*, 83(4): 663-705; for the improved information and principal-agent arguments favoring federalism see also Oates, Wallace. 1972. *Fiscal Federalism*. New York: Harcourt Brace Jovanovich.

¹² Weingast (1995); Qian, Yingyi and Barry R. Weingast. 1997. "Federalism as a Commitment to Preserving Market Incentives" *Journal of Economic Perspectives* 11(4): 83-92.

¹³ Mokyr 1990, 2002

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- ¹⁴ Hayek, Friedrich A. 1945. "The Use of Knowledge in Society." *American Economic Review* 35(4): 519-530
- ¹⁵ Tiebout, Charles. 1956. "A Pure Theory of Local Expenditures." *Journal of Political Economy* 64(5): 416-424.
- ¹⁶ Surowecki 2004
- ¹⁷ Drezner 2001; Mokyr 1990, 2002; Rosenberg & Birdzell 1984; Weingast 1995; Acemoglu et. al. 2005.
- ¹⁸ Drezner, Daniel. 2001.
- ¹⁹ Shilts, Randy. 1987. *And the Band Played On: Politics, People, and the AIDS Epidemic*. New York: St. Martin's Press.
- ²⁰ 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).
- ²¹ Arrow, Kenneth. 1962. "Economics of Welfare and the Allocation of Resources for Invention" in Nelson, Richard R. ed. *The Rate and Direction of Inventive Activity*. Princeton University Press.
- ²² Drezner 2001, Acemoglu et. al. 2005.
- ²³ Drezner 2001
- ²⁴ Nelson 2005.
- ²⁵ Mokyr 1990, 2002; Rosenberg & Birdzell 1984.
- ²⁶ Drezner 2001
- ²⁷ Mokyr 1990, 2002
- ²⁸ Mokyr 2002, p. 282. A virtually identical conclusion can also be found in his prior essay on the same subject. See Mokyr 1990, p 180.

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- ²⁹ Dunlavy, Colleen A. 1994. *Politics and Industrialization: Early Railroads in the US and Prussia*. Princeton, NJ: Princeton Univ. Press; Hall, Peter A. 1986. *Governing the Economy: The Politics of State Intervention in Britain and France*. Cambridge: Polity. Pempel, T. J. 1998. *Regime Shift: Comparative Dynamics of the Japanese Political Economy*. Ithaca, NY: Cornell University Press.
- ³⁰ McNeill, William Hardy. 1982. *The Pursuit of Power: Technology, Armed Force, and Society Since A.D. 1000*. Chicago: University of Chicago Press.
- ³¹ Drezner, Daniel. 2001.
- ³² Cutler, Sidney J. 1955. "A Review of the Statistical Evidence on the Association Between Smoking and Lung Cancer" *Journal of the American Statistical Association* 50(270):267-282;
- Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: The Scientific Basis* Cambridge Univ. Press;
- ³³ Van Evera, Stephen. 1997. *Guide to Methods for Students of Political Science*. Cornell Univ. Press: Ithaca: 30-32.
- 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.
- ³⁵ Henisz, Witold J. 2000. "The Institutional Environment for Economic Growth" *Economics & Politics* 12(1): 1-31.
- ³⁶ 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.
- ³⁷ For example: $([X_{US}/X_{world}]_{t=1990-1995} - [X_{US}/X_{world}]_{t=1970-1975})$, where X=forward patent cites/population.

³⁸ 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 www.nber.org/patents.

³⁹ Poisson regression is not used because the data neither follows, nor satisfies the assumptions for, a Poisson distribution.

⁴⁰ Scherer, Frederic M "Firm Size, Market Structure, Opportunity, and the Output of Patented Innovations" *American Economic Review* 55 (5) (1965) pp. 1097-1125; Schmookler, Jacob *Invention and Economic Growth* (Harvard Univ. Press, 1966).

⁴¹ Griliches, Zvi ed. *R&D, Patents, and Productivity*. (Univ. of Chicago Press, 1984)

⁴² Trajtenberg, Manuel. "A Penny for Your Quotes: Patent Citations and the Value of Innovations" *The RAND Journal of Economics* 21 (1) (1990) pp. 172-187; Hall, Bronwyn H., Adam Jaffe, and Manuel Trajtenberg. "Market Value and Patent Citations: A First Look" Working Paper, 7741. (National Bureau of Economic Research, 2000); Lanjouw, Jean O and Mark Schankerman. "The Quality of Ideas: Measuring Innovation with Multiple Indicators" Working Paper, 7345. (National Bureau of Economic Research, 1999); Jaffe, Adam B., Manuel Trajtenberg, and Michael Fogarty. "The Meaning of Patent Citations: Report of the NBER/Case Western Reserve Survey of Patentees" Working Paper, 7631. (National Bureau of Economic Research, 2000).

⁴³ Amsden, Alice H. and Mona Mourshed "Scientific Publications, Patents and Technological Capabilities in Late-Industrializing Countries" *Technology Analysis and Strategic Management* 9(3) (1997).

⁴⁴ McMillan, G. Steven and Robert D. Hamilton. 2000. "Using Bibliometrics to Measure Firm Knowledge: An Analysis of the US Pharmaceutical Industry". *Technology Analysis & Strategic Management* 12 (4):465-475; Bourke, P. and L. Butler. 1996. "Publication Types, Citation Rates, and

Evaluation” *Scientometrics* 37 (3):473-494; Glanzel, Wolfgang and Henk F. Moed. 2002. “State-of-the-Art Report: Journal Impact Measures in Bibliometric Research” *Scientometrics* 53 (2):171-193

⁴⁵ Yamashita, Shoichi (ed.) 1991. *Transfer of Japanese Technology and Management to the ASEAN Countries* (Tokyo: University of Tokyo Press); Blomstrom, Magnus and Edward N. Wolff. 1994. “Multinational Corporations and Productivity Convergence in Mexico” in William Baumol, Richard Nelson and Ed Wolff, eds., *Convergence of Productivity: Cross-National Studies and Historical Evidence*, Oxford University Press Oxford; United Nations Conference on Trade and Development. 2003. *Investment and Technology Policies for Competitiveness: Review of Successful Country Experiences*. New York : United Nations.

⁴⁶ Although data availability for some independent variables may limit the number of countries considered in each regression, the remaining countries consistently account for at least 98 percent of the USPTO patent dataset.

⁴⁷ See OECD. 1986. *Science and Technology Indicators* (Paris: OECD), pp58-74; OECD. 2003 *Science, Technology and Industry Scoreboard 2003-Towards a Knowledge-Based Economy*. (Paris: OECD)

⁴⁸ Specifically, SITC (rev.2) codes 54, 75, 76, 77, 87, and 792.

⁴⁹ In this case the dummies are coded (1 =federal, 0 =non-federal) according to Watts, Ronald L. 1999. *Comparing Federal Systems* Kingston, ONT: McGill-Queens Univ. Press. The dummy federal states include: Arab Emirates, Argentina, Australia, Austria, Brazil, Canada, Germany, India, Malaysia, Mexico, Nigeria, Pakistan, Spain (1978 onwards), Switzerland, USA, Venezuela, and Yugoslavia

⁵⁰ Wibbels, Erik. 2000. “Federalism and the Politics of Macroeconomic Policy and Performance” *American Journal of Political Science* 44(4): 687-702; Treisman, D. 2000. “The Causes of Corruption: A Cross-National Study” *Journal of Public Economics* 76(3): 399-457; Treisman, D. 2000.

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Science Review 94(4): 837-857; Escobar-Lemmon, M. 2001. "Fiscal Decentralization and Federalism in Latin America" *Publius-The Journal of Federalism* 31(4): 23-41.

⁵¹ Lijphart, Arend. 1999. *Patterns of Democracy: Government Forms and Performance in Thirty-Six Countries*. New Haven: Yale University Press. The twenty-nine countries measured by Lijphart's indices include: Australia, Austria, Belgium, Canada, Columbia, Costa Rica, Denmark, Finland, France Germany, Greece, India, Ireland, Israel, Italy, Jamaica, Japan, Mauritius, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Trinidad & Tobago, UK, USA, Venezuela. While Lijphart also provides measure for Bahamas, Barbados, Iceland, Luxemborg, Malta, and New Guinea, the Polity4 database does not, hence these countries do not appear in the regressions reported below.

⁵² E.g $Sum\ Lijphrt = Lijphrt\ Fed + 1/executive\ dominance\ (inverse) + bicameralism + judicial\ review$;
 $Sum\ Lijphrt\ Horiz = 1/executive\ dominance\ (inverse) + bicameralism + judicial\ review$

⁵³ To control for annual fluctuations, I use lagged 4-year period averages of *POLCON* such that, for example, the average *POLCON* 1980-84 index is used when testing patenting during the 1985-90 sub-period.

⁵⁴ 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 produce high variance inflation factors (and hence high multicollinearity) when used alongside GDP.

⁵⁵ Monty G. Marshall, Keith Jagers, and Ted Robert Gurr. 2003. "Polity IV Project: Political Regime Characteristics and Transitions, 1800-2002" Integrated Network for Societal Conflict Research, University of Maryland: <http://www.cidcm.umd.edu/inscr/polity/>.

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- ⁵⁶ Furman Jeffrey, Porter Michael, Stern Scott, "The Determinants of National Innovative Capacity" *Research Policy* 31(6): 899-933 August 2002; Jones, C. *Introduction to Economic Growth* (New York: WW Norton & Company, 1998).
- ⁵⁷ Furman, Porter, Stern (2002).
- ⁵⁸ Daniels P.L. 1997. "National Technology Gaps and Trade: An Empirical Study of the Influence of Globalisation" *Research Policy* 25 (8): 1189-1207; Grossman, Gene and Elhanan Helpman. 1995. "Technology and Trade." In G. Grossman and K. Rogoff, eds., *Handbook of International Economics*, vol. III, New York: North Holland p. 1279-1337; Grossman, Gene and Elhanan Helpman. 1991. *Innovation and Growth in the Global Economy*. Cambridge, MA: MIT Press. Data source for regressions is World Bank, *World Development Indicators*.
- ⁵⁹ Smith, Merritt Roe ed. 1985. *Military Enterprise and Technological Change: Perspectives on the American Experience*. Cambridge, MA: MIT Press; McNeil, William H. 1982. *The Pursuit of Power: Technology, Armed Force and Society Since AD 1000*. Chicago: Univ. of Chicago Press. Data source for the regressions is United States Arms Control and Disarmament Agency. 1975-1996. *World Military Expenditures and Arms Transfers*. Wash DC: USGPO.
- ⁶⁰ Ross, Michael L. 1999. "The Political Economy of the Resource Curse" *World Politics* 51(2): 297-322; Sachs, Jeffrey D. and Andrew M. Warner. 1995. "Natural Resource Abundance and Economic Growth" Working Paper 5398. Cambridge, MA: National Bureau of Economic Research; Gelb, Alan. 1988. *Oil Windfalls: Blessing or Curse?* New York: Oxford Univ. Press.
- ⁶¹ World Bank. 2002 *World Development Indicators*. (CD-ROM) Wash DC: World Bank.
- ⁶² Mokyr 2000; pp. 274, 291.
- ⁶³ World Bank 2002; United Nations *COMTRADE Database*.
- ⁶⁴ Grossman, Gene M and Elhanan Helpman. 1991; Dosi, Giovanni, Keith Pavitt, Luc Soete. 1990. *The Economics of Technical Change and International Trade* New York: New York University Press.

⁶⁵ Simple bivariate regressions of innovation on logged GDP per capita (as an alternate development measure) produced results nearly identical to those on logged electricity consumption per capita. For comparison, I further note the next highest R^2 's for the simple bivariate regressions of patents or publications are found on logged GDP (0.34) or democracy (0.39).

⁶⁶ According to Klein's rule, when an individual variable's VIF is greater than $1/(1-R^2)$ of the overall regression then problematic multicollinearity may exist. See Klein L *An Introduction to Econometrics*. Englewood Cliffs: Prentice Hall, 1962., Green, William H. *Econometric Analysis 4th Edition* (Prentice Hall, 2000) p. 257-258.

⁶⁷ Achen, Christopher H. 2000. Why Lagged Dependent Variables Can Suppress the Explanatory Power of Other Independent Variables. Paper Presented at the Annual Meeting of the Political Methodology Section of APSA 2000; Kelly, Nathan J. The Nature and Degree of Bias in Lagged Dependent Variable Models (unpublished mimeo); Keele Luke and Nathan J. Kelly. 2004. Dynamic Models for Dynamic Theories: The Ins and Outs of Lagged Dependent Variables.

⁶⁸ Gerschenkron, Alexander. 1962. *Economic Backwardness in Historical Perspective*. Cambridge, Belknap Press of Harvard University Press.

⁶⁹ The "wealthy" countries for the period starting 1975-1995 include: Austria, Belgium, Denmark, France, Japan, Kuwait, Netherlands, Sweden, Switzerland, United Arab Emirates, United States.

⁷⁰ Taylor Mark Z. 2004. "Empirical Evidence Against Varieties of Capitalism's Theory of Technological Innovation" *International Organization* 58 (3): 601-631.

⁷¹ EPO patent data obtained through the cooperation of Thomas Cusak, David Soskice, and Peter Hall. See also 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. New York, NY: Oxford University Press., p 42-43.