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Measuring and Modeling Trans-Border Patent Rewards

by

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ABSTRACT

Patent rewards in countries with strong patent systems and economies serve as world-wide inducements for technological progress. Due to the national treatment provisions of leading patent laws – requiring that foreign inventors be treated equally with inventors who are citizens of the countries enacting the laws – foreign inventors and companies gain access to patent-mediated market controls and commercial rewards in the world's strongest economies. The result is that the patent systems of our strongest economies such as the United States, Japan and the larger European Union countries serve as technology markets not only for inventors in those countries but around the world. Hence, inventors around the world (including in countries with substantively weak or poorly enforced patent laws) should look to patent filings and enforcement in the countries supporting the world's great economies for innovation rewards. Conversely, the parties in these economies can look to innovators around the world for new technologies, provided that the parties in the leading economies are willing to pay for those new technologies through patent enforcement in the major economies.

This article expands on this theme of trans-border technology flow and patent rewards through an empirical study of patenting in the United States by foreign inventors and companies. It treats such patenting as means for using United States markets and commercial gains to incentivize and reward foreign technology innovation. This study utilizes data on over 3 million United States utility patents to determine how domestic and foreign parties are using the United States patent system to gain controls over new technologies. The study compares the efficiency of various countries' economies (on a per Gross Domestic Product (GDP) basis) in generating new technologies patented in the United States and realizing associated patent rights and innovation rewards. While this study focuses exclusively on practices involving foreign innovators patenting in the United States, the patterns identified are indicative of the rewards that are probably also being sought by international innovators through similar patent rights obtained in other major economies such as those in Japan and the larger European Union countries.

The article also considers some of the normative implications of trans-border patenting as a strategic tool for companies and potential innovators in developing countries. It argues that

innovators in developing countries should not look primarily to their own patent laws – which may be weakened by poor drafting or enforcement – but rather to the patent laws and patent-mediated commercial gains of major economies like those in the United States. This view is not based on criticisms of the quality of laws or legal processes in developing countries – although there is reason to doubt the respect for the rule of law in many developing countries and to discount the value of intellectual property laws there accordingly. Rather, this desirability of looking to the patent laws in major economies is a consequence of economic realities. Even with the best of patent laws, the commercial rewards to be gained by patenting in a country with a small economy are limited by the size of that economy. For a country (or even a single foreign company) on the way up in economic development, the optimal approach is to produce new technologies that are of interest in a large economy such as that in the United States and then to gain patent rights that ensure rewards commensurate with the importance of the new technologies in that larger economy. In short, the United States is the big ticket (along with several other large economies) and international technology development should focus first on United States patenting and patent enforcement.

I. Introduction

Technology transfers and controls through multi-country patenting of key technologies are increasingly common. Such practices help innovators to realize the full commercial value of these technologies worldwide and to increase associated innovation rewards. A successful program of international patenting regarding a particular invention should respond tactically to the national scope of patent laws. That is, an international patenting program should be based on the notion that patents in a particular country like the United States will control the use of an invention in that country and produce associated rewards from the markets and economy in that country.

A commercially significant technology will ideally be patented and controlled in most of the countries where sales and use of products incorporating the technology will have substantial commercial value. Families of patents should produce patent controls aimed at key markets regardless of the sources of the technologies involved. Even the smallest countries can produce commercially significant inventions by using the patent laws of foreign countries like the United States to produce commercial returns. Indeed, contrary to the assertions of some commentators, the encouragement of technology research in developing countries may have less to do with the strength or enforcement of patent rights in those countries than it does with the effectiveness with which technology originators in those countries use the patent laws of the United States and other developed countries with major markets.

Seen as the entre to market controls in some of the biggest world economies (such as those in the United States, Japan and the European Union countries), patents in a few specific countries may produce large commercial rewards regardless of whether patents are pursued elsewhere. Market control and large economies are the key to rewards; patents in counties with weaker economies may have little impact on commercial rewards and be rationally ignored in an overall patenting program (except insofar as patents are needed in smaller countries to prevent copying or illegal manufacturing of patented products that will leak over into larger economies and undercut patent rewards in the large economies).

This article will analyze the use of patent laws in one large market to reward technological innovation elsewhere. It will focus on a particular type of trans-border technology flow: the flow of new technologies into the United States as reflected in United States utility patents involving foreign inventors. These patents are taken as efforts by foreign parties – usually the companies employing the inventors of the patented inventions – to use patents and patent rights in the United States to establish large-scale market controls in the United States and to gain rewards for innovations produced elsewhere. These studies permit conclusions about countries with smaller economies – such as Switzerland, Taiwan, and Korea – that appear to be already using United States patent rights to gain substantial United States payments and rewards for new technologies developed in these foreign countries. As case studies in the development of particular technologies to produce international benefits and rewards, these countries may illustrate useful paths for future technological progress by developing countries. In addition, by furthering our understanding of sources of new technologies patented in the United States, these studies also provide new information on the present external sources of new technologies entering the United States and on the types of foreign concerns that may have substantial future control of key United States markets due to patent rights over valuable technologies.

By looking to United States patent laws (and those of other developed countries) for innovation rewards, an optimal worldwide patenting and patent rewards system for innovators in smaller countries can serve as an important driver for technological innovation where IP laws domestically may be weakly framed or enforced. A worldwide perspective focusing primarily on patents in the larger economic markets such as the United States, Japan and the European Union can incentivize and reward innovation worldwide, creating a practical worldwide patent reward system. This may also provide worldwide incentives for the development of certain patentable subject matters, such as innovative software products, that are only protected by some patent systems (as in the United States) and are not rewarded and incentivized under the laws of many countries.

An international system of patent rewards like this will at once depend primarily on the relatively stable laws and legal systems of developed countries with large commercial markets and can be implemented largely by careful planning and procedures for patent application filings by foreign innovators without substantial efforts by their home country officials or legal systems. Such a system, if implemented in connection with research in a particular foreign country, might not only bring additional research rewards to successful innovators in that country, it might also bring foreign investment to those countries that have the best researchers in a given field or that have some other advantage in conducting a particular type of research over other venues for similar research elsewhere in the world.

II. Reasons to Study Foreign Sources of United States Patenting

A. It's the Markets – Lessons for Developing Countries in the Secondary Importance of Home Country Patent Laws

Analyses of foreign sources of United States patenting are worthwhile in part because United States markets – and the payments for new technologies derived from those markets through patent rights – are the largest and most important source of rewards and incentives for technological advances worldwide. A party anywhere can benefit from United States patenting and seek substantial compensation through the enforcement of patent rights and the realization of licensing revenues or the charging of patent-influenced product prices. These rewards can influence and subsidize technological development anywhere. In essence, the United States is a key market for new technologies from around the world, with payoffs achieved through United States patenting and patent enforcement. This view of United States markets as sources of technology development rewards to the world has several implications for new technology development programs in developing countries.

Many commentators have mistakenly viewed the strength of patent and other IP laws in developing countries as key determiners of technological progress in those countries. If only, this view argues, patent laws were strengthened and regularly enforced in country X, the levels of technological research and development in country X would be incentivized and increased materially. This view is misleading in at least four respects.

First, even if a country had strongly drafted and comprehensively enforced patent laws, the scope of patent-influenced revenues and rewards that an originator of new technology in that country might obtain from local patent enforcement concerning the small stream of commercial transactions in the developing country would be dwarfed by the comparable patent-influenced revenues available in the United States. This is simply a consequence of the size of the economies involved. The enforcement of patent rights typically produces rewards as products or services incorporating patented inventions are sold. Smaller sales (as would occur in a developing economy as opposed to in the United States) produce smaller rewards. In addition, the patent rights of some countries may cover a narrower range of subject matters as patentable inventions, thereby further curtailing the range of invention rewards and incentives that can be obtained in these foreign systems relative to the rewards in the United States.

Second, it is still the reality in many developed countries that laws on the books are poorly enforced, meaning that the meager promise of patent rewards through home country enforcement in country X are probably an illusion. At least the projected net revenues to be obtained by an inventor in country X from commercial development of his or her invention in country X must be discounted by the chances that the invention involved will simply be copied without compensation due to poor patent enforcement in country X and that the inventor involved will gain little or nothing from enforcement in country X. This contrasts with the relatively strong legal system in the United States and the potential for substantial damage recoveries and other remedies from enforcement of patent rights in the United States.

Third, the focus of small country patent law improvement on the potential for new levels of original technology development there obscures the real reason that some developing countries will want to strengthen their patent and other IP laws. Parties with new technologies developed elsewhere may be unwilling to establish large scale manufacturing or distribution activities for products in countries where the new technology may be subject to unauthorized copying and "leakage" to others in the country. The result of such leakage may be unauthorized manufacturing and distribution into other countries with large markets, thereby undercutting patent rewards in those countries. For example, country X may wish to strengthen its patent laws and enforcement because it wishes to expand its manufacturing of high-tech products and to induce in-bound transfers of technologies and investment to support such manufacturing. Strong patent rights and enforcement in country X may induce outside technology developers to seek patents there as a means to police later manufacturing of the patented technology. Patent rights enhancement for this reason may indeed benefit country X, but because manufacturing there will be aided and enhanced, not because more technologies are likely to be produced in country X. Keeping this rational straight may influence how patent rights are drafted and enforced in countries emphasizing manufacturing (for example, placing a premium on licensing provisions and the obligations of licenses to maintain control over patent-protected technologies). Understanding this rational also suggests that even it will not justify strong patent rights and enforcement in countries that lack the workforces or other resources needed to follow through on substantial manufacturing programs.

Fourth, the primary beneficiaries of stronger patent rights in some developed countries may not be parties in those countries at all, but rather technology developers and rights holders in developed countries that are trying to plug technology leaks and prevent widespread technology copying that will undercut large patent rewards for the rights holders. This strategy will help rights holders in developing countries but may raise prices and limit access to new technologies in the developing countries that strongly enforce patent rights. Thus, stronger patent enforcement in country X may just raise the prices for products incorporating a patented feature in that country (thereby limiting access to that product) and transfer the increased revenues gained from these higher prices back to rights holders in developed countries who have gained and enforced patent rights in country X. The real stakeholders and beneficiaries in strong patent rights in developing countries may be the outsiders who produce new technologies and who stand to obtain and gain from enhanced patent rights in country X. This may actually suggest that country X (if it cannot rely on the increased manufacturing logic just described) may actually benefit from weak patent laws and widespread copying and access to patented inventions.

For these various reasons, parties in developing countries may wish to give their own patent rights secondary attention and place more emphasis on the aggressive use of foreign patent rights (such as United States patent rights) to incentivize and support new technology development in the developing countries. Studying how some small countries have already made this use of United States laws should provide valuable lessons on how developing countries can do the same thing in the future.

B. Analyzing Specialized Sources of Technologies – Multiple Country Case Studies

The track records of particular foreign countries in seeking and benefitting from United States patent rights can also provide multiple case studies in how to develop and commercialize technological strengths in particular regions and localities. Recent studies of research communities have emphasized the importance of physical proximity among researchers in producing successful research and inventive results. By studying the track records of various foreign communities in producing technologies that have qualified for United States patents, we can identify particular geographic communities that have been particularly successful in producing specific types of technologies on an efficient basis.

Each of the countries identified as a significant source of United States patents can be treated as a case study in technology production. By adjusting (that is, normalizing) the size of patent outputs of various countries by measures of economic power and commercial activity (such as by dividing the number of patents for each country by the Gross Economic Product (GDP) for that country), we can treat the various countries supplying patented technologies to the United States as relatively equal sources of patented technologies and compare their track records and technology production efficiencies. This approach effectively treats countries with large and small economies as equally likely sources of new technologies per dollar of economy and then looks to how well various countries have followed through on this promise. This permits comparisons of efficiency in producing patented advances. It also assists with the identification of concentrations of especially effective progress in particular technology areas without the potential confounding effects of large patent volumes that simply reflect the large economy of the source country and the fact that large economies generally produce extensive research programs and large numbers of resulting patents.

By identifying countries that appear to be particularly efficient sources of new technologies (perhaps in only one technology area), further research regarding the practices in that country can be conducted to determine why researchers there are able to produce patented advances more effectively than elsewhere. These further studies should produce insights into research techniques and circumstances that will prove valuable to a wide range of researchers seeking to improve their efficiency and total production of new inventions.

C. Providing a Patent Protection Baseline for Protection Studies Elsewhere

Examining the patent protection practices of foreign parties filing for United States patents can establish a baseline for further studies of patent protection practices of the same parties in other major patent systems. The tendency of, say, German technology producers to seek protection in the United States can be compared to the degree to which the same parties seek protection in Japan and major European Union countries other than Germany. These studies may aid in determining the most prevalent patterns of patent coverage for different types of technologies.

D. Projecting Patent-Mediated External Control Over United States Trade

Examining the submissions of foreign parties of technologies qualifying for United States patents and patent rights can also provide interesting findings from the perspective of trade controls. Countries that are obtaining large numbers of patents in the United States (perhaps only in a few technology areas) stand to have major impacts in future commercial activities in the United States markets affected by the patent rights involved. Foreign companies that stake our particularly strong patent positions in particular markets with patents that cover strongly attractive product features will be in a position to gain large sales volumes (for products with features that cannot be offered by others). Consequently, these companies may not only be consumer favorites, they may also be highly powerful figures in dominating and controlling (at least to the extent of their patent rights) certain United States markets and trade practices. In short, extensive foreign patent rights – coupled with apparent efficiency in the production of those rights suggesting that the foreign parties involved will continue to generate similar United States patent positions in the future – may be a source of concern in limiting the competitiveness of United States markets and placing control over key United States products in foreign hands.

E. Extending the Trans-Border Model to Intra-Country Technology Development

Finally, although the emphasis in the discussion above has been on the importance of studying foreign inputs to United States patenting as a means to better understand technology production in smaller foreign countries, the lessons learned from these studies may also have regional importance for technology producers in both larger foreign countries and in the United States. To understand how these lessons may translate, assume that an assessment of the patenting practices of various foreign countries shows that inventors in country X have been particularly efficient (on a patents per GDP basis) in producing patented advances (as protected by United States patents) in a specific technology area. A careful study of the technology efforts in country X has identified several distinctive research practices or circumstances that seem to account for the country's success in the technology area. Other research communities may wish to consider these same techniques to further technology research generally (assuming that the circumstances or practices in country X are potentially applicable and translatable to all types of research) or to at least further research in the particular technology area emphasized in country X (assuming that the circumstances or techniques accounting for the success of research in country X are peculiar to one field of technology and associated research). In short, if technology development practices work particularly well in a relatively small economy like that in Switzerland (as later discussions in this article will describe), these same techniques may have similar value if replicated in regions or local areas of countries with larger economies.

Lessons from successful smaller countries and economies might be replicated in portions of both the United States and foreign countries. That is, if a technology development and patenting program from a particular country X can be identified as having produced a large number of patents on a per GDP basis, the practices involved may be ones that firms representing a fraction of the economy in a country with a larger economy may be able to replicate and similarly benefit from. Thus, techniques used by researchers in small country X to be particularly effective producers of patented technologies in a given technical field may assist research communities in a region of the United States or in a region of one of the major foreign sources of new technologies (such as Japan or Germany) to establish similar regional strengths in the same technical field and to produce similar United States patent filings and sources of rewards.

III. Empirical Evaluation of Foreign Inventor Patenting in the United States

A. Study Design

The empirical study described here focuses on the countries (including the United States for comparison purposes) that are the top ten sources of patented inventions covered by over 3 million United States utility patents (hereinafter "patents"). The patents involved stemmed from patent applications submitted in 1975 to 2002, reflecting inventions made in approximately those years. Patents were grouped by application years so as to compare relatively contemporaneous inventions and technology advancement processes in the various countries studied. The countries comprising the top ten sources of United States patents in the period of the study were Canada, France, Germany, Italy, Japan, Korea, Switzerland, Taiwan, the United Kingdom, and the United States. Table 1 summarizes the fraction of patents from these sources (as well as all of the additional countries supplying at least .1 percent of all United States patents during this period).

TABLE 1

Country	Patent Number	Percent
United States (US)	1341917	44.42
Japan (JP)	582854	19.3
Germany (DE)	184477	6.11
France (FR)	73090	2.42
United Kingdom (GB)	54005	1.79
Canada (CA)	36868	1.22
Korea (KR)	35073	1.16
Switzerland (CH)	32422	1.07
Italy (IT)	26250	0.87
Taiwan (TW)	26180	0.87
Sweden (SE)	22801	0.75
Netherlands (NL)	20536	0.68
Finland (FI)	11078	0.37
Australia (AU)	9421	0.31
Israel (IL)	7737	0.26
Belgium (BE)	7488	0.25
Denmark (DK)	6015	0.2
Austria (AT)	5881	0.19
Norway (NO)	3112	0.1
Total	3020639	100

These countries reflected the countries of the assignees (predominantly business corporations) of the patents recorded. The countries of the assignees were assumed for purposes of this study to be the same as the countries of the lead inventors of the patented inventions. An inspection of the patent records reflected that this assumption generally held true (that is, the number of patents for which inventors in one country assigned their patents to a party in another was very small). Patents that were not assigned were not included in the country-specific patent totals used in this study. Had the patents without assignees been included, they would probably have primarily increased the figures for inventions by United States inventors. The totals for inventors from foreign countries would have been largely unaffected as foreign individuals, acting with no financial backing of patent assignees, were unlikely to have pursued the extreme expense of a foreign patent filing in the United States on their own.

In the studies conducted here, the focus was on the number of inventions covered by United States patents that were produced by inventors in the countries analyzed (as listed above). The use of United States patent counts as the dependent variables and focuses of the analyses here had several advantages. First, it avoided any concerns about differences in patent law requirements or patent drafting strategies from country to country. All of the applicants who submitted the patent applications leading to the patents measured here were seeking to comply with the same United States laws regarding what is a patentable invention. All of their applications were assessed against the same United States patent laws for sufficiency in reviews by USPTO patent examiners before resulting in an issued patent and entering the data considered here. Hence, legal requirements and legally-influenced strategy choices should have exerted similar force on applicants from different countries, resulting in no country-specific biases in the data. Second, all of the applicants for patents here would have looked to the same range of later enforcement throughout the same United States economy to gauge the value of a United States patent and whether or not to seek such a patent. The range of commercial value for two similar types of inventions from different country sources would be the same as the inventors of both devices could seek the same United States patent regardless of what countries the two were located in. Hence, the same commercial value of the patents available would have influenced the parties, resulting in similar likelihoods of United States patent filings for rationally motivated inventors in various countries regardless of the actual countries of invention.

Each patent recorded in the data was treated as a reflection of one invention (nominally a requirement of United States patent laws). The study design implicitly treated the various inventions reflected in the data as of equal importance. While the inventions covered by all United States patents are clearly not all of equal importance in complexity, commercial value or societal importance, there is no reason to believe that the importance of inventions along any of these dimensions is correlated with country source. Hence, any differences in importance should be roughly equally distributed across the various countries studied and these differences should not affect the value of the findings here.

The data analyses proceeded in two stages. First, data visualizations of patent count data from 1975 to 2002 were prepared to assess the changes in patented invention production per GDP over time for the various countries studied. Substantially different patterns of invention production were found both across the countries studied and over time. Second, a linear regression model was developed and applied to assess the production of patents. The regression model was used to determine the impacts of economy size and other factors on the production of patented advances. United States patent counts per year for inventions from various countries were treated as dependant variable data (with the patent count for each country in a particular year treated as one data point). Separate counts were kept for each of the six technology types analyzed in this study, resulting in seven dependent variables (one for all patents and one each for the six technology categories). Several independent variables were used to control for differences from country to country in economy and population size. The effects of several other factors – such as variations in spending on research in the various countries over time and variations in the number of researchers over time) were determined though regression studies involving the seven dependent variables. Through these studies, it was possible to determine how these factors differentially affected the production of patented advances in the six technology areas scrutinized.

In these regression studies, data on United States patents from United States sources was not considered. The objective was to assess how foreign sources contributed to United States patenting and inclusion of domestic sources of similar patented technologies would have muddied the analyses with invention sources and patenting practices that were arguably responding to different forces and considerations than those affecting foreign inventors. In addition, data on patents from Taiwan were not included in these regression studies as data on many of the independent variable characteristics included in these studies were not gathered and reported by the Organization for Economic Co-operation and Development (OECD) in its assessments of country features (perhaps because of the disputed status of Taiwan as a separate country). Finally, as complete data on country characteristics were only available for years starting with 1981, the regression studies relied on patent count data from 1981 to 2002 (meaning that the data for 1975 to 1980 were not considered).

B. Data Sources

This study relies on data derived from United States utility patents issued from 1976 to 2006. The data was obtained from information on patented invention characteristics complied by the National Bureau of Economic Research (NBER).[1] This dataset includes information on patent application dates, issue dates, numbers of claims, patent assignee countries, and technology types.[2] The dataset used in the present study was released in 2010 and covers all patents issued from 1976 to 2006. This dataset updated a prior NBER dataset on patents granted

1 The present project relied on the pat76_06_ipc file within the NBER dataset. This file contains information on each patent issued from 1976 to 2006 and is available for downloading from the NBER website. *See* National Bureau of Economic Research, Patent Data Project Downloads, https://sites.google.com/site/patentdataproject/Home/downloads (last visited on 4/6/2012).

2 National Bureau of Economic Research, patn data description, https://sites.google.com/site/patentdataproject/Home/downloads/patn-data-description (last visited on 4/6/2012).

between 1963 and 1999. These datasets are the products of a long-standing project studying patent citation patterns and other aspects of patented inventions.[3]

The NBER dataset is particularly useful as it records NBER researchers' classifications of all patented inventions within six broad technology categories. The six categories were created by mapping 443 technology categories used by the USPTO to classify the primary technology area of each patented invention into the NBER's six technology categories.[4] The six technology categories include advances in the following areas: 1) chemical (excluding drugs), 2) computers and communication, 3) drugs and medical, 4) electrical and electronic, 5) mechanical, and 6) other technologies.[5]

The research design was tailored to avoid possible problems with truncation effects concerning patent applications submitted at the end of the period covered by the dataset. The dataset contained information on patents issued by the USPTO between 1976 and 2006. To ensure that roughly contemporaneous inventions were grouped for analysis in the present study, inventions were grouped and analyzed by the year of their patent applications. However, some of the patent applications submitted in the years immediately preceding 2006 were still being processed by the USPTO as of the end of 2006. Patents based on these applications still being processed at the end of 2006 do not appear in the dataset. Therefore, data on patents stemming from applications submitted in the years approaching 2006 were artificially cut off or "truncated" due to the absence of records in the dataset for patents issued after 2006. The solution to this

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3 The background and potential uses of the NBER patent data are described in Bronwyn H. Hall, Adam B. Jaffe, and Manuel Trajtenberg, *The NBER Patent Citations Data File: Lessons, Insights, and Methodological Tools*, http://elsa.berkeley.edu/~bhhall/pat/NBERpatdata.pdf (last visited on 4/6/2012).

4 These six technology categories were defined and used by NBER researchers for earlier studies of patent citation patterns. The six categories group together multiple USPTO primary technology classes in each of the NBER categories. The USPTO classifies the technology involved in every patent application as part of processing that application. Each patent is assigned a primary technology class code that reflects the primary field of the invention covered by the patent. A patent may also be assigned additional technology class codes if an invention involves advances in multiple fields. These technology categories and codes are used by the USPTO to aid patent examiners and others in finding relevant patents when researching advances in particular technology fields. Because research tasks and efforts to properly classify patents to support such research are important to the USPTO, this technology classification system is the object of considerable efforts and care on the part of USPTO personnel.

The six technology categories used by the NBER (and relied on in the present study) are determined directly from USPTO classes. Several USPTO technology classes are mapped into each of the six NBER technology categories. Information on the mappings of the USPTO technology classes into the NBER technologies categories (including which NBER category includes each of the USPTO classes) is available in NBER, *classification_06,* https://sites.google.com/site/patentdataproject/Home/downloads/patn-data-description/classification_06.xls?attredirects=0&d=1 (last visited 4/6/2012).

5 The "other technologies" category contains a very diverse mixture of invention types, with advances ranging from textiles to toilets. Hence, conclusions based on patent records grouped in this category may have limited value as the inventions being assessed varied vastly in types and inventive environments. *See id.*

problem was to include in this study only data on patents applied for in the years 1975 to 2002 (on the ground that analyses of the data showed clear truncation effects for patents applied for in years later than 2002, meaning that data for these patents could not reliably be compared to the more complete data for patents applied for earlier). Data on patents applied for in 1975 were included in the study because most of the resulting patents were issued in 1976 and after and were therefore recorded in the dataset.

C. Initial Data Visualization Studies of Innovation Efficiency

The analyses in this phase of the project involved using data visualization software (Tableau Public 7.0) to generate displays reflecting the relative efficiency of the ten countries under study as sources of patented advances. In addition, an eleventh data value representing the invention production of the rest of the world other than the ten countries under study was included in each of the evaluations (with the label of Other or "OT").

1. All Inventions

Figure 1 reflects the production of patented advances in 1975 from the indicated countries. The vertical axis in this graph reflects the number of patents from each country divided by the GDP for that country. This value is a measure of the efficiency of invention production per GDP dollar. A higher point reflects greater invention generation efficiency than a lower point. The horizontal axis reflects the raw GDP value for each country displayed on a logarithmic scale to better spread the values for countries (from Switzerland to the United States) varying substantially in GDP. Higher GDPs are potted to the right along this axis. The size of the marks plotted along these vertical and horizontal axes reflects the count of patents resulting from inventions in each country. A bigger dot means that the country involved accounted for more patented inventions than a country with a smaller dot.

Figure 2 reflects the same type of display for the production of inventions in 2002. By comparing these two displays, the substantial changes in invention production efficiency (as reflected in the rise or fall of individual country dots) can easily be seen. To make these changes more clearly apparent (and to record the year-by-year changes that account for the change from 1975 to 2002, Figure 3 displays the 2002 data with history "tails" that track how the country dots moved through the chart as the data moved year-by-year from their 1975 values to their 2002 values. This type of display directly records the substantial changes in invention productivity over time.

FIGURE 1
All Patents 1975

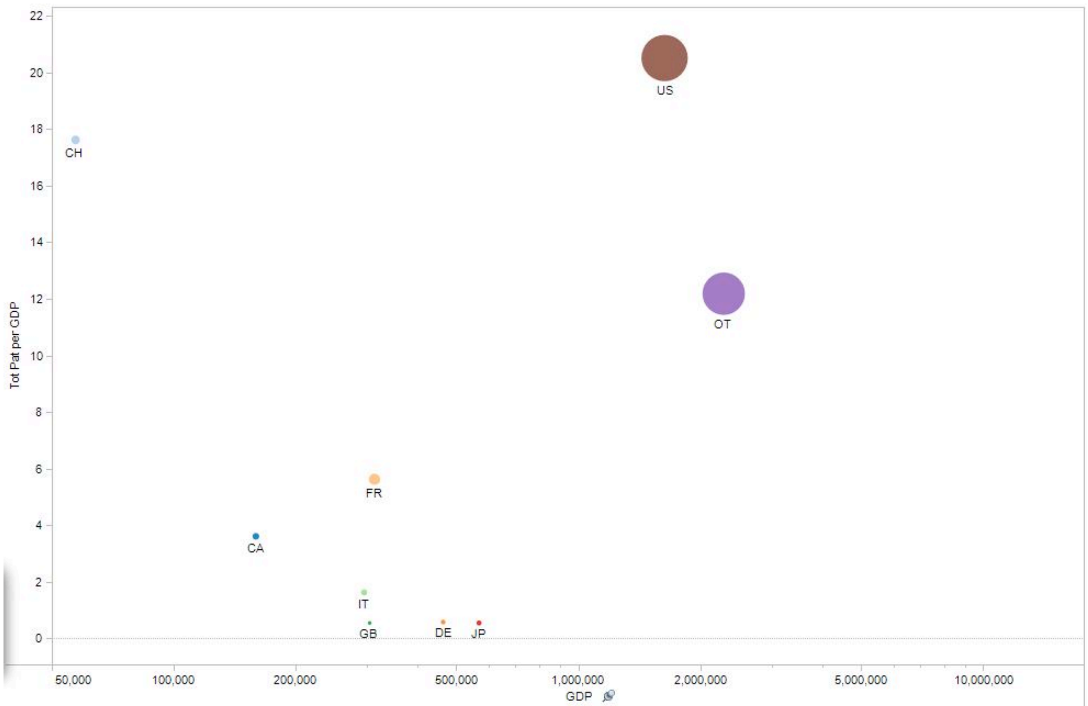


FIGURE 2
All Patents 2002

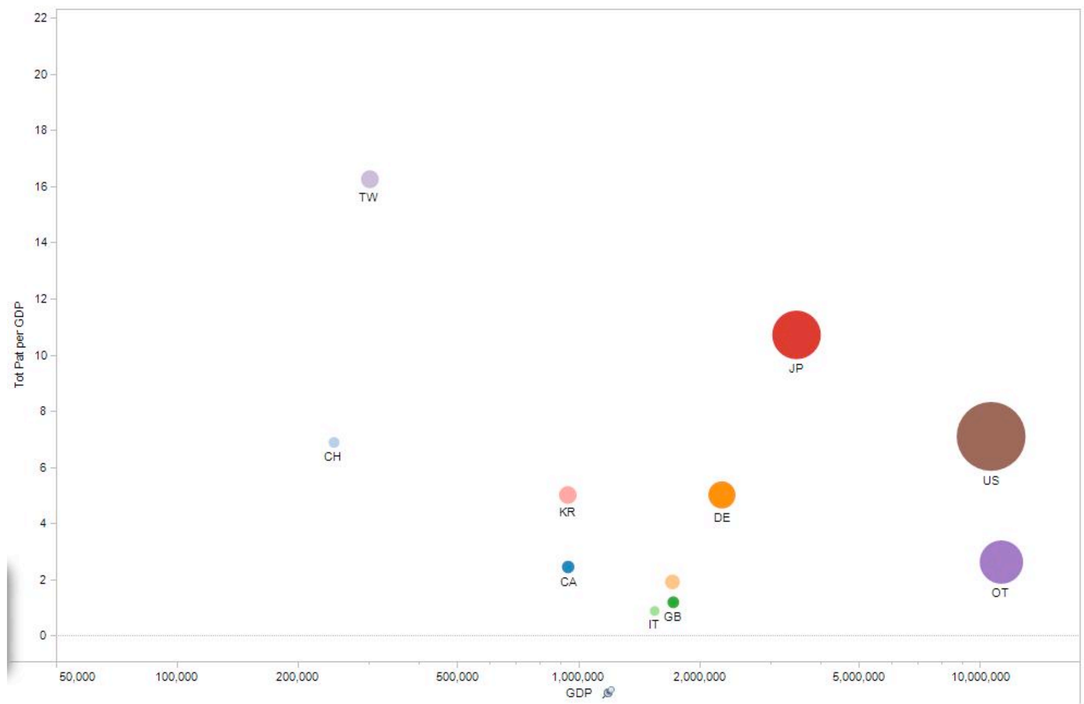
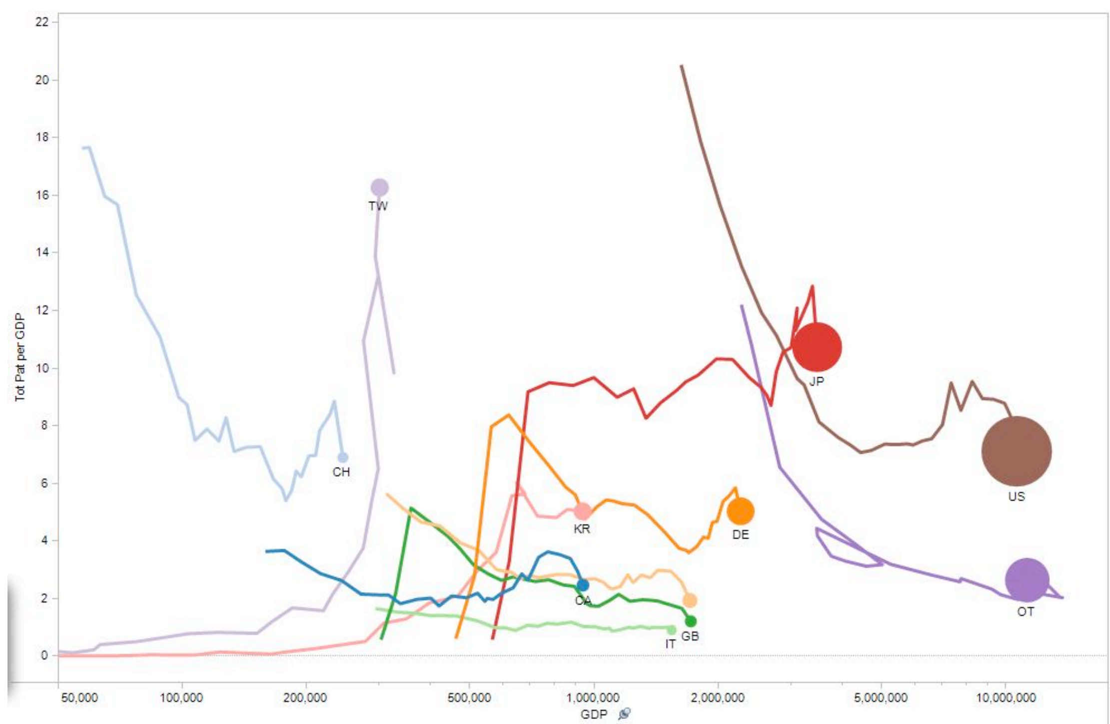


FIGURE 3
All Patents 2002 w/ History



The histories of patent production reflected in Figure 3 support several interesting findings. First, the efficiency of invention production by United States inventors (as recorded in the brown dot and history trail) seems to have gone down substantially. There is a substantial case here for the conclusion that there are not enough patented advances being produced in recent years relative to the United States own per GDP prior production. Innovation in this country may be weakening over time when the evolution of our GDP is taken into account.

Second, the production of several other countries does not seem to have reflected a similar drop. The production of advances by innovators in Japan (red) and Germany (orange) produced relatively flat lines over several years (meaning that the number of advances produced in these countries grew at about the same pace as their economies in these years). Again, there is reason to be concerned about the technology generation reductions in the United States because some of our primary competitors have not experienced similar reductions but rather have grown their production of protected technologies along with their economies.

Third, there are some countries that appear to have maintained (at least in some years) substantially higher levels of invention production efficiency than innovators in the United States. Early in the years covered by this figure Switzerland (light blue) showed invention production efficiency that was much higher than the United States present production (as indicated by the higher position of the left-most portions of the history tail for Switzerland in the chart than the dot reflecting the United States efficiency level in 2002). Later in the period studied, innovators in Taiwan (light purple) rapidly increased their efficiency of invention production as reflected in the much higher position of that country's dot for 2002 relative to the similar dot for the United States in 2002.

Fourth, the invention efficiency levels for most countries addressed in this figure are remarkably low across all years of the study. The low levels for several European countries, including France (beige), the United Kingdom (dark green) and Italy (light green) are substantially lower than Germany despite their geographic proximity and similar access to European Union resources. Two other countries stand out as being relatively high in their invention production efficiency. Canada (dark blue) demonstrated similar invention production efficiency to France despite having a much smaller economy. This success by Canadian innovators may reflect some advantages of physical proximity to United States innovators or commercial resources. The upward movement of innovation efficiency in Korea (light pink) brought it to levels similar to Japan and the United States although there has apparently been a drop off in recent years. Even with this drop off, Korea matched the innovation efficiency of Germany in 2002.

The results displayed in the above figures illustrate some differences in the overall technology development patterns during the years of this study, but raise the possibility that the changes reflect different mixes of technologies under development in the years studied and different efficiencies in overall invention production due to these changes in the subject matters of the inventions leading to the patents being measured. To reduce the potential effects of changes in the technologies being produced over time, the production efficiency changes for particular countries were evaluated for each of the six technology categories recorded in the

NBER dataset. This approach also permitted technology-specific changes in innovation efficiency to be evaluated. The results of these technology-specific analyses are presented in next six sets of figures displayed and discussed below.

2. Chemical Inventions

Figure 4 plots chemical invention production data for the countries under study in 2002. The vertical axis, horizontal axis, and dot size characteristics are the same as in the prior figures except that the values reflect only inventions in the chemical technology category. Figure 5 includes the history tails tracking the development of chemical invention efficiency levels over the period of the study from 1975 to 2002.

FIGURE 4
Chemical Patents 2002

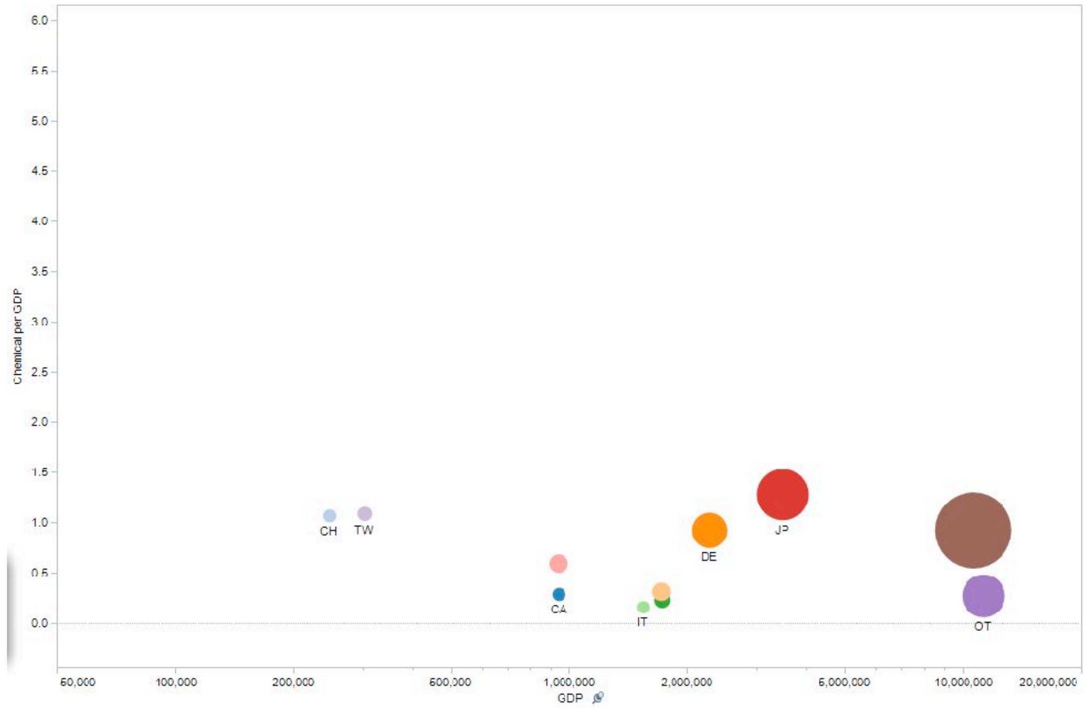
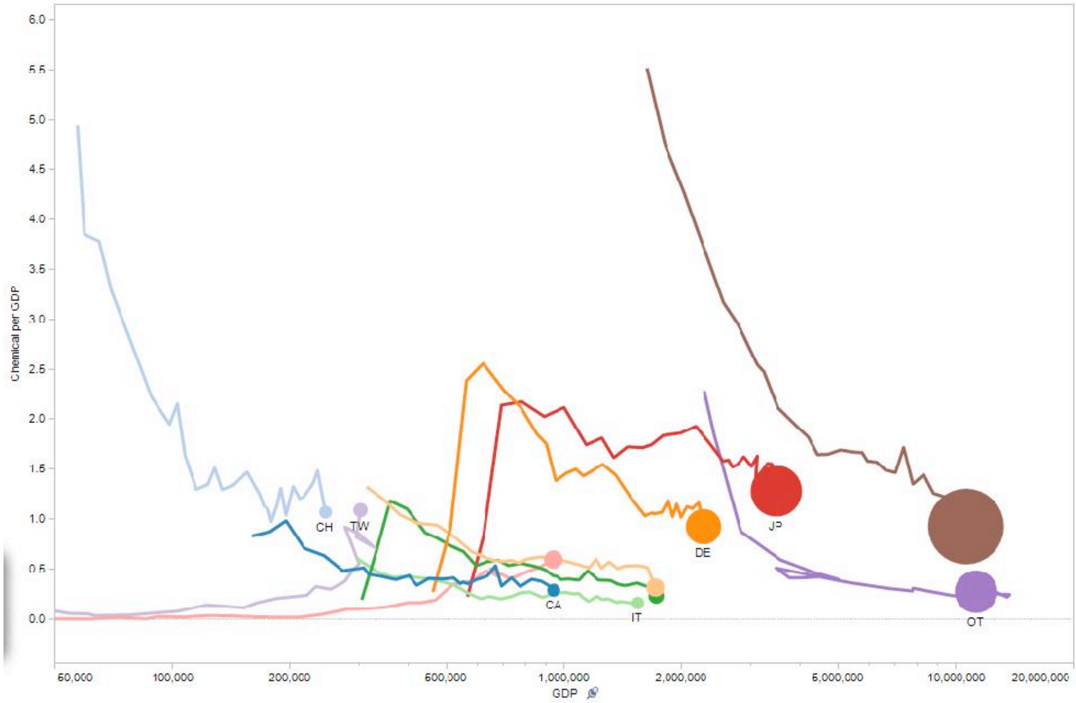


FIGURE 5
Chemical Patents 2002 w/ History



One striking feature of the data shown in these figures is the significant drop over the period of the study in the production of chemical inventions in many of the countries assessed. One a per GDP basis, Switzerland and the United States (the most efficient producers at the beginning of the study) drop substantially. Other major producers of chemical patents such as Japan and Germany also dropped from their highest levels although less rapidly. At the end of the period, several countries (including Switzerland, Taiwan, Germany, Japan and the United States were producing new patented chemical advances at about the same rate on a per GDP basis. The rates in the other countries under study were much lower (at less than half the levels for the United States).

The similarity in 2002 of the chemical invention production efficiencies in Switzerland, Taiwan, Germany, Japan and the United States suggests that innovators in the United States were basically keeping up and holding their own in the production of chemical advances at the end of the study. However, the large drop in production efficiency from earlier periods is troubling in that it suggests that much higher levels of invention production efficiency were once common in United States firms. Further studies of practices and challenges in the field of chemical product innovation will be needed to determine why United States (and Swiss) production levels dropped so substantially over the years of this study. The aim for United States innovators concerning chemical advances is to consider what has changed in inventive resources, methods, and challenges in chemical fields since the 1970s and to determine whether it is possible to move United States back to increased invention efficiencies on a per GDP basis of the sort that were prevalent for United States researchers in these earlier "glory days" for chemical research and patented invention production.

3. Computer and Communication Inventions

Figures 6 and 7 present efficiency data on the production of patented inventions in the computer and communication fields.

FIGURE 6

Computer and Communications Patents 2002

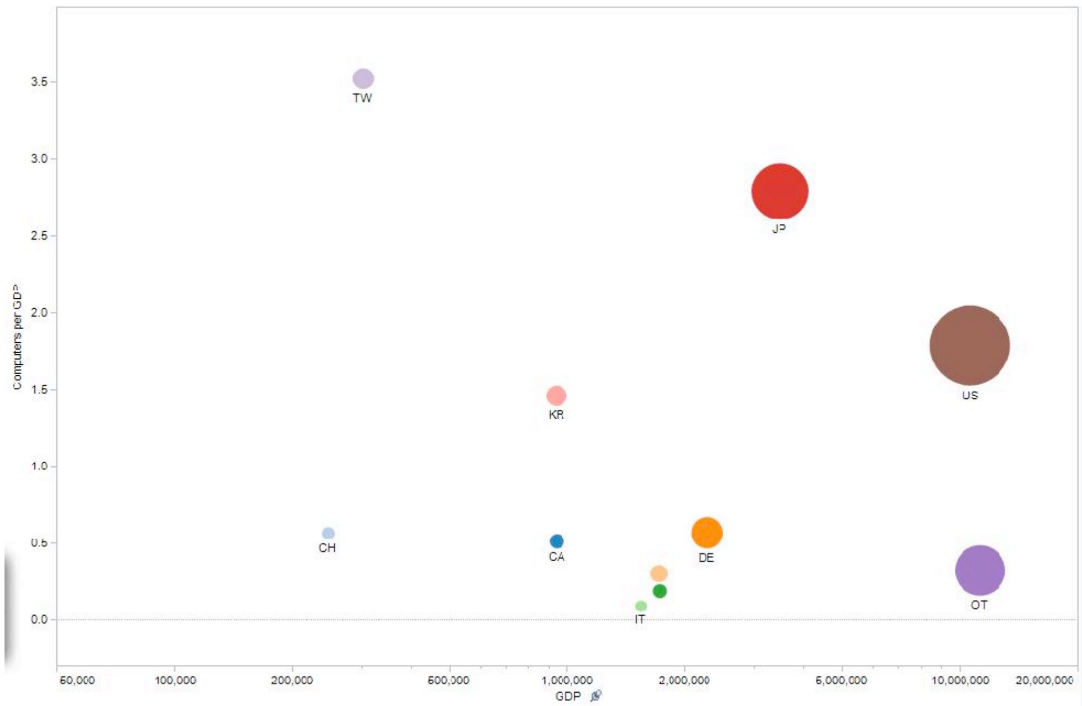
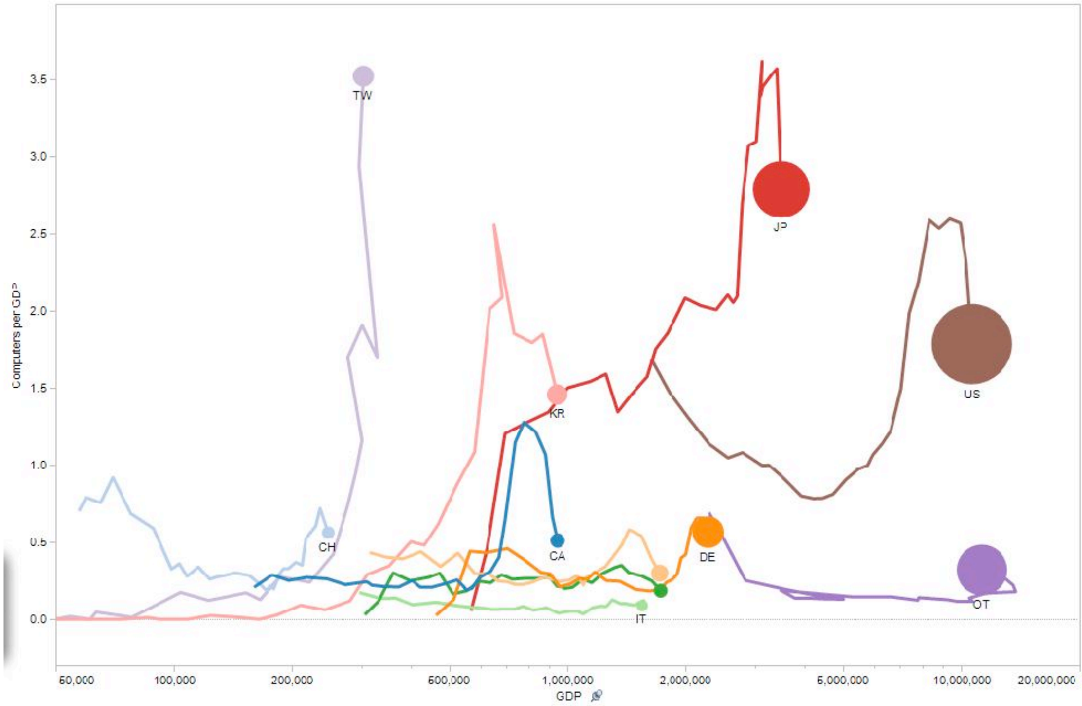


FIGURE 7

Computer and Communications Patents 2002 w/ History



Invention development patterns in these fields reflect rapid rises in efficiency in some countries. Taiwan, Korea, Canada, Japan and the United States showed big jumps in their production of patented advances during the period of the study (although production efficiency in all of these countries other than Taiwan subsequently dropped towards the end of the study. These widespread increases suggest innovation trends that were driven more by technology characteristics or commercial market potential that would have driven and expanded innovation in diverse geographies. The ability of innovators in multiple countries to respond to these forces and to rapidly increase their production of patented advances concerning computer and communication devices and processes suggests the inputs and facilitators of research in these areas may be relatively easily transferable and applicable regardless of variations in local workforces or other conditions. However, the lack of similar increases in the efficiency of computer and communication invention production in the European countries included in the study is a puzzling feature, suggesting that there are geographically-linked characteristics that hinder computer and communication innovation in these countries.

At the end of the study period, innovators in the United States were being out produced on a per GDP basis in the computer field by their counterparts in Taiwan and Japan and were only roughly equal to counterparts in Korea. To stay ahead in these highly important commercial fields for the future, United States firms and innovators should pursue invention track records that are at least as productive as their counterparts in other countries. This means some substantial learning from Taiwanese and Japanese innovators and corresponding improvements in United States invention programs concerning computer and communication advances. There are simply too few patented advances emerging in these fields from United States sources given the increasing strength of the United States economy.

4. Drugs and Medical Inventions

Productivity data for inventions in the drugs and medical fields are displayed in Figures 8 and 9.

FIGURE 8
Drugs and Medical Patents 2002

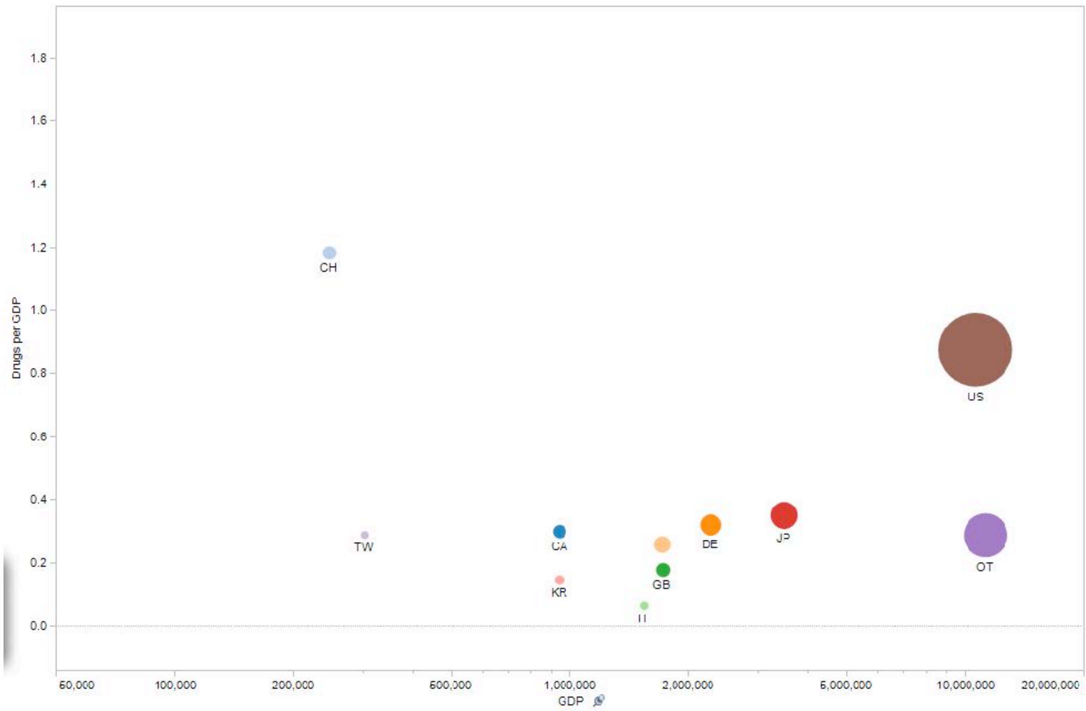
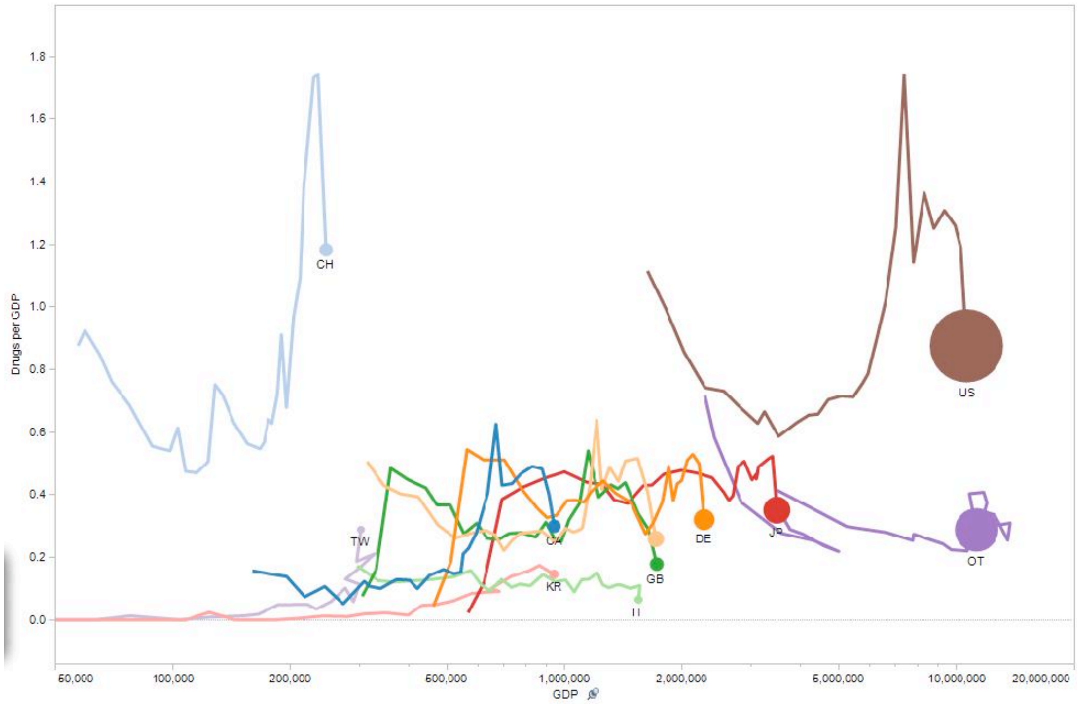


FIGURE 9
Drugs and Medical Patents 2002 w/ History



The data reflected in these figures show yet another pattern of technological development. For drugs and medical advances, innovators in Switzerland and the United States showed substantially higher efficiency in producing patented inventions than innovators anywhere else in the countries under study. The efficiency of innovators in these two countries rose dramatically during the middle of this study (suggesting some common practices or innovation drivers affecting research in these two countries), but fell during the last few years. Surprisingly, production efficiencies in most other countries were relatively low and constant during the period of the study. Why innovators in none of the other major technology producing countries (such as Japan and German) were not able to make use of the same invention-facilitating practices as spurred medical and drug research in the United States and Switzerland is a major question for future evaluation raised by the findings of this study.

Advances concerning drugs and medical inventions represent a bright spot for the United States in the overall mix of technologies addressed in this study. The United States is by far the most efficient producer of patented inventions in these areas, with the exception of Switzerland which is even more efficient but which accounted for only a small fraction of the number of patented advances as did the United States. The techniques used by the Swiss to achieve even higher efficiencies than United States researchers may be worth study to help adjust United States levels to even higher efficiencies matching those which the Swiss have already achieved. However, in general, researchers in the United States and Switzerland are the leaders in these fields of research and innovators in other countries should learn from these leaders to raise their respective levels of innovation efficiency regarding patented advances in the drugs and medical fields.

5. Electrical and Electronic Inventions

Figures 10 and 11 describe the country-specific efficiencies in the production of electrical and electronic inventions.

FIGURE 10
Electrical and Electronic Patents 2002

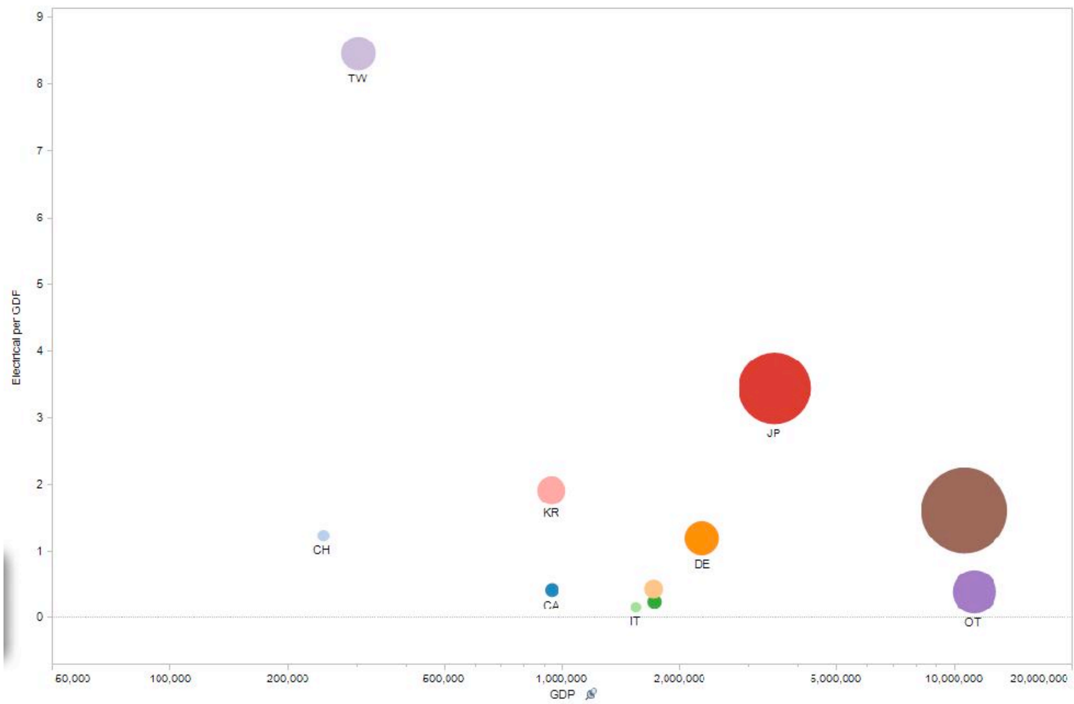
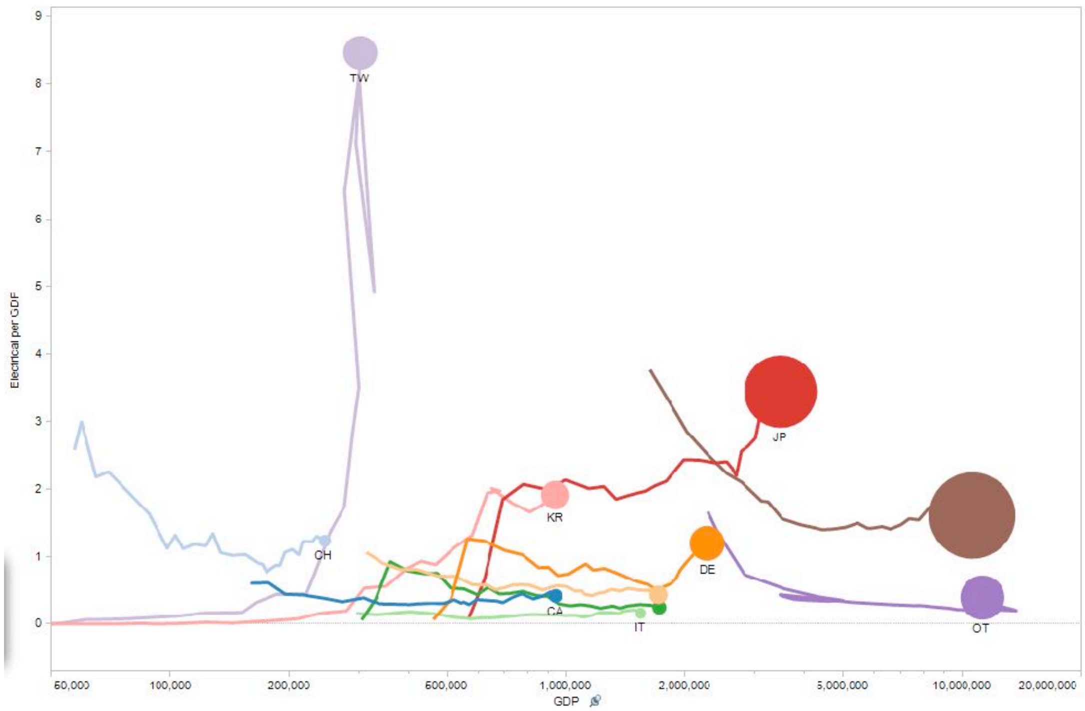


FIGURE 11
Electrical and Electronic Patents 2002 w/ History



These figures point up the great success (and rapid increases in efficiency) that innovators in Taiwan have been able to achieve in recent years. Taiwanese innovators have realized a much higher level of efficiency of patented invention production than innovators in any other country at any time during the period of the study. Other countries – notably Japan and Korea – increased their invention production efficiency rapidly at certain points in the study period, but stayed at relative flat levels near the end of the study period (which still meant that their increases in invention production were keeping up in proportion to their increases in economy size). The United States, by contrast, showed a marked drop in invention efficiency, ending up the period at about the same levels per GDP as the other major producers in these fields (i.e., Japan, Korea, and Germany). The remaining European countries in the study and Canada were never large producers of advances in this field and did not realize the same type of growth seen by the other countries just mentioned.

The reasons why innovators in Germany were able to increase the efficiency of their production of patented advances concerning electrical and electronic inventions when nearby innovators in France, Great Britain, and Italy achieved no parallel increases would be interesting to determine. The reasons for Germany's particular success in these fields may suggest research techniques or environments that other countries can use to enhance their methods for technology development and achieve greater efficiency and success than similarly situated nearby economies.

Interpreted from a United States perspective, these figures raise questions about the sufficiency of United States production of patented advances in the electrical and electronic fields in recent years. On a per GDP basis, Taiwanese and (to a lesser extent) Japanese innovators seem to be substantially more productive than their American counterparts. The Koreans and the Germans, with much smaller economies, are about our equals in the rate of production of advances in the electrical and electronic fields. The reasons for the drops in efficiency in United States research and for the ascendency of these other countries in rates of inventions produced per GDP deserve further study and attention.

6. Mechanical Inventions

Mechanical inventions – arguably the simplest type of technology addressed in this study – had production efficiency levels shown in Figures 12 and 13.

FIGURE 12
Mechanical Patents 2002

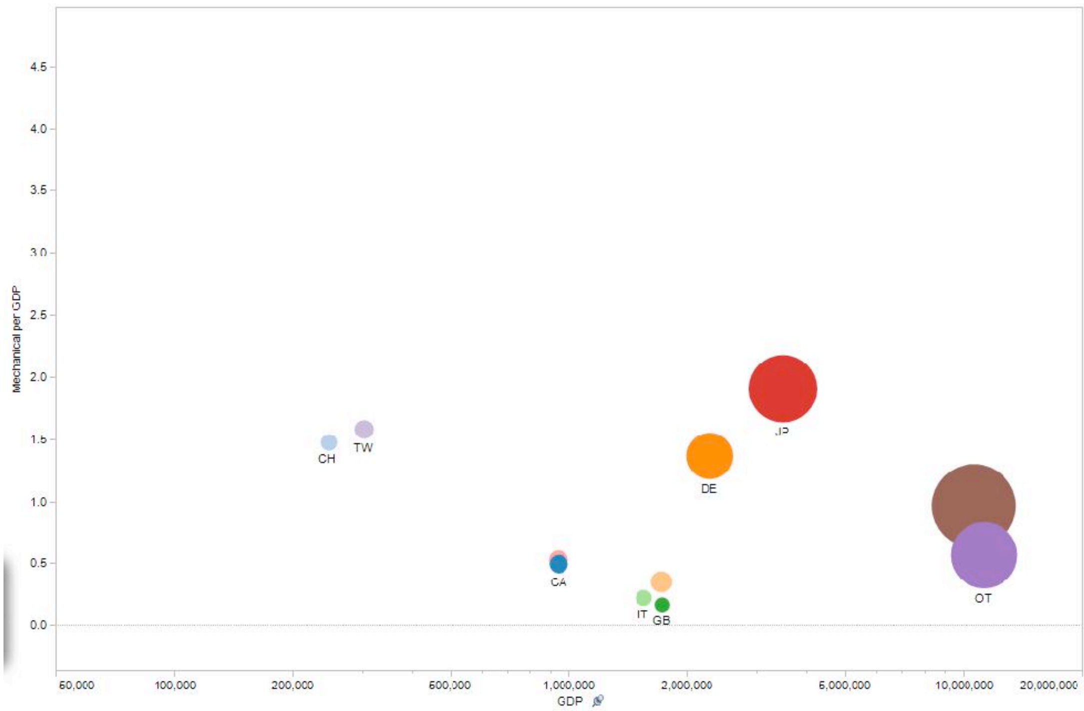
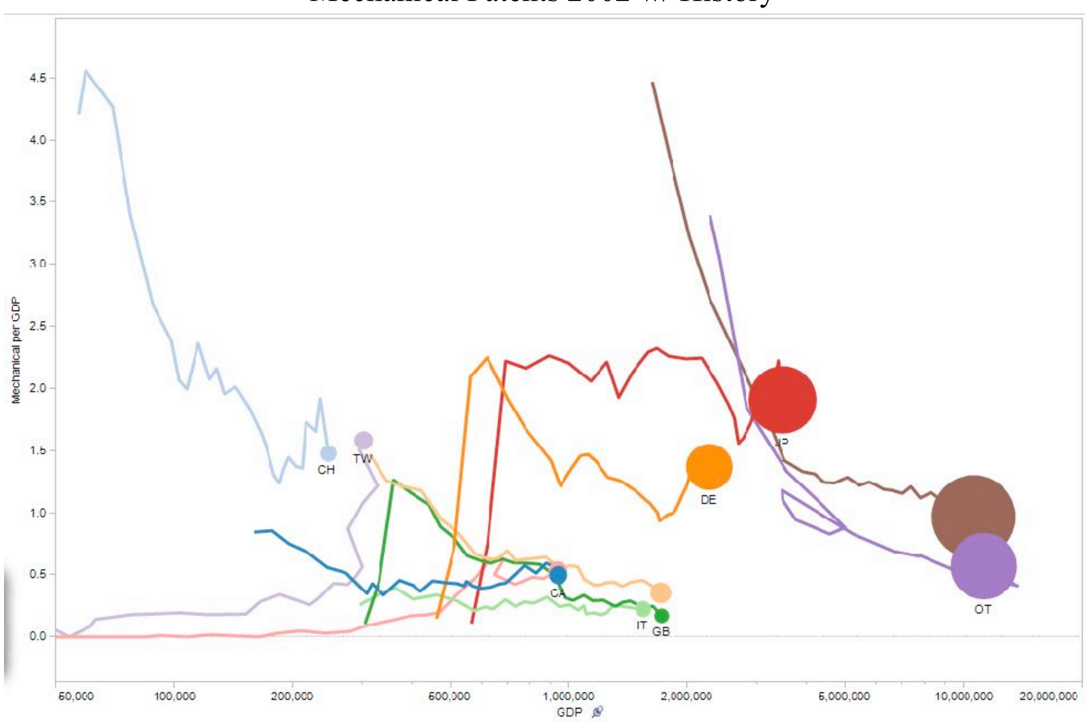


FIGURE 13
Mechanical Patents 2002 w/ History



The most remarkable finding that these figures support is that the United States is again bested in invention production efficiency as of 2002 by innovators in several other countries. United States' innovation efficiency regarding mechanical inventions, while starting the period of the study at a high level (matched only for much smaller invention volumes by innovators in Switzerland), dropped markedly during the period of the study. In this same interval, innovators in Japan and Germany were able to increase their invention efficiency regarding mechanical inventions and then to hold their efficiency at relatively constant levels over the period of the study even as the economies of these countries grew (which means that they were producing more mechanical inventions in proportion to the growth in their economies). Innovators in Taiwan were able to markedly increase their production of mechanical inventions late in the study period to bring their efforts up to about the invention efficiency level where United States innovators ended the period.

The ability of innovators in other countries to support higher levels of invention production per GDP (as well as the ability of United States' innovators to support higher levels prior to 2002) suggests that, as with some prior areas of technology, United States technologists and policy makers should be concerned by the low numbers of mechanical innovations and patents emerging from research in this country. We are, put simply, not keeping up with the Japanese, Germans, and others in producing mechanical inventions at rates commensurate with the size of the United States economy.

6. Other Technology Inventions

The final two sets of data visualizations presented in Figures 14 and 15 concern a group of miscellaneous technologies (recorded here as the "Other Technology" category). This technology category basically contains all of the types of technologies left over when inventions in the other five, more specific categories are removed from United States patent records. Because this Other Technology category contains highly diverse types of technologies emerging from what are likely to have been highly diverse research personnel, resources, and settings, it is difficult to draw many conclusions about the trends seen in the data on Other Technology patents and inventions. One possible way to think of the results for this mixed technology category is that these reflect forces and changes across diverse technologies, which may be generally applicable trends on top of which other technology-specific changes worked additional increases or decreases. In this way, the changes seen for other technology advances may be thought of as indicative of foundational changes in invention efficiencies, from which the size of changes in other technologies can be measured.

FIGURE 14
Other Technology Patents 2002

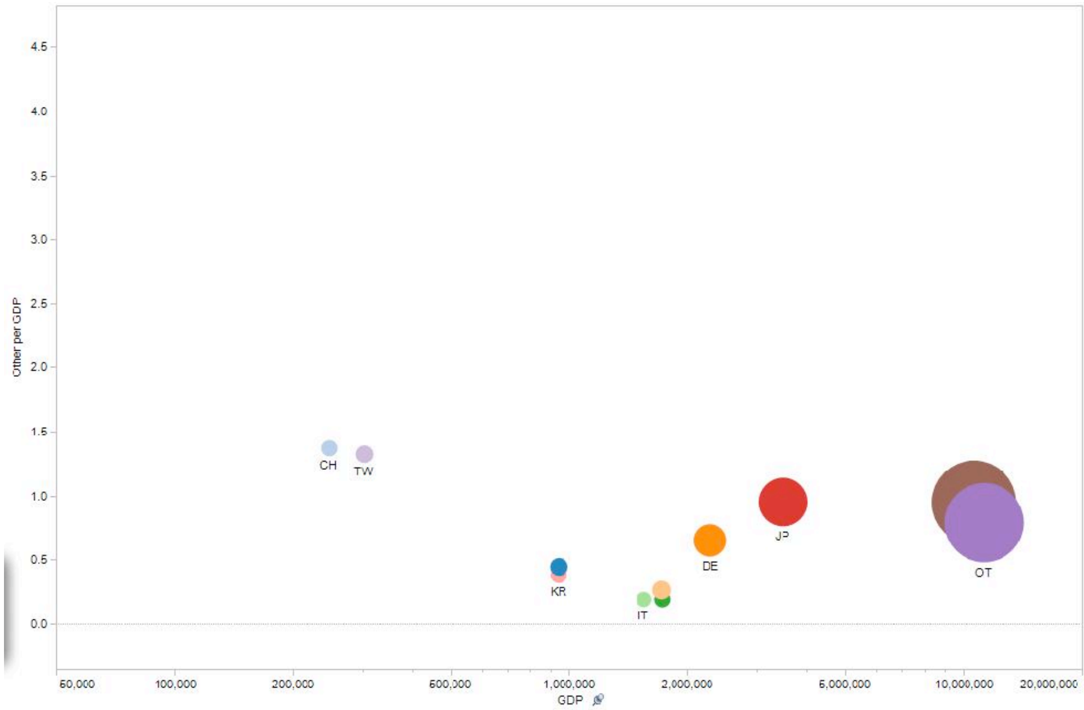
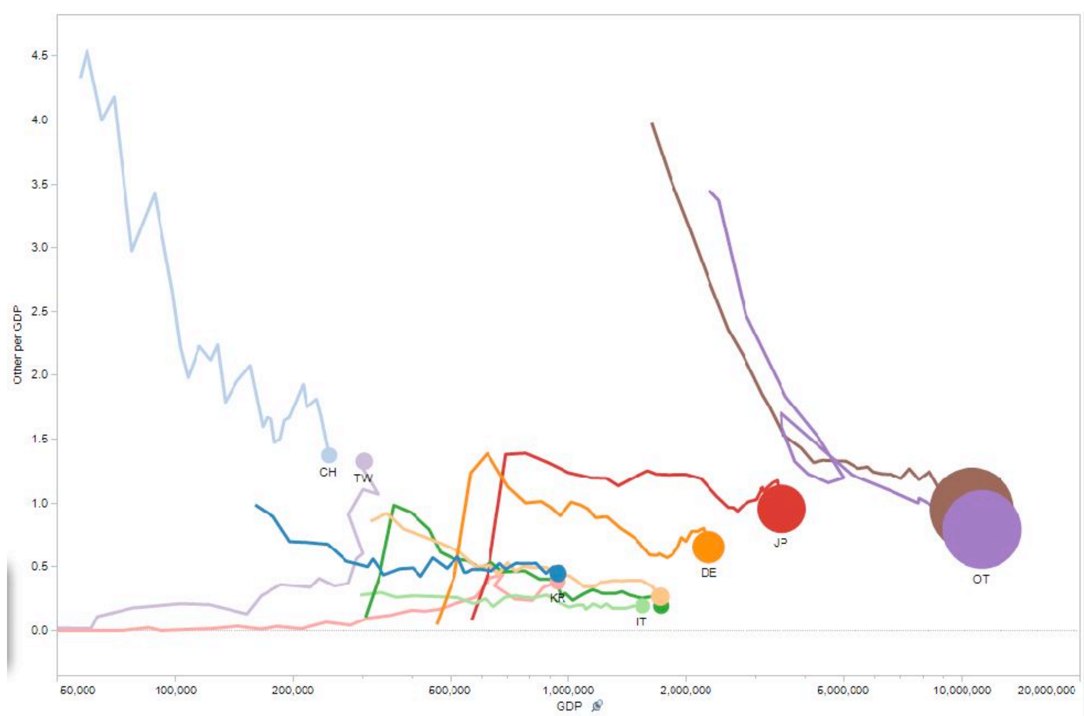


FIGURE 15
Other Technology Patents 2002 w/ History



Taken as indicators of broadly applicable changes in technology production in the countries indicated, the data shown in these figures (particularly the historical information shown in Figure 15) support at least three conclusions. First, there appears to have been a substantial drop in invention efficiency in the United States over the period of the study. This was matched worldwide by a similar drop in efficiency in the numerous countries making up the OT country group graphed in these figures (which, you will recall, is made up of all countries in the world generating advances patented in the United States other than the ten countries specifically addressed in this study). These widespread trends in invention efficiency may reflect overarching increases in commercial activities away from invention in various countries, a trend which would (as the respective economies grew for reasons other than a focus on inventions) tend to reduce the rate of inventions per GDP dollar.

Second, despite the drop seen in the United States, other countries were able to substantially increase their inventive efficiency across a wide range of technologies and economy sizes. Innovators in Japan, Germany, Great Britain, and Taiwan were able to achieve much increased efficiency as indicated by their countries' sharply upward angled efficiency curves for at least some of the period of the study. The means that they used to achieve these desirable changes (as well as the reasons why the trends in the United States were uniformly in the opposite direction) deserve further analysis.

Third, several counties – most notably Japan and Germany – were able to keep their invention efficiency relatively constant despite vast changes in their economies and the steady drop in inventive efficiency among United States innovators in the same period. The techniques used by these countries to keep their production of patented advances apace with their GDP increases (while the United States was not, thereby producing its drops in invention production efficiency) deserve greater study.

D. Regression Studies and Results

The second phase of this project involved linear regression studies of the foreign sources of United States patents. The dependent variables in these studies were country-specific United States utility patent counts for the application years 1981-2002 (only issued patents were counted, but each patent was associated with its application date to ensure comparisons of invention volumes emanating from the various countries at about the same time). This approach produced 135 dependant data values (N=135). Using data from the Organization for Economic Co-operation and Development (OECD),[6] information on economic and population characteristics of the various countries being examined here over the period of 1981 to 2002 was obtained and used as the basis for several independent variables in the linear regression analyses.

For these analyses, the variables were as follows:

6 The source of this data was Organization for Economic Co-operation and Development, OECD.Stats Extract, http://stats.oecd.org/ (last visited on 8/1/2012).

Dependent Variables

The analyses involved seven parallel regression equations. Each equation involved one of the following as the single dependent variable:

totpat = count of all United States utility patents from one country in one application year

chemical = count of chemical technology United States utility patents from one country in one application year

computer = count of computer and communication technology United States utility patents from one country in one application year

drugs = count of drug and medical technology United States utility patents from one country in one application year

electrical = count of electrical and electronic technology United States utility patents from one country in one application year

mechanical = count of mechanical technology United States utility patents from one country in one application year

other = count of other technology United States utility patents from one country in one application year

Independent Variables

The independent variables used in each of the seven dependent variable analyses for each country and year were:

pop = country population

respers = research personnel (per thousand employed, full-time equivalent)

gdp = gross domestic product (GDP)

grossres = gross domestic expenditures on R&D (GERD)(as a percentage of GDP)

busres = percent of research performed by business enterprises (as percent of GERD)

exports = international exports of goods and services (as percentage of GDP)

These variables were selected to control for the effects of country size (pop & gdp) and to study the effects of several potential inputs to the production of patented advances. The degree to which a country emphasized research personnel within its workforce (as measured by the respers variable) was thought to have a potential impact on the intensity and success of research activities. The degree to which revenues matching a country's GDP were plowed back into research activities (as measured by the grossres variable) was thought to represent the degree of economic and resource support for research activities. The degree to which business (as opposed to universities or government agencies) conducted research in a given country (as measured by the busres variable) was thought be a potential influence on whether research was focused on the sorts of commercially significant items and services likely to result in patented inventions. The degree to which a country's economy was focused on the production of exports (as measured by the exports variable) was thought to be an influence on how much local countries might emphasize patented advances as a means to ensure that only their exported items had patent-protected features.

These reasons for including the various independent variables in the analysis also suggest how patent counts were expected to vary with these variables. In general, as larger populations and larger economies were expected to produce more research activities than smaller ones, all else being equal, it was expected that patent counts would go up with both increasing population and increasing GDP. As a workforce more devoted to researchers was anticipated to produce more successful research projects and patented advances than one with a smaller fraction of researchers, patent counts were expected to go up with increases in the respers variable. As the investment of a greater fraction of a country's GDP in research was expected to enhance the number and success of research projects, patent counts were expected to rise with increases in the grossres variable. An emphasis on research by businesses (as opposed to more theoretical research by university personnel or research aimed at government ends by government personnel) was expected to produce more patented advances than would otherwise be the case, leading to the expectation that patent counts would go up with increases in the busres variable. And, as it was anticipated that substantial export activities would give parties in a country a stake in gaining patents to protect features of their exported products and to promote exclusive sales of those products overseas, it was anticipated that increases in the export variable would produce accompanying increases in patent counts.

The following tables report the results of the linear regression analyses:

TABLE 2
All Patents

totpat	Coef.	Std Err.	t	P>|t|	Beta
pop	-0.01364	0.02793	-0.49	0.626	-0.04545
respers	1449.387***	382.9848	3.78	0	0.292254
gdp	0.006376***	0.000946	6.74	0	0.499665
grossres	1676.273	1436.184	1.17	0.245	0.105589
busres	54.4892	81.53702	0.67	0.505	0.043257
exports	-261.184***	69.41868	-3.76	0	-0.23317
_cons	-9103.8**	3512.726	-2.59	0.011	.

N=135 R^2= 0.87 *p<.1 **p < .05 ***p < .01

TABLE 3
Chemical Technology Patents

chemical	Coef.	Std Err.	T	P>|t|	Beta
pop	0.01241***	0.003197	3.88	0	0.2835
respers	151.8489***	43.84304	3.46	0.001	0.209872
gdp	0.00061***	0.000108	5.63	0	0.327573
grossres	465.0763***	164.4103	2.83	0.005	0.2008
busres	-5.0577	9.334134	-0.54	0.589	-0.02752
exports	-19.449**	7.946859	-2.45	0.016	-0.11901
_cons	-1446.5***	402.1272	-3.6	0	.

N=135 R^2= 0.92 *p<.1 **p < .05 ***p < .01

TABLE 4
Computer and Communication Technology Patents

computer	Coef.	Std Err.	T	P>|t|	Beta
pop	-0.02722**	0.010483	-2.6	0.011	-0.32552
respers	566.9873***	143.7494	3.94	0	0.410154
gdp	0.001997***	0.000355	5.62	0	0.561347
grossres	-177.092	539.0567	-0.33	0.743	-0.04002
busres	46.02916	30.60408	1.5	0.135	0.131091
exports	-113.304***	26.05558	-4.35	0	-0.36288
_cons	-2312.89*	1318.456	-1.75	0.082	.

N=135 R^2= 0.77 *p<.1 **p < .05 ***p < .01

TABLE 5
Drug and Medical Technology Patents

drugs	Coef.	Std Err.	T	P>|t|	Beta
pop	-0.00031	0.000974	-0.32	0.751	-0.02435
respers	68.93734***	13.35632	5.16	0	0.328446
gdp	0.000352***	0.000033	10.66	0	0.651195
grossres	41.11148	50.08587	0.82	0.413	0.061189
busres	1.635296	2.843545	0.58	0.566	0.030674
exports	0.04264	2.420926	0.02	0.986	0.000899
_cons	-558.939***	122.5038	-4.56	0	.

N=135 R^2= 0.91 *p<.1 **p < .05 ***p < .01

TABLE 6
Electrical and Electronic Technology Patents

electrical	Coef.	Std Err.	T	P>|t|	Beta
pop	-0.01812*	0.009211	-1.97	0.051	-0.21838
respers	379.1545***	126.3054	3	0.003	0.276485
gdp	0.002043***	0.000312	6.55	0	0.579101
grossres	415.9302	473.6422	0.88	0.382	0.094749
busres	28.43825	26.89028	1.06	0.292	0.081644
exports	96.1554***	22.89374	-4.2	0	-0.31044
_cons	-2252.54*	1158.47	-1.94	0.054	.

N=135 R^2= 0.81 *p<.1 **p < .05 ***p < .01

TABLE 7
Mechanical Technology Patents

mechanical	Coef.	Std Err.	T	P>|t|	Beta
pop	0.013975***	0.004758	2.94	0.004	0.25406
respers	167.1469**	65.24074	2.56	0.012	0.183835
gdp	0.00089***	0.000161	5.52	0	0.380549
grossres	624.9555**	244.6512	2.55	0.012	0.214721
busres	-10.9464	13.88968	-0.79	0.432	-0.0474
exports	-19.5591	11.82534	-1.65	0.101	-0.09524
_cons	-1763.74***	598.3864	-2.95	0.004	.

N=135 R^2= 0.89 *p<.1 **p < .05 ***p < .01

TABLE 8
Other Technology Patents

other	Coef.	Std Err.	T	P>|t|	Beta
pop	0.005631**	0.002385	2.36	0.02	0.193397
respers	115.3119***	32.70421	3.53	0.001	0.23961
gdp	0.000484***	8.08E-05	5.99	0	0.391026
grossres	306.2914**	122.64	2.5	0.014	0.198821
busres	-5.60943	6.962689	-0.81	0.422	-0.04589
exports	-12.7584**	5.927867	-2.15	0.033	-0.11737
_cons	-769.187**	299.9621	-2.56	0.011	.

N=135 R^2= 0.90 *p<.1 **p < .05 ***p < .01

E. Interpretation of the Regression Results

The standardized coefficients (betas) in the preceding tables permit some comparison of the size of the effects measured. These beta coefficients represent the size of the impacts of the variables as computed on a common scale of significance, without regards to the units of the factors measured. Hence, a factor with a large beta has a greater effect (over the range in which it varies within the data) on changes in the dependant variable (that is, on numbers of patented advances emerging from the countries studied) than does a factor with a small beta.

Only those variables with statistically significant coefficients can be considered to be materially different than zero. The implications of the statistically significant coefficients shown in the preceding results are discussed in the remainder of this subsection.

1. Lack of Impact of Business Targeting

Somewhat remarkably, the fraction of research undertaken in business enterprises (as opposed to in university or governmental enterprises) was not significantly significant for any of the technology categories. It would appear that business environments (and an especially strong emphasis on research in these environments as opposed to elsewhere) does not materially increase numbers of patented advances, all other things being equal. This may indicate that increased emphasis on "research" in business settings often involves activities like marketing research or engineering adjustments of a sort that are unlikely to lead to patented advances. Hence, an emphasis on these sorts of activities does not change the likelihood of patented advances from a particular country.

2. Varying Impact of Population

Population (as a factor independent of country GDP) had a widely varying impact on invention counts, registering as a positive factor for chemical, mechanical, and other technology inventions, a statistically insignificant factor for drug and medical advances, and a negative factor for computer and communication advances and electrical and electronic advances, in all cases with all other factors being equal. This suggests highly different patterns of innovation success in countries of different size. For drug and medical advances, innovation is spread across countries of very different sizes. For chemical, mechanical, and other technology inventions, larger countries support more innovation (all other things including GDP size being equal), suggesting that, perhaps, larger populations produce more ideas that can form the basis for patented designs in these areas. For computer and communication advances and electrical and electronic advances, smaller countries produce more patented advances p(all other things including GDP size being equal), suggesting that a few key individuals may go far to produce many innovations in these fields. This implies that computer, communication, electrical, and electronic innovation may be particularly advantageous areas of technological development for countries with small populations.

3. Positive and Large Impact of Researcher Prevalence

The prevalence of researchers within a country's workforce was a significant and large factor in accounting for increasing numbers of patented inventions across all technology categories, controlling for population size, GDP, and the other factors considered in this study. A plentiful supply of research workers may be a key to conducting research projects. Alternatively, the prevalence of research workers in a particular economy may reflect an ongoing value placed on research and a training (and attraction to training) of researchers to respond to business and university demands for valued research participants. The results here suggest, however, that high percentages of researchers typically accompany high invention production. Thus, developing countries seeking to improve technology production in a particular field may wish to emphasize the training of a large number of specialists in that field so as to produce a large group of potential researchers in the relevant technology field.

The impact of qualified researchers in increasing numbers of patented advances seems to be particularly large in certain technology areas, all other factors being equal. The results here suggest that an increase in researcher prevalence in a workforce is particularly likely to produce additional advances in the computer and communication fields (as indicated by the larger beta for the impact of the respers variable on patent counts for this field than the betas for the same variable in other fields). This may indicate that only highly specialized parties are generally capable of producing patented advances regarding devices and processes in these fields, such that increases in the general workforce do not greatly change invention numbers, but changes in researcher numbers (which would tend to include some increases in numbers of computer and communications specialists) would increase the chances of producing patented computer and communication advances. By contrast, the impact of increased researcher prevalence on mechanical technology and other technology advances was relatively low although still significant and positive. This suggests that increasing the prevalence of researchers in an economy may produce far less incremental impact in these areas than in the computer and communication field.

4. Positive Yet Varying Impact of GDP

Overall economic size of a country's economy (as measured by its GDP) was a significant and positive factor in accounting for patent numbers across all of the technology categories. In short, larger economies produce more inventions of all types. Yet there was some difference in the size of the impact of GDP across the different technology types. Increasing GDP had a large impact on advances in the drugs and medical, computers and communication, and electrical and electronic fields, suggesting that increasing economic resources and support may be keys to expanding advances in these areas. This will be somewhat discouraging for parties seeking technology development in many developing countries with low GDPs. However, it may suggest that these are logical technology targets for countries that already have substantial GDPs due to other types of economy strengths. For example, these are all areas that would be strong candidates for pursuit by Chinese technological specialists as extensions of the large GDP in that country. It may also suit developing countries with substantial GDPs based on mineral wealth or other, non-technological sources of products and production.

5. Mixed Impact of Research Spending Within Economy

For economies of a give size (that is, with similar GDP), an increased emphasis on research spending seems to have mixed impacts on different types of inventions. For some types of advances, including drugs and medical and computer and communication advances, an increased percentage of GDP devoted to research seems to have no significant impact on invention numbers, all other factors being equal. This may, as was noted with the earlier discussion of increases in fractions of research conducted by business enterprises, suggest that shifts toward greater ratios of research spending to GDP levels in particular economies do not support more research leading to patented advances in these technology areas. Alternatively, this may suggest that other factors – such as levels of trained personnel – limit successful research in these fields no matter how much parties in a particular economy emphasize research spending.

An emphasis on research spending (as indicated by increases in the grossres variable) was a statistically significant and substantially large influence on increased numbers of advances in some technology areas, including chemical, mechanical, and other advances. This same factor also had a positive but smaller impact on numbers of patented advances in the electrical and electronic field. These results suggest that companies may be able to orchestrate additional advances in these areas more easily by simply placing more of a spending emphasis on research than in the computer, communication, drug, and medical fields.

6. Mixed and Negative Impacts of Exports

Contrary to the expectations at the outset of the research that exports would correlate with patent outputs (as product exporters sought means to distinguish their products by developing and protecting patented features for the exported products), exports were a significant and negative influence on patent counts in many of the technology categories. This factor affected patent counts negatively in the chemical, electrical and electronic, mechanical, and other technology categories. Apparently, economies devoted to producing large volumes of exports (other factors in this study being equal) generally are focused on the manufacturing and distribution of those exports and less concerned with new technology development than economies with fewer exports. This suggests that large export oriented countries – such as China – may face particular challenges in focusing on technological development at the same time as keeping their export levels high. Conversely, countries lacking significant workforces of the sort that make large-scale manufacturing and export volumes possible may find new technology development a useful alternative means to expand their economies.

In some fields, including computer and communication advances and drug and medical advances, the export levels of the producers of the advances showed no significant relationship to export levels. Advances in these fields are apparently similarly developed in countries with large and small export levels, all other factors being equal. This suggests that new advances in these fields may come from a wider range of countries than in other technology fields.

IV. Conclusion

This article has presented an initial analysis of new technology flows into the United States and of some of the factors that may affect these flows. Studies of technologies submitted from foreign sources for patenting in the United States are valuable in that they measure how parties in diverse foreign settings respond to the common societal needs and commercial potential of United States consumers and businesses. Regardless of the sources of patented inventions, United States patents for similar advances have a similar commercial and societal importance. Hence, by focusing on the common target of United States patenting and the dissimilar circumstances of foreign innovators who have hit that common target, we can assess how the various differential characteristics and circumstances of foreign innovators appear to influence the production of patented inventions.

The analyses presented here have attempted to pursue this perspective on patented advances in two ways. First, visualization studies were used to illustrate how foreign invention production per GDP dollar has varied across countries and over time. These studies also illustrated the same changes over time for United States innovators. The results suggest that the United States may presently suffer from too few patents given the size of its economy and its much higher production of patented advances per GDP dollar in earlier years. This conclusion stands in contrast to the criticisms of many commentators suggesting that we are suffering from too few patents. In addition, the country-to-country studies in this phase of the product suggest that United States innovators may be falling behind their foreign counterparts in some technology fields, again a troubling implication in a period when technological production may equal economic power in world economies and when technological prowess may be one of the few areas of continuing American excellence in world competition.

Second, the regression studies conducted in this project seek to analyze which country-to-country differences appear to be related to differences in patented invention outputs. The differences that have mattered in the past indicate factors that foreign countries and innovators may wish to emphasize in expending their production of new technologies and in accessing United States markets as sources of patent-mediated rewards for new innovations. The same factors may also afford narrower geographical areas – such as specific regions or cities in the United States or overseas – to gain technology development strength and to serve as particularly effective and efficient producers of new technologies.

As the potential sources of socially valuable new technologies spread throughout the world, the effectiveness of would wide sources of technologies needed and valued by United States parties – and potentially rewarded by the enforcement of United States patent rights – will be of increasing concerns. By virtue of United States patent enforcement, United States companies and consumers are ready to pay for new technology of value whatever its source. The factors described here suggest how innovators in other countries can better accept this attractive offer.