Patent Tigers: The New Geography of Global Innovation

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It is widely argued that international extension of the patent system hinders innovation and growth in developing countries by restricting access to technological inputs. I re-examine the connection between patents, innovation and development by assessing the extent to which the U.S. *patent regime supports R&D investment by firms in emerging market countries. Based on USPTO data covering all utility patents issued to U.S. and foreign inventors (a total of 6,122,194 patents issued to inventors resident in 188 countries and territories) during 1965-2015, and supplemented by additional data sources, I argue that the U.S. patent system has supported innovation in a cluster of foreign countries that have developed rapidly and dramatically since the 1980s. The increase in the proportion of foreign (and especially, East Asian) innovators in the USPTO patentee population is so large that it accounts for much of the significant increase in USPTO patent issuance that has commonly been attributed to policy changes by U.S. courts and the USPTO. Within this expanded foreign patentee population, three smaller and late-developing countries are now (together with Japan) the most intensive foreign users of the U.S. patent system on a per-capita and per-GDP basis: Israel, South Korea and Taiwan. Based on entity type, industry type and other salient characteristics of the leading "first-named" assignees of USPTO patents in Israel and Taiwan during 2000-2015, and supplemented by other evidence relating to these countries' innovation capacities and performance, I argue that these countries rely on USPTO patents to extract value from their R&D investments by supplying product or process inputs to the global value chains that connect innovation sources with commercialization sources on the pathway to target consumption markets. While prior work has presented evidence that patents sometimes promote entry into technology markets by upstream R&D firms that lack downstream production and distribution capacities, this paper extends that rationale and presents evidence that patents can promote entry into technology markets by economies that are rich in intellectual and human capital but have small domestic markets in which to extract returns on that capital. For those countries, the patent system (or at least the U.S. patent system) is an aid, not a hindrance, to development.*

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> "*[T]he clever Englishman transforms [invention] by a patent into real possessions . . . One may well ask why they are in every respect in advance of us?"* – J.W. von Goethe[1]

Legal, economic and policy commentary on the international expansion of the patent system has widely adopted a narrative in which developed countries have "compelled" the rest of the world to unwisely adopt excessively strong patent regimes.[2] However, empirical studies support some positive relationship between patent protection, innovation and economic growth, although the extent of that relationship is far from settled.[3] In this paper, I re-examine this popular narrative by switching the point of reference. I examine empirically the extent to which the patent regime in the United States has supported innovation in certain foreign countries that have moved rapidly from emerging to "late-developing" countries. More specifically, I examine how U.S. patents support global value chains in which suppliers of R&D and commercialization inputs interact to deliver technology-intensive goods and services to intermediate and end-users in target consumption markets. This inquiry illustrates how the U.S. patent system operates as a *de facto* world patent system that has enabled a cluster of smaller and late-developing economies, which are rich in intellectual capital but have limited domestic markets, to supply global supply chains with product and process innovations. Consistent with standard economic theories of national comparative advantage, the result is a presumptively efficient global allocation of innovation, production and distribution functions, resting in significant part on the legal infrastructure supplied by the U.S. patent system. Contrary to the standard narrative, the patent system—or specifically, the U.S. patent system—appears to have helped, not harmed, at least some countries that have made impressive leaps up the economic development ladder.

I start by using USPTO data during the past fifty years (1965-2015) to identify historical trends in patenting activity by foreign inventors. The dataset comprises 6,122,194 utility patents issued to inventors resident in 188 countries and territories (including the U.S.). Since approximately the late 1990s, there has been a dramatic and continuing surge in patent issuances to foreign inventors in general and, in particular, inventors resident in East Asian countries (principally Japan, South Korea and Taiwan).

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1 Quoted in JOEL MOKYR, THE LEVER OF RICHES: TECHNOLOGICAL CREATIVITY AND ECONOMIC PROGRESS 246 (1990). For the original, see J.W. VAN GOETHE, NATURWISSENSCHAFT IM ALLGEMEINEN 134, 255 (1893).

2 For representative examples, see JOSEPH E. STIGLITZ, MAKING GLOBALIZATION WORK 116-17 (2006); JOSEPH E. STIGLITZ & ANDREW CHARLTON, FAIR TRADE FOR ALL: HOW TRADE CAN PROMOTE DEVELOPMENT 103 (2005); SUSAN SELL, PRIVATE POWER, PUBLIC LAW: THE GLOBALIZATION OF INTELLECTUAL PROPERTY RIGHTS 108-09 (2003); PETER DRAHOS & JOHN BRAITHWAITE, INFORMATION FEUDALISM: WHO OWNS THE KNOWLEDGE ECONOMY? 133-37 (2002); JAGDISH BHAGWATI, FREE TRADE TODAY 75-76 (2002); Michele Boldrin and David K. Levine, *The Case Against Patents*, 27 J. ECON. PERSP. 3, 19 (2013); Neil Weinstock Netanel, *The WIPO Development Agenda and Its Development Policy Context*, in THE DEVELOPMENT AGENDA: GLOBAL INTELLECTUAL PROPERTY AND DEVELOPING COUNTRIES 2-3 (ed. Neil Weinstock Netanel 2009); Rochelle C. Dreyfuss, *The Role of India, China, Brazil and Other Emerging Economies in Establishing Access Norms for Intellectual Property and Intellectual Property Lawmaking*, IILJ Working Paper 2009/5; Amy Kapczynski, *The Access to Knowledge Mobilization and the New Politics of Intellectual Property*, 117 Yale L. J. 804, 824-827 (2008); Jerome H. Reichman & Rochelle Cooper Dreyfuss, *Harmonization Without Consensus: Critical Reflections on Drafting a Substantive Patent Law Treaty*, 57 DUKE L. J. 85, 94-99, 103-108 (2007).

3 For reviews of the empirical literature (which adopt different views of its aggregate implications for the policy debate), see Stephen Haber, *Patents and the Wealth of Nations*, 23 GEORGE MASON L. REV. (2016); Jonathan M. Barnett, *Do Patents Matter? Empirical evidence on the incentive thesis*, in HANDBOOK ON LAW, INNOVATION AND GROWTH 191-92 (ed. Robert E. Litan 2011); Daniel Gervais, *TRIPS and Development*, *in* INTELLECTUAL PROPERTY, TRADE AND DEVELOPMENT: STRATEGIES TO OPTIMIZE ECONOMIC DEVELOPMENT IN A TRIPS-PLUS ERA (ed. Daniel Gervais 2007); Peter K. Yu, *TRIPs and Its Discontents*, 10 MARQ. INTELL. PROP. L. REV. 369 (2005).

Foreign inventors now constitute a slight majority of all patent applicants and grantees at the USPTO and East Asian inventors now outnumber inventors resident in any region outside North America. The increased entry of foreign inventors into the USPTO patenting population is so significant that it accounts for much of the "patent explosion" that has attracted concern in policy discussions since the establishment of the Court of Appeals for the Federal Circuit in 1982.[4] Remarkably, when annual patent issuance rates are measured on a per capita basis and compared to rates that prevailed as of 1965, there is no increase in patent issuances to *U.S.* inventors until 1998 and no significant and sustained increase until 2010.

Within the population of high-performing foreign inventors, three countries are exceptional: Israel, Korea and Taiwan. All three countries—which I call the "patent tigers"—exhibit rates of patent issuance, whether measured on a per capita or per GDP basis, that exceed dramatically all countries in recent years except the United States and Japan. To address the concern that these countries may be "patent factories" rather than productive sources of innovation inputs (or some mixture of both), I use various measures to assess each patent tiger's innovative capacities and performance. First, I assess each patent tiger's "success ratio" in the USPTO examination process, which, subject to certain methodological complications, provides some insight into the quality of a country's applications. Relatedly, I survey existing data on the relative citation rates of USPTO patents issued to inventors from these countries. Second, I review existing data relating to other commonly used measures of innovative performance, such as investment in higher education, per capita R&D personnel, R&D as a percentage of GDP, and the technology balance of payments. Each of the patent tigers scores highly (and sometimes exceptionally highly) on most of these measures, which mitigates the "patent factory" concern.

It then remains to consider why the tiger countries invest so heavily in the acquisition of USPTO patents. I argue that these countries' high-intensity patenting strategy mitigates a common transactional dilemma. The tiger countries have relatively small domestic markets and therefore can only maximize returns on their human and intellectual capital investments through sales of technology inputs, or products or services that incorporate technology inputs, to larger foreign markets. But the pathway to those rich consumption markets is encumbered by expropriation risks that are peculiar to commercial relationships involving informational assets. Patents ameliorate the expropriation risk inherent to exchanging information between a firm that holds an innovation input and third parties that hold the complementary inputs required to support commercialization in target markets. Existing theory and empirics suggest that patents often enable smaller upstream R&D-intensive firms to transact safely with larger production and distribution partners located downstream on the supply chain.[5] That same rationale can be applied at the country level: that is, patents enable smaller R&D-intensive countries to transact safely with countries that excel in the production and distribution capacities required to reach market. The result is a classic case of comparative advantage, resulting in a presumptively efficient division of tasks among specialized providers situated along a commercialization pipeline disaggregated across the globe.

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4 John Golden has similarly observed that increased rates of foreign patenting since the 1950s account for much of the general increase in patent issuance by the USPTO. *See* John M. Golden, *Proliferating Patents and Patent Law's "Cost Disease",* 51 HOUSTON L. REV. 455, 470-472 (2013). My analysis relating to this point examines closely the period 1965-2015 and supplies additional detail through regional and country-level breakdowns of foreign patenting on a per capita and per GDP basis, which is then used to identify the most active regional and country-level segments within the foreign patentee population at the USPTO.

5 For key references, see *infra* note 84.

I explore the proposed link between patents, transactional hazards, and comparative advantage through case studies of two patent tigers, Israel and Taiwan.[6] To undertake this inquiry, I use USPTO and other data to identify the leading Israeli and Taiwanese users of the USPTO system as well as those firms' position on the technology supply chain. Based on this data, supplemented by existing evidence, I argue that the USPTO system supports knowledge exchanges that are critical to each country's ability to monetize its R&D investments in global technology supply chains. In the case of Israel, patents primarily enable upstream entities to monetize R&D investments through licensing, corporate-control and other transactions with foreign integrated firms. This applies to three important categories of Israeli patentees: (i) academic research institutions; (ii) the R&D affiliates of leading foreign technology firms (typically established or expanded through the acquisition of local startups); and (iii) local technology firms in the IT and life sciences markets. In the case of Taiwan, the patenting data reflect an innovation economy consisting primarily of three entity types: (i) a government-sponsored applied research institute that develops technologies for licensing to the private sector; (ii) "foundries" that develop process innovations in chip production for the semiconductor market; and (iii) chip design firms that contract with the foundries for production services. As in Israel, the research institute and chip design firms are upstream innovation entities that rely on patents to monetize their R&D investments through transactions with downstream production and distribution partners. Taiwan's foundries are "mid-stream" entities that use patents to extract returns on their R&D investments in developing production technologies for chip design firms.

Organization is as follows. In Part I, I show why a U.S. patent is commercially valuable to a foreign firm. In Part II, I present data relating to historical changes in foreign patenting behavior at the USPTO, the exceptional group of patent tigers, and the quality of tiger countries' patents. In Part III, I propose a transactional rationale for tiger countries' intensive acquisition of U.S. patents. In Part IV, I assess the strength of that rationale through case studies of patenting and innovation activities in Israel and Taiwan. I briefly conclude.

I. The Unique Role of the U.S. Patent System

I will focus on the relationship between the patent system and innovation in foreign, especially certain emerging market, countries. Unlike the existing empirical literature, however, I address this question by examining the relationship between *U.S.* patent protection and foreign innovation. Focusing on a single patent regime avoids the "apples/oranges" problem inherent to comparative studies that must address inconsistencies between patent regimes across different countries. However, my approach is only

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6 Israel's intensive patenting activities at the USPTO appear to have been first addressed in detail by Prof. Manuel Trajtenberg, along with some discussion of USPTO patenting by Korea and Taiwan. *See* Manuel Trajtenberg, *R&D Policy in Israel: An Overview and Reassessment,* Natl. Bureau of Econ. Res. Working Paper No. 7930 (2000); Manuel Trajtenberg, *Innovation in Israel 1968-1997: A Comparative Analysis Using Patent Data,* Natl. Bureau of Econ. Res. Working Paper No. 7022 (1999). My study extends that data through 2015, supplements detailed study of Taiwan, updates detailed study of Israel, and accounts for Israel's, Korea's, and Taiwan's intensive patenting as a response to a common set of transactional hazards. Based primarily on qualitative observations, Prof. AnnaLee Saxenian discusses the prominence of Israel and Taiwan (mostly the latter) in the global technology marketplace. *See* ANNALEE SAXENIAN, THE NEW ARGONAUTS: REGIONAL ADVANTAGE IN A GLOBAL ECONOMY 122-196 (2006). She attributes these countries' achievements in large part to the international circulation of human capital, whereas my account emphasizes the role of patent rights and contractual agreements in regulating the exchange of knowledge assets between these countries and foreign partners in the commercialization pipeline.

sensible if there were something especially attractive about the U.S. patent system from the perspective of a foreign inventor. This assumption appears to be reasonable based on observed market behavior: as of 2014, foreign applications at the USPTO constituted a significantly larger percentage of total applications as compared to any other large patent office (the European Patent Office, Japan, China and Korea).[7] Data compiled by the World Intellectual Property Organization show that (as of 2009), if an inventor files a patent in his or her home country's office and then seeks patent protection in a foreign country, the USPTO is the most popular subsequent destination.[8] Below I identify and discuss three principal reasons why a USPTO patent is especially attractive to foreign inventors.

A. Rich Target Market

Perhaps the most obvious reason is the simplest: the U.S. is the world's largest consumer market, representing 29.7% of world household consumption as of 2014.[9] That statistic understates the attraction of the U.S. market since the U.S. provides firms with not only the largest consumer market, as measured by sales, but with a consumer market that enjoys among the world's highest per capita income levels[10], thereby allowing firms to enjoy larger profit margins as compared to other countries in which consumers are subject to stronger budget constraints.

B. Lower Filing Costs

The patent prosecution and maintenance process is not an economically trivial exercise. This requires payment of tens of thousands of dollars in filing fees, legal fees, and maintenance fees both at the application stage and throughout the lifetime of a patent. As compared to the European Union ("EU"), which offers a comparably sized and comparably wealthy consumer market, the U.S. simply offers patent applicants "more bang for the buck". More precisely, the U.S. offers a foreign inventor lower filing fees and greater administrative convenience since its market can be accessed through a single filing. To replicate this outcome in the EU requires incurring multiple filing, renewal, and translation fees in various countries.[11] To achieve and maintain coverage for a single patent for the full 20-year term in the six most popular European filing jurisdictions (representing 67% of the total economic output of the EU), an inventor must incur fees almost six times greater than the fees that would be incurred at the USPTO.[12]

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7 Author's calculations, based on data in: IP5 STATISTICS REPORT, 2014 EDITION.

8 *See id.*, at 54.

9 THE WORLD BANK, HOUSEHOLD FINAL CONSUMPTION EXPENDITURE (constant 2005 $US) (current as of 2014, based on World Bank and OECD national accounts data), avail. at http://data.worldbank.org/indicator/NE.CON.PRVT.KD.

10 Based on World Bank data, the U.S. was ranked 9th in per capita GDP as of 2015 (on a purchasing power parity basis). Except for Switzerland and Luxembourg, all higher-ranked countries are small "petro" states. *See* THE WORLD BANK, INT'L COMPARISON PROGRAM DATABASE, GDP PER CAPITA, PPP (avail. at http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?end=2015&start=2015).

11 While this burden is mitigated somewhat by the implementation of the European Patent Office, which enables a patentee to access all member countries through a single patent application, there are still country-specific validation, translation and renewal fees that remain. *See* EUROPEAN COMMISSION, PATENT COSTS AND IMPACT ON INNOVATION: INTERNATIONAL COMPARISON AND ANALYSIS OF THE IMPACT ON THE EXPLOITATION OF R&D RESULTS BY SMES, UNIVERSITIES AND PUBLIC RESEARCH ORGANIZATIONS (Dec. 2014) [hereinafter, "EUROPEAN COMMISSION"].

12 *See id.*, at 21.

C. Lower Enforcement Costs

A patent's value ultimately rests on a credible enforcement threat against infringers. A USPTO patent offers a more attractive enforcement alternative than two other comparably sized markets: China and the EU. In the first case, the enforcement difficulties are well-known, even taking into account limited reported improvements in recent years.[13] In the second case, the EU raises enforcement obstacles that do not exist in the U.S. because there is doubt whether injunctions issued by a court in one EU member country will be honored by other EU member countries.[14] By contrast, in the U.S., there is no such uncertainty once a federal court issues an injunction in a patent infringement litigation. Additionally, the U.S. has an especially effective enforcement venue for patent holders seeking to block the importation of infringing goods into the U.S. For this purpose, the patentee can seek redress at the International Trade Commission (the "ITC", a federal administrative body) to obtain an exclusion order that instructs U.S. customs to block importation of the infringing product.[15] Compared to a federal district court, the ITC can generally rule with greater speed, force and reliability. ITC proceedings typically last 15 to 18 months until relief, which is significantly faster than a patent infringement litigation in federal court[16] (where median time-to-*trial* is approximately 2.4 years[17]) and, unlike a plaintiff in a federal district court action, the patentee can secure a general exclusion order that applies broadly to an entire class of goods.[18] Critically, the ITC is not bound by the Supreme Court's 2006 decision in *eBay, Inc. v MercExchange LLC* (547 U.S. 388 (2006)), in determining whether to issue an exclusion order.[19] That provides a significant advantage over infringement litigation in a district court, where the *eBay* precedent has significantly raised the bar for securing injunctive relief in patent infringement cases.

II. The USPTO Goes Global: Patenting Trends (1965-2015)

In this Part, I present evidence relating to trends among residents of foreign countries who apply for patents at the USPTO. I then assess whether those patenting trends are indicative of innovation

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13 For a recent account, see EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES, 2014 SPECIAL 301 REPORT 35-37 (2014).

14 *See* Stuart J.H. Graham & Nicholas Van Zeebroeck, *Comparing Patent Litigation Across Europe: A First Look*, 17 STAN. TECH. L. REV. 655 (2014).

15 19 U.S.C. § 1337.

16 *See* H. Mark Lyon and Sarah E. Piepmeier, *ITC Section 337 Investigations: Patent Infringement Claims,* PRACTICAL LAW COMPANY (2012).

17 PRICEWATERHOUSECOOPERS, 2015 PATENT LITIGATION STUDY: A CHANGE IN PATENTEE FORTUNES (2015).

18 This is because the ITC exercises *in rem* jurisdiction over the allegedly infringing imports. *See* Russell E. Levine, *The benefits of using the ITC,* MANAGING IP, Sept. 2004. However, the plaintiff must show that there is a U.S. industry relating to the "article" protected by the patent (the "domestic industry requirement, *see* 19 U.S.C. § 1337(a)(2)-(3)). While uncertainty remains, courts have sometimes interpreted this requirement generously, concluding that it has been satisfied by foreign entities solely engaged in patent licensing in the U.S. (see *In re Certain Semiconductor Chips With Minimized Chip Package Size and Products Containing Same,* Inv. No. 337-TA-432, 2001 WL 1426690 (Sept. 25, 2001) at *52, 60) or foreign entities with a U.S. subsidiary engaged in engineering support (see *In re Certain Integrated Circuits, Processes for Making Same and Products Containing Same*, Inv. No. 337-TA-450 (May 6, 2002), at 247-275, 277.

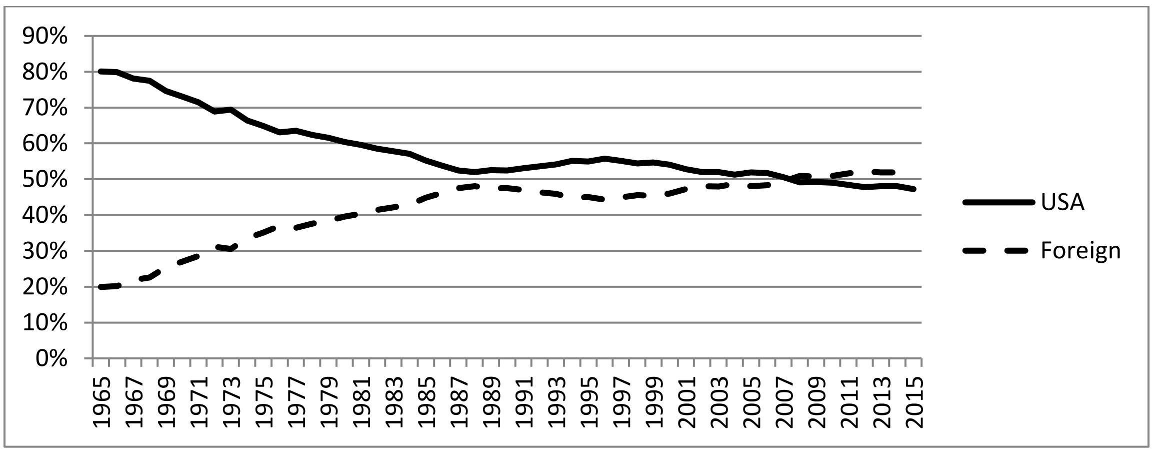
19 *Spansion v. Int'l Trade Cmm'n,* 629 F.3d 1331, 1358-59 (Fed. Cir. 2010).

activities in those foreign countries. The time period is generally 1965-2015, although in some cases shorter periods are studied due to data availability.[20]

A. Rise of Foreign Inventors

As measured by changes in absolute figures for patent grants, there has been a significant increase in the percentage of non-U.S. patent grantees during 1965-2015, starting in particular in the early 1980s. In 1965, non-U.S. patent grantees constituted 20% of total grantees. [21] By 2008, non-U.S. patent grantees constituted a majority of total grantees, and, in 2015, non-U.S. residents constituted 53% of all grantees.[22] The same trends are true of patent applications. By 2009, non-U.S. patent applicants constituted a majority of total applicants and, in 2015, constituted 51% of all applicants.[23] Clearly the USPTO has become the *world*'s patent office.

Figure I: U.S. and Non-U.S. Recipients of USPTO Utility Patents (1965-2015)[24]



B. **Rise of East Asian Inventors**

If we break up the world into four principal regions (North America, Europe, East Asia and "Rest of World"), we can observe which regions have exhibited increasing, constant, or declining "market share" in patent grants at the USPTO. All countries and territories for which the USPTO provides grant data during 1965-2015 were placed into four categories: (i) North America; (ii) Europe; (iii) East Asia; and (iv) Rest of World. "North America" refers to Canada, Mexico and the United States[25]; "Europe"

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[20] Two methodological notes apply throughout. First, all data relate solely to utility patents (that is, *not* design patents and plant patents) and, unless otherwise indicated, are based on data available through the USPTO. Second, I follow the USPTO's practice that determines the applicant's or grantee's nationality based on the stated residence of the first named inventor in the patent application.

[21] Author's calculations, based on USPTO, EXTENDED YEAR SET – ALL TECHNOLOGIES (UTILITY PATENTS) REPORT, PART A1 (last modified Feb. 15, 2017).

[22] *See id.*

[23] *See id.*

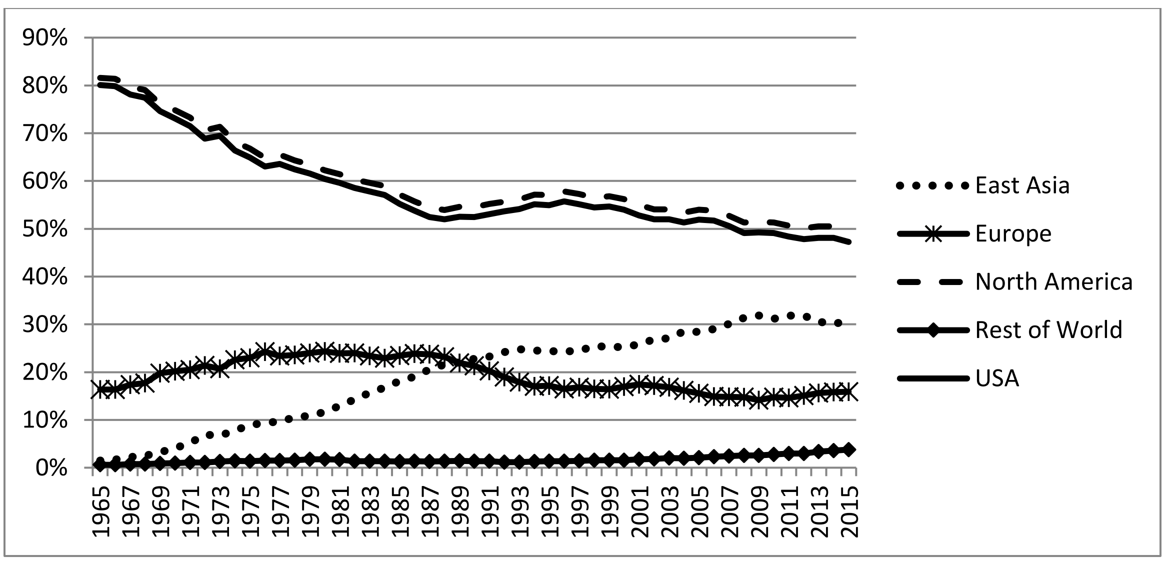
[24] *See id.*

[25] The overwhelming majority of patents awarded to North American applicants are awarded to U.S. applicants. In 2015, U.S. applicants received 140,969 patents, representing more than 95% of all North American patent grants; Canadian applicants received 6,802 patents, representing 4.6%; and Mexican applicants received 172

refers to all countries that are principally located on the European continent[26]; "East Asia" refers to the People's Republic of China (including Hong Kong and Macau), Japan, North Korea, Singapore, South Korea, and Taiwan. "Rest of World" refers to all other countries.

North America has held the largest but declining share of total patent applicants and grants, Europe has maintained a smaller but significant share, while East Asia has achieved dramatic growth from a baseline of almost no USPTO patenting activity. In 1990, East Asia overtook Europe as the second-largest regional recipient of U.S. patents and has steadily increased its market share. More specifically, if we look at the end points of the time range shown below (1965 and 2015), North America's share of total grants has declined from 83% to 50%; Europe's share has held constant at slightly more than 15% (after a surge past 20% during the late 1970s and 1980s); and East Asia has experienced a dramatic increase from 1% in 1965 to 31% in 2015. The Rest of the World (with the exception, to be discussed, of Israel and, to a lesser extent, India) has not experienced any material change in its relative percentage of total patents issued. Clearly there has been a shift in the relative share of patenting volume at the USPTO toward East Asia and away from North America.

Figure II: USPTO Utility Patents on Regional Basis (1965-2015)[27]



patents, representing less than 1%. Author's calculations, based on: USPTO, EXTENDED YEAR SET – ALL TECHNOLOGIES (UTILITY PATENTS) REPORT, PART A1 (last modified Feb. 15, 2017).

[26] This excludes Turkey, the U.S.S.R., and all former members of the U.S.S.R. (including the Russian Federation), except Estonia, Latvia, Lithuania, and Moldova. Hence, the number of countries included in the "Europe" region increases slightly after the dissolution of the Soviet Union in the early 1990s. Since these four additional European countries are not significant recipients of USPTO patents, this is unlikely to affect regional percentages to any material extent.

[27] USPTO, EXTENDED YEAR SET – ALL TECHNOLOGIES (UTILITY PATENTS) REPORT, PART A1 (last modified Feb. 15, 2017).

C. **Foreign Entry Mostly Accounts for the Patent "Explosion"**

It has become a commonplace to observe that there has been an "explosion" in the issuance of patents by the USPTO since the establishment of the Court of Appeals for the Federal Circuit in 1982 and the associated strengthening of patent rights. Government policymakers, economists and legal academics have observed, and often lamented, dramatic increases in the number of patents awarded starting in the 1980s and widely attributed this development to patent-friendly decisions by the Federal Circuit and purportedly relaxed examination standards at the USPTO.[28] When assessed on a per capita basis, the data on the issuance of USPTO patents challenges this account.[29]

Consistent with the conventional narrative, there *is* a significant increase in per capita patent issuance among U.S. inventors starting in the early 1980s, lasting with some declines through 2005 and then resuming in 2010 through the present. However, contrary to that narrative, this increase among *U.S.* inventors was not *historically* significant and persistent on a per capita basis until as late as 2010, as shown most clearly in *Figure V* below.[30] The increase starting in the early 1980s merely started to restore per capita patenting rates among U.S. inventors to the levels that had existed as of 1965, which had been followed by a dramatic decline in per capita annual patenting levels among U.S. inventors (as much as a 48% decline in 1979, as compared to the 1965 reference year). The increase starting in the 1980s was gradual and U.S. inventors only started regularly matching 1965 patenting levels in 1998, which was then followed by approximately static per capita patenting rates until 2010.[31]

This is not to deny that there has been a historically significant increase in patent issuance at the USPTO *in general* across the total patentee population consisting of U.S. and non-U.S. applicants since

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[28] See, e.g., NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES, A PATENT SYSTEM FOR THE 21ST CENTURY 28-30 (2004); ADAM B. JAFFE AND JOSH LERNER, INNOVATION AND ITS DISCONTENTS: HOW OUR BROKEN PATENT SYSTEM IS ENDANGERING INNOVATION AND PROGRESS, AND WHAT TO DO ABOUT IT (2004); MICHELE BOLDRIN & DAVID LEVINE, AGAINST INTELLECTUAL MONOPOLY (2008); JAMES BESSEN AND MICHAEL MEURER, PATENT FAILURE: HOW JUDGES, BUREAUCRATS AND LAWYERS PUT INNOVATORS AT RISK (2008).

[29] Based on rates of growth in patenting by U.S. and foreign inventors at the USPTO, John Golden has similarly observed how foreign patenting since the 1950s has driven much of the increase in patent issuance, which casts some doubt on the conventional account that there has been an "explosion" in patent issuance at the USPTO. *See* Golden, *supra* note 4, at 470-472.

[30] All per capita figures were calculated based on (i) USPTO, EXTENDED YEAR SET – ALL TECHNOLOGIES (UTILITY PATENTS) REPORT, PART A1 (last modified Feb. 15, 2017); and (ii) estimated national population figures in the International Data Base (IDB) Division of the United States Census Bureau (last updated July 2015, available at http://www.census.gov/population/ international/data/idb/informationGateway.php). I extracted data on each country's estimated population at five-year intervals (starting in 1965) and assumed an equal annual rate of growth between the start and end year of each interval. I calculated country-specific annual per capita patenting figures and then, based on each country's regional attribution (as explained above, see *supra* note 26 and accompanying text), consolidated those figures to calculate regional annual per capita patenting rates. Note that, in the case of Germany, the Census Bureau consolidates population data for East and West Germany as if the two countries were a single country throughout the period above. Source: Author communication with Demographic and Economic Studies Branch, Population Division, U.S. Census Bureau (July 5, 2016).

[31] If there is concern that 1965 patenting levels may be abnormally high and therefore not an appropriate reference point, it should be noted that the per capita patenting rate in 1965 (260 patents per 1 million population) is below the average annual per capita patenting rate for U.S. inventors for the entire period 1900-1964 (273 patents per 1 million population). Even if we used the 1900-1964 average annual patenting rate as the benchmark, the annual per capita patenting rate for U.S. inventors only overtakes that rate in 1998 (the same "catch up" date based on the 1965 benchmark). The 1965 date may be preferred because, prior to 1963, the USPTO data distinguishes between foreign and U.S. patentees but does not distinguish between utility, design and plant patents.

the early 1980s. But, until 2010, this is only historically significant and persistent with respect to foreign inventors, using 1965 as our reference point. Hence, the "explosion" in patenting rates until 2010 appears to be largely attributable to the expanded entry of foreign (and, in particular, East Asian) inventors into the USPTO applicant population. During the same period that U.S. per capita patenting rates declined and then held approximately constant (1972-1998), non-U.S. per capita patenting rates never stopped increasing and East Asian patenting rates in particular rose sharply. Specifically, as shown below in *Figures III* and *IV*, all foreign but, especially, East Asian inventors have exhibited continuous and dramatic increases in per capita patenting rates since the early 1970s, increased growth in the mid-1980s, more pronounced growth in the late 1990s, and then an even sharper increase in the late 2000s. This is only true of U.S. inventors starting in 1998 and only true to a significant and sustained extent starting in 2010.

Figure III: USPTO Utility Patents, Regional Deviation from 1965 Per Capita Issuance Rates (per 1M population), All Filers (1965-2015)

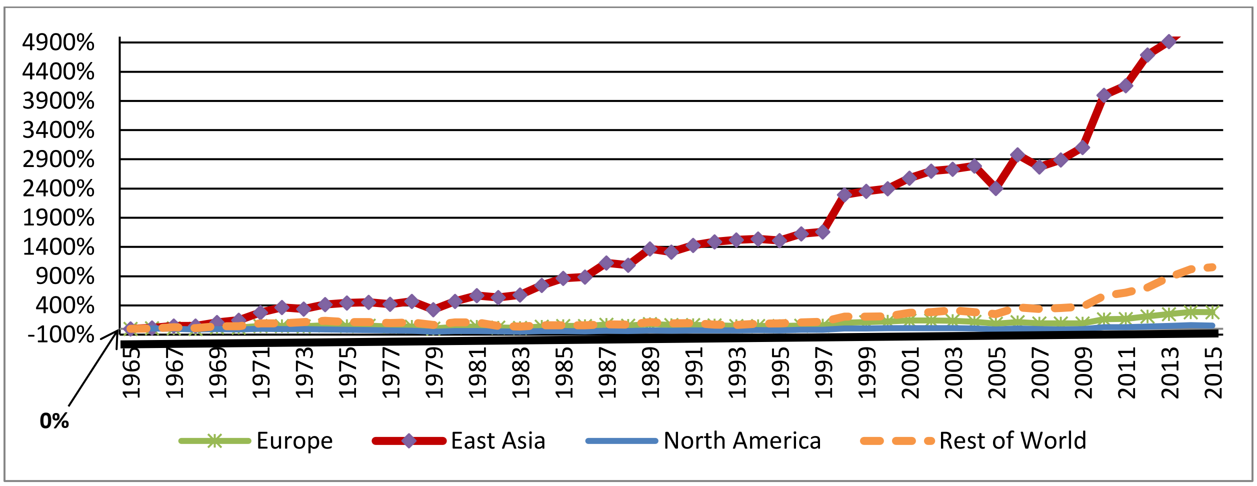


Figure IV: USPTO Utility Patents, Regional Deviation from 1965 Per Capita Issuance Rates (per 1M population), All Filers Except East Asia (1965-2015)

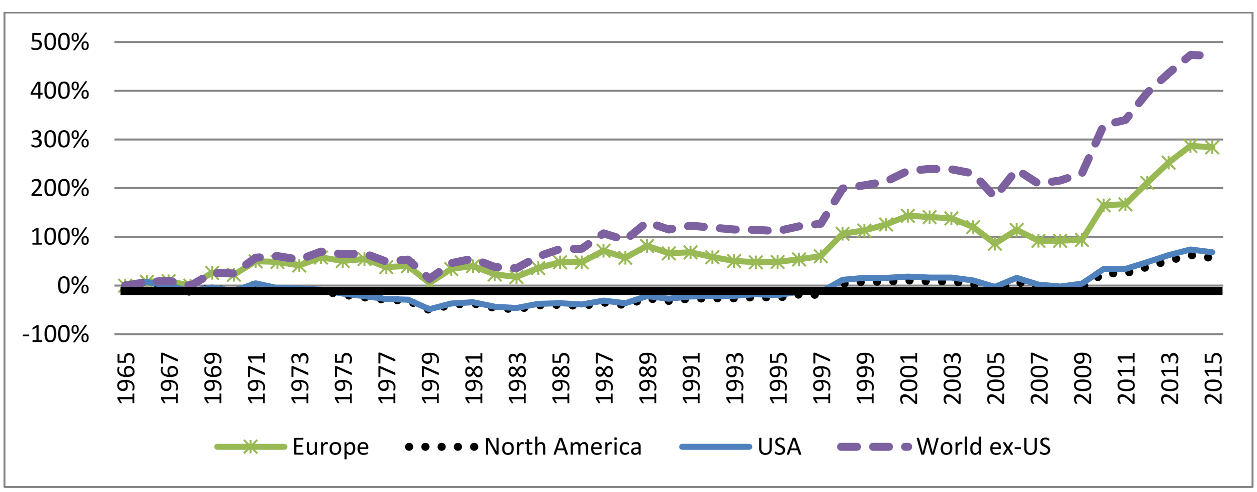
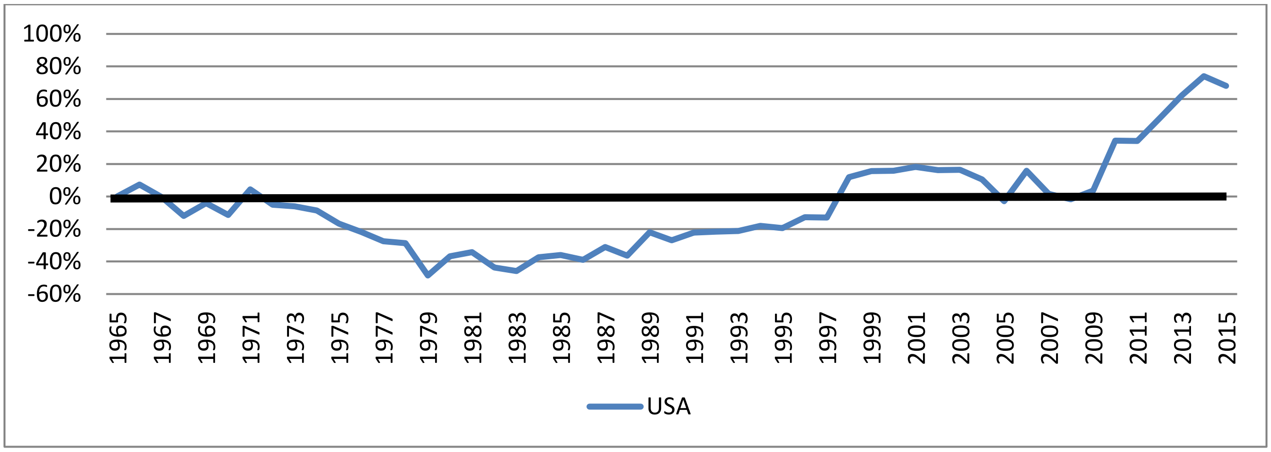


Figure V: USPTO Utility Patents, Deviation from 1965 Per Capita Issuance Rates (per 1M population), U.S. Filers Only (1965-2015)



D. **Patent Tigers**

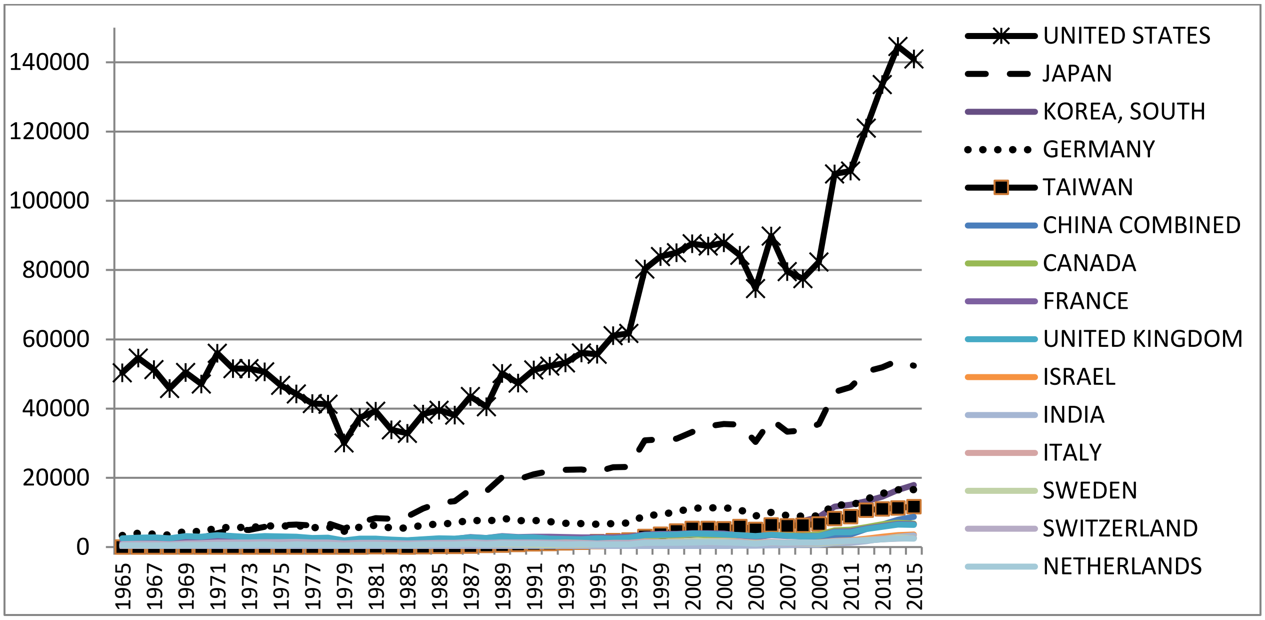
I will now move below the regional level of analysis and identify specific countries that are particularly intensive users of the patent system. For this purpose, I use three alternative measures of USPTO patenting activity: (i) absolute numbers of patent grants; (ii) patent grants per capita; and (iii) patent grants per gross domestic product ("GDP"). The per-capita and per-GDP measures yield a comparable ranking of countries but deviate significantly from the ranking derived using absolute measures of patent grants. In particular, these two measures identify a group of three smaller and "late-developing" countries—namely, Israel, Korea and Taiwan—that outperform almost every other country outside the U.S. in terms of USPTO patenting activity, starting in the early to mid-2000s through the present. For purposes of all three measures below (absolute, per capita, and per GDP), I only assessed the 22 countries that had received at least 10,000 patents in total during 1965-2015.[32] I refer to these 22 countries as the "selected countries".

1. Absolute Patenting Rates

The Figure below shows historical changes in the number of patents granted annually to residents of the 15 countries that were issued the largest number of patents in 2015. "China Combined" refers to patents granted to residents of the People's Republic of China, Hong Kong and Macau, which I will refer to collectively as "China". By this absolute measure, the United States and, to a significantly lesser extent, Japan are the most intensive users of the USPTO. Both the U.S. and Japan exhibit increasing absolute grant rates starting in the mid-1980s and then increasing sharply through the 1990s and 2000s.

[32] For purposes of this calculation, I treated the U.S.S.R. and the Russian Federation as a single entity. Based on that assumption, the combined entity crosses the 10,000 patent threshold for this period. Note also that the USPTO data credits to "Germany" the patents granted to East and West Germany. The selected countries are (in declining order of total patents granted during 1965-2015): USA, Japan, Germany, United Kingdom, Korea, France, Taiwan, Canada, Switzerland, Italy, Sweden, Netherlands, China Combined, Israel, Australia, Belgium, Finland, Austria, India, Denmark, Spain and Russia/USSR.

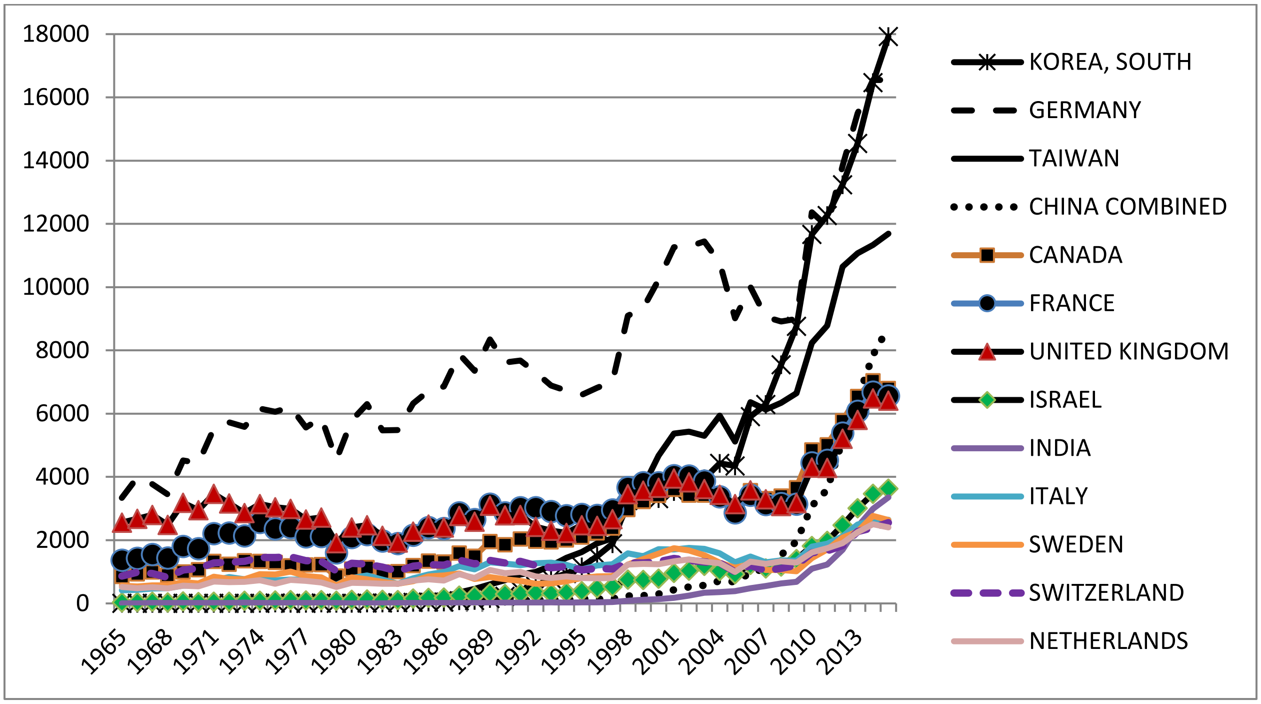
Figure VI: Top 15 USPTO Grantee Countries (1965-2015)[33]



If we remove the two patenting leaders, U.S. and Japan, we can observe the sharp increases in patenting rates starting in the late-1990s, measured in absolute terms, among Taiwan and Korea, with the latter overtaking Germany in 2015. Remarkably, Taiwan now substantially exceeds the patenting rates of larger countries such as France and the United Kingdom, which had occupied the 3rd and 4th positions in USPTO patenting rates in 1965.

33 Author's calculations, based on: USPTO, EXTENDED YEAR SET – ALL TECHNOLOGIES (UTILITY PATENTS) REPORT, PART A1 (last modified Feb. 15, 2017). Countries appear in the legend based on their ranking in terms of patents issued in 2015.

Figure VII: Top 15 USPTO Grantee Countries (1965-2015), Ex-U.S. and Japan[34]



2. *Per Capita* Patenting Rates

To better compare patenting activities across countries irrespective of the size of a country's population, I determined the per capita patent grant rates for the selected countries. Below I show the changes in annual per capita patent grant rates for the selected countries with the 15 highest per capita patent grant rates in 2015.[35] Per capita is defined as per 1 million resident population.

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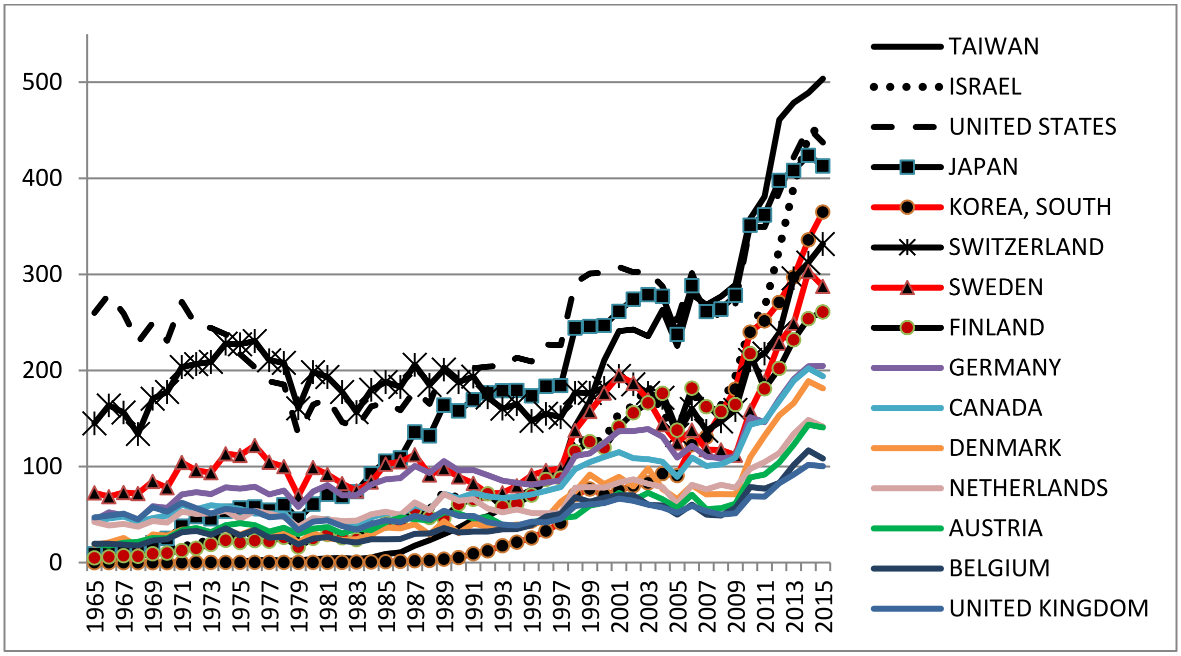
34 Author's calculations, based on: USPTO, EXTENDED YEAR SET – ALL TECHNOLOGIES (UTILITY PATENTS) REPORT, PART A1 (last modified Feb. 15, 2017). Countries appear in the legend based on their ranking in terms of patents issued in 2015.

35 For details on sources and methodology, see *supra* note 30. Note that Singapore and Norway place among the top 15 countries on a per capita patenting basis for 2015 (12th and 15th respectively); however, they are not included in the group above because they do not qualify as a "selected country" (that is, they did not accumulate at least 10,000 patents during 1965-2015).

Figure VIII: Top 15 USPTO Grantee Countries (per 1M population) (1965-2015)[36]



The graph supports several interesting observations.

First, use of the per-capita measure provides a more insightful sorting of high-patenting and low-patenting countries. In particular, use of the per-capita measure eliminates three large countries that had appeared as leaders when assessed on an absolute basis: Italy, France, and China Combined, which are replaced by four smaller countries, Finland, Denmark, Belgium and Austria. Additionally, a larger and developed country, the United Kingdom, moves down to last, while other smaller and late-developing countries move up (most notably, Taiwan and Israel, which are now the first and second-place countries in patenting rates, measured on a per capita basis).

Second, all countries in the group have shown increased per capita patent grant rates as compared to 1965. As of 1965, only two countries, the U.S. and Switzerland, had per capita patenting rates in excess of 100 patents/1 million population; as of 2015, every country had crossed that threshold.

Third, the period from 1965 through approximately the mid-1990s is a dormant period of little growth (but no significant decline) in per capita patenting rates for almost all countries. However, in the case of the United States (as previously noted) and, to a lesser extent, Switzerland, this is a period of significant decline in per capita patenting rates starting in the early to mid-1970s. An exception to both trends is Japan and Taiwan, which show a significant increase in patenting rates starting in the late-1980s and lasting through the present.

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36 Countries appear in the legend corresponding to their ranking in terms of per capita patent grants in 2015.

Fourth, the period from the late-1990s through the present is a period of significant growth in per capita patenting rates for all countries. This period is characterized by two "explosions" in patent issuance. The first commences in the late 1990s and, in the case of the United States and Switzerland, represents a return to pre-1972 patenting levels. Patenting rates then subside approximately in 2004 and a second and steeper increase in patenting rates commences, starting in 2010.

Fifth, during the two significant increases in patent issuance, there is more heterogeneity in patenting rates across countries as compared to any prior period in the data presented above. As of 2015, per capita patenting rates ranged from slightly more than 100 per 1 million population in the case of the United Kingdom to slightly more than 503 in the case of Taiwan. By contrast, as of 1965, all countries except the United States and Switzerland (later joined by Japan in the mid-1980s) were clustered together at values around or below 50 patents per 1 million population. More specifically, as of 2015, we can distinguish three groups of countries based on per capita patenting rates. Within each group, countries are listed by descending order of per capita patenting rates. In each case, *x* denotes the ratio of patents to 1 million residents as of 2015.

(i) Group I (x > 400 patents per 1M): Taiwan, United States, Israel, Japan.
(ii) Group II (200 < x < 400): Korea, Switzerland, Sweden, Finland, Germany.
(iii) Group III (x < 200): Canada, Denmark, Netherlands, Austria, Belgium, United Kingdom.

The Group I countries, which show the highest per capita patenting rates, consist of two expected members, the United States and Japan, the world's two largest developed economies. Both countries are home to the world's leading firms in two patent-intensive industries—namely, information technology (in the case of Japan and the U.S.) and biopharmaceuticals (in the case of the U.S.). Both countries have well-developed science and engineering education systems, rich consumer markets for technology-intensive products and, in the case of the U.S., rich capital markets to fund the commercialization of technology-intensive products. Some of those same characteristics are true of the Group II and III countries, which are (with the exception of Canada and Korea) Western European countries that have access to rich consumer and capital markets. Canada is in a similar situation insofar as it has easy geographic (and linguistic) access to the rich consumer and capital markets of its neighbor. Korea has a moderately sized consumer market (15th in the world as of 2014, representing 1.76% of world household consumption[37]) but a relatively undeveloped capital market.[38]

Two smaller countries, Israel and Taiwan, appear in Group I and do not share these characteristics. Two points are notable about these countries. First, unlike the other members of Group I and most members of Group II and III (Korea being the exception), both countries (especially, Taiwan) started from extremely low to low rates of patenting, both in absolute and per capita terms, as of the mid-1980s. Even when measured in absolute terms, both of these small countries appear among the top 10 recipients of U.S. patents as of 2015, as noted above. When measured on a per capita basis, these countries move to the top of *all* countries as of 2015. Israel and Taiwan have become USPTO patenting

[37] THE WORLD BANK, HOUSEHOLD FINAL CONSUMPTION EXPENDITURE (constant 2005 $US) (current as of 2014, based on World Bank and OECD national accounts data), avail. at http://data.worldbank.org/indicator/NE.CON.PRVT.KD.

[38] OECD ECONOMIC SURVEYS: KOREA 2014 (noting limited capital for entrepreneurial firms in Korea, in part due to dominance of conglomerate firms).

powerhouses (on a per capita basis and, to a lesser extent, even on an absolute basis) in a remarkably short time. In 1985, Taiwan had 9 and Israel had 44 patents per 1 million population; as of 2015, Taiwan had 504 and Israel had 457 patents per 1 million population. Second, also unlike the other members of Group I (and, if we treat the European market as a single market, all other members of Groups II and III, with the partial exception of Korea), Israel and Taiwan do not have rich consumer or capital markets.

3. Per GDP Patenting Rates

Another measure that can provide insight into comparative levels of USPTO patenting activity irrespective of population differences is "per GDP" patenting rates, which yields a measure of "patent productivity".[39] Specifically, I measured each selected country's annual patenting rates per billion dollars of that country's annual GDP (in constant 2010 dollars). For the period 1980-2015, the graph shows annual patent productivity for the selected countries with the 15 highest patent productivity scores as of 2015.[40]

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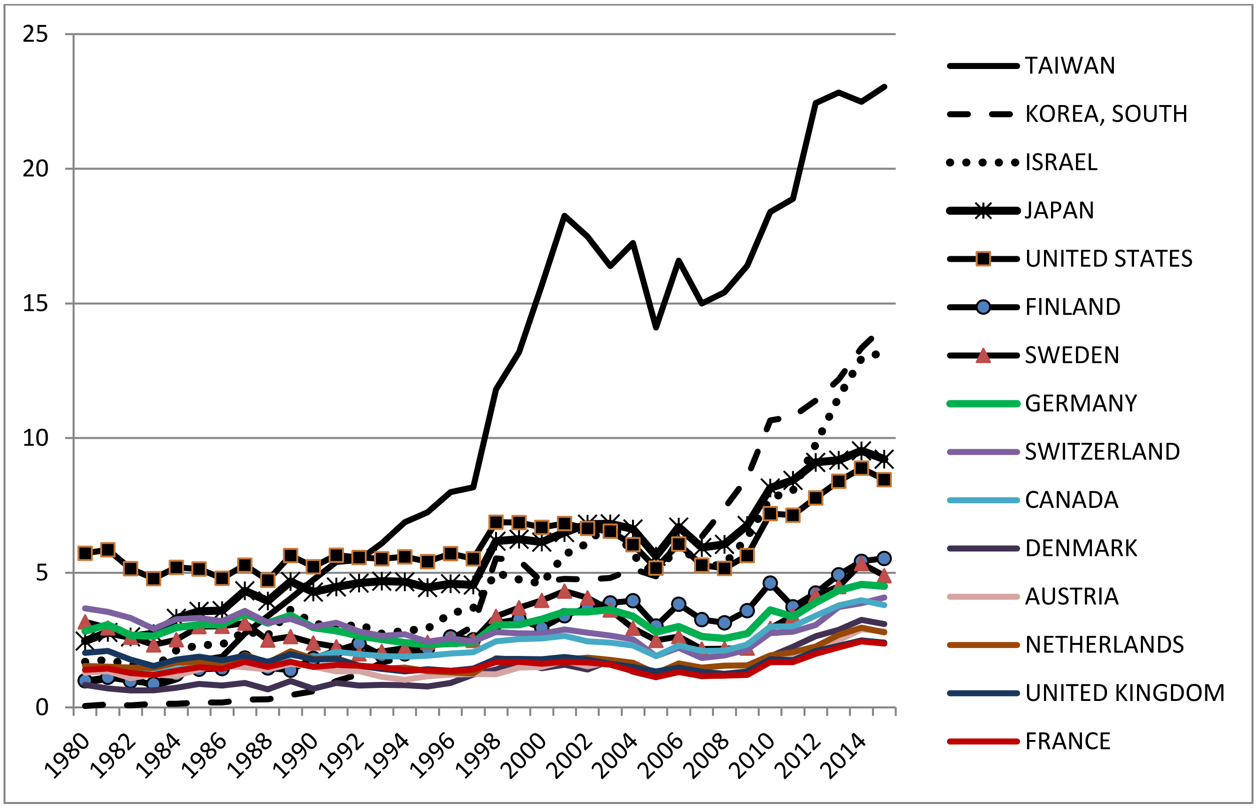
[39] I borrow the phrase from Richard Gruner, who performs a similar analysis of country-level USPTO patents/GDP ratios but covers a smaller set of countries and shorter time period (specifically, patents issued for applications that were filed during 1977-2001 and granted by 2006). *See* Richard S. Gruner, *The World as Our Technologist: Visualizing Worldwide Sources of Technologies Patented in the United States*, J. L. TECH. & POL'Y (2013). Prof. Gruner also uses a different patent dataset compiled by the National Bureau of Economic Research, which bases national affiliation on the location of the assignee. By contrast, I rely on USPTO data that bases national affiliation on the residence of the first-named inventor.

[40] Source for GDP figures: U.S. DEPT. OF AGRICULTURE, ECONOMIC RESEARCH SERVICE, INTERNATIONAL MACROECONOMIC DATA SET, REAL HISTORICAL GROSS DOMESTIC PRODUCT AND GROWTH RATES OF GDP FOR BASELINE COUNTRIES/REGIONS (in billions of 2010 dollars) 1980-2015 (updated Sept. 21, 2016). Avail. at: http://www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx. These figures are based on "World Bank World Development Indicators, International Financial Statistics of the IMF, IHS Global Insight, and Oxford Economic Forecasting, as well as estimated and projected values developed by the Economic Research Service all converted to a 2010 base year." *See id.* GDP data for 2015 and, in limited cases, 2014 are based on forecasted growth rates. Note that, in the case of Germany, the dataset treats East and West Germany as if the two countries were a single country throughout the period above. For purposes of these calculations, I attributed all of the USSR's patents to Russia but used the GDP figures for Russia only; although this artificially increases Russia's per GDP patenting rates, this is immaterial because Russia still lags far behind the other "selected" countries for which I calculated these rates. Note that Singapore would place 10th among all countries in terms of patents per GDP but is not included because it does not fall within the category of a "selected country".

Figure IX: Top 15 USPTO Grantee Countries (Per Billion USD GDP) (1980-2015)[41]



The patents/GDP measure yields rankings that are similar to the rankings derived by comparing patenting volume on a per capita basis. As in the per capita rankings, China and some large developed countries are either absent (Italy and Spain) or at the bottom of the list (United Kingdom and France). From 1980 through the late 1990s, patent productivity measures for all countries except the United States (and, starting in 1993, Taiwan) clustered below 5 patents per 1 billion USD GDP. With the exception of the United States, Japan, Taiwan, Israel and Korea (and, since 2014, Finland), all other countries have remained below the 5 patent per 1 billion USD GDP threshold. The U.S. does not significantly outperform other countries during much of this period, maintaining patent productivity measures during 1980-2010 at 5-6 patents per 1 billion USD GDP. Starting in 2006 and through the present, Japan and all the patent tigers have outperformed the U.S. in terms of patent productivity.

These results have an important implication. As Richard Gruner has documented over a shorter time period ending in 2011, U.S. patent productivity trends run contrary to widespread views that the U.S. has suffered from an "explosion" of patenting activity.[42] Under the per GDP measure of patent issuance, the U.S. experienced no significant increase in patent productivity from 1980 until 2010. By contrast, Japan and the patent tiger countries have exhibited a significant increase in per GDP patenting activity starting in the late 1990s (in the case of Taiwan, starting in the early 1990s). Hence, both the per capita

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41 Countries are listed in the legend in declining order of their utility patent/GDP rate, as of 2015.

42 See Gruner, *supra* note 39.

and per GDP measures undercut the standard view that the U.S. has experienced an abnormally high level of patenting activity. At least until 2010, that proposition is only true with respect to foreign inventors.

As of 2015, the per GDP measure identifies three clusters of countries, as shown below. Within each group, countries are listed by descending order of per GDP patenting rates. In each case, *x* denotes the ratio of patents to 1 billion USD GDP.

(i) Group I (x > 10 patents per1 billion USD GDP): Taiwan, Korea, Israel.
(ii) Group II (5 < x < 10): Japan, United States, Finland.
(iii) Group III (x < 5): Sweden, Germany, Switzerland, Canada, Denmark, Netherlands, Austria, United Kingdom and France.

In contrast to rankings based on absolute patents or the per capita measure, the world's patent powerhouses, the United States and Japan, are not the world's leaders when evaluated on the basis of patents/GDP, although they remain closely behind. Taiwan and Israel are again members of Group I, which further confirms these countries' "patent tiger" membership. Given that Korea ranks fourth in terms of absolute patent grants and fifth in terms of per capita patent grants and now just exceeds Israel on a patents per GDP basis, it seems appropriate to place Korea among the "patent tigers".[43] Like Israel and Taiwan, Korea has become a patent powerhouse in a relatively short time since the late 1990s. In 1985, Korea was granted .18 patents per 1 billion USD GDP (the lowest among the countries set forth above); in 2015, it was granted over 14 patents on that same basis (second place, after Taiwan). Like Israel and Taiwan, it is a late-developing country; as mentioned, partially like Israel and Taiwan, it has moderately but not large-sized consumer and capital markets.

III. Patent Tigers or Patent Factories?

Based on multiple measures, we have identified three countries that are the most intensive users of the USPTO system, outmatching to a significant extent all other countries, except the U.S. and Japan (which they match or outmatch on some measures). We are now in a position to consider whether those measures of patenting intensity are reasonably reliable indicators of innovative performance. Economic analysis of innovation has long used patents as a proxy for innovative performance. This is in part due to convenience: patents are an easily measured output indicator and may not be any less reliable than alternative measures of innovative output. Nonetheless patents are inherently an imperfect proxy for innovative performance.[44] The concern is easily illustrated. Jurisdiction A may generate more innovative output (by some non-patent measure) than jurisdiction B even though it invests fewer resources into patenting. In particular, there may be a concern that jurisdiction B is investing resources into acquiring patents strategically as a litigation tool, an entry-blocking device against competitors, or a bargaining chip in licensing negotiations, in which case patenting output would not reflect innovative activity.

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[43] A more broadly defined group of patent tigers would include Switzerland, Sweden and Finland, all of which placed highly in both the per capita and per GDP rankings. If we lift the 10,000 total patent threshold (that is, 10,000 patents issued total during 1965-2015), then Singapore would join that group as well.

[44] *See* Zoltan J. Acs and David Audtresch, *Patents as a measure of innovative activity,* 42 Kyklos 171-180 (1989). For an overview, see Zvi Griliches, *Patent statistics as economic indicators: a survey*, 28 J. Econ. Lit. 1661 (1990); Ariel Pakes and Zvi Griliches, *Patents and R&D at the firm level: a first report,* 5 Econ. Letters 377, 383 (1980).

While sensible in theory, this concern should not be overstated: when tested empirically, there is evidence that patents are a fairly reliable proxy for innovative output at the industry level, state level and metropolitan area level.[45] Nonetheless, some legitimate concern persists. In this Section, I use multiple measures to gain insight into the productive or unproductive motivations behind the tiger countries' investments in acquiring USPTO patents. Each of the patent tigers scores highly on all but one measure, which tends to exclude the "patent factory" concern.

A. Patent Quality

1. Success Rates

The rate at which applications from residents of a particular country are granted by the USPTO, as compared to applications from residents of other countries, can provide evidence as to whether that country's patent intensity levels are reflective of underlying innovative strength.[46] If a given country is patenting intensively but has a low success rate compared to other countries, that suggests that its high patenting levels are not reliably indicative of R&D capacities; and *vice versa.* For the period 1980-2013[47], the data discussed below indicate average annual success rates for patent applications filed by residents of each of the tiger countries, as compared to two benchmarks: (i) the average annual success rate for all non-U.S. filers; and (ii) the average annual success rate for U.S. filers. With reference to both benchmarks, a similar two-stage pattern is apparent. In the early part of the period, the tiger countries perform poorly compared to both benchmarks. In the later part of the period, all tiger countries exhibit improved performance, in some cases exceeding the benchmarks. Korea outperforms both benchmarks, Taiwan approximately matches both benchmarks, and Israel intermittently approaches and moderately underperforms the benchmarks. Starting in 2010, however, all the tiger countries approximately match both benchmarks. This pattern suggests that the tiger countries took time to learn how to achieve higher levels of patent quality, which may imply greater skill in navigating the USPTO application process, greater R&D capacities, or a combination of both. Alternatively, the initially lower success rates may be attributable to the relatively small number of patents filed by the tiger countries during those years, which may have translated into more volatile quality across the country's patent portfolio. While these results tend to support confidence in the quality of the tiger countries' patents, they are subject to certain methodological constraints.

a. Methodological Issues

There is an ongoing and unresolved debate over the appropriate methodology to most precisely estimate the rates at which patent applications are ultimately granted by a patent office (variously called

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[45] See Acs and Audtresch, *supra* note 44; Zoltan J. Acs, Luc Anselin, Attila Varga, *Patents and innovation counts as measures of regional production of new knowledge,* 31 RESEARCH POLICY 1069 (2002).

[46] I am aware of two prior efforts by economists to assess historical success rates among U.S. patentees, see Michael McAleer & Daniel Slottje, *A new measure of innovation: the patent success ratio,* 63 SCIENTOMETRICS 421 (2005), and one other comparative study that assess success rates of Israeli patentees as compared to a reference group of countries during 1968-1997, see Trajtenberg (1999), *supra* note 6. In both cases, the authors do not address the methodological challenges raised by examination lag and continuation patents. I discuss those issues below.

[47] While data exist for the period prior to 1980, the tiger countries' patenting levels were so low during this period that comparing success rates would not be a reliable indicator of patent quality. The year 2013 is chosen due to the examination time lag between application and grant (or abandonment), as discussed further below.

"success rates", "grant rates" and "allowance rates", each with its own definition). The success rates shown in the graphs below are "uncorrected" because I make two simplifying assumptions. First, I calculate success rates by dividing (i) the number of patents issued to residents of that country in a given year by (ii) the number of patent applications filed by a particular country's residents two years earlier.[48] The two-year period was selected based on the average historical range of lag times at the USPTO[49], but it is inherently imprecise in the case of a particular application (or in the case of technology classes that tend to have longer or shorter lag times compared to the average). Second, I rely on USPTO applications data, which does not distinguish between "parent" applications and related types of "continuing" applications. A continuing application refers to several categories of patent applications that an applicant may file at the USPTO to claim different aspects of, or improvements to, an invention disclosed in an original application or to resume prosecution of a previously filed application. Failure to distinguish between these different types of continuing applications in the USPTO data may result in imprecise estimates of the "true" success rate. [50] Nonetheless, if these sources of imprecision impact all countries to an approximately equal extent, then it would still be insightful to examine the *relative differences* in the success rates across filers from different countries, even if the *absolute values* may not be fully reflective of "true" success rates in the case of any specific country in any given year.[51] That is the approach I follow below.

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[48] For the source of this country-specific application and grants data, respectively, see: USPTO, NUMBER OF UTILITY PATENT APPLICATIONS FILED IN THE UNITED STATES, BY COUNTRY OF ORIGIN, CALENDAR YEARS 1965 TO PRESENT (avail. at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm);USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY, STATE, AND YEAR – UTILITY PATENTS (December 2015) (avail. at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utlh.htm).

[49] Subject to rounding, the two-year assumption is consistent with USPTO data on average pendency times (28.2 months during 1996-2014). Note that the USPTO defines the pendency rate as the total time from filing of a patent application until it is abandoned or a patent issues. *See* USPTO, ANNUAL REPORT, FISCAL YEAR 2014, at 41. This assumption is largely consistent with the most comprehensive empirical study of time-to-grant lags (mean grant lag of 28 months and a median grant lag of 23 months) at the USPTO during 1976-1996, see David Popp, Ted Juhl, and Daniel K.N. Johnson, *Time in Purgatory: Determinants of the Patent Lag for U.S. Patent Applications*, Nat'l Bureau of Econ. Res. Working Paper No. 9518 (2003). Note that there is no evidence indicating significant differences in lag times as a function of the applicant's country of residence, although there are differences across certain technology classes. *See* Popp et al., *supra* note 49.

[50] Both overestimates and underestimates can result. On the one hand, to avoid artificially decreasing the total number of applications (that is, the denominator) and thereby overestimate the success rate, it is necessary to include continuing applications that represent improvements to the invention covered by the parent application. On the other hand, to avoid artificially increasing the total number of applications and thereby underestimate the success rate, it is necessary to exclude certain types of continuing applications that solely resume prosecution of claims included in prior applications. For the most ambitious studies to address these concerns (but not on a country-specific basis), see Michael Carley, Deepak Hedge & Alan Marco, *What is the Probability of Receiving a Patent?,* Working Paper No. 2013-2 (USPTO Economics Working Paper); Ron D. Katznelson, *Bad Science in Search of Bad Patents,* 17 FED. CIR. BAR J. 1, 8-16 (2007). For a study that measures allowance rates on a country-specific basis for India, Korea and China, see Jay P. Kesan, Alan Marco & Richard Miller, *More Than Bric-A-Brac: Testing Chinese Exceptionalism in Patenting Behavior Using Comparative Empirical Analysis,* 22 MICH. TELECOMM. & TECH. L. REV. 53 (2015).

[51] I note that, based on a definition of "allowance rate" as the number of issued patents in a given month divided by the number of "completed cases" (issuance of a patent or abandonment), Prof. Dennis Crouch finds trends for the period 1986-2015 that are directionally similar to the trends I found using the success ratio measure described above. In particular, Crouch observes a noticeable increase in grant rates during 1998-2001 and then a continuous decline through 2010. *See* Dennis Crouch, *USPTO Allowance Rate,* Patentlyo, Aug. 10, 2015, at http://patentlyo.com/patent/2015/08/uspto-allowance-rate.html. I observed the same pattern but the timing is about

b. Benchmark I: Non-U.S. Filers

The success rate of non-U.S. Filers (the "All-Ex-US" rate) provides a useful benchmark for assessing the patent quality of the tiger countries' applications. The rationale is as follows. USPTO applications filed by foreign filers should in general be of higher quality than applications filed by U.S. filers. That is because foreign filers are likely to file applications at the USPTO for higher-value applications since it requires incurring an additional cost after, as is typical, the filer has already obtained a patent in its home jurisdiction. By contrast, there is no inherent selection effect in the case of U.S. filers, which should therefore in general file applications of lower patent quality (assuming an equal distribution of R&D capacity and patent prosecution skills across countries).[52]

The graph below shows percentage deviations in the average annual uncorrected success rate for each selected country relative to the average annual uncorrected success rate for All-Ex-US filers. This comparison supports several observations. First, consistent with the assumption stated above, in all but two years, U.S. patent applications exhibited lower success rates compared to non-U.S. patent applications. Second, during the earlier part of the period, the tiger countries significantly underperform the All-Ex-US benchmark. Third, in the later part of the period, the tiger countries show significantly improved performance. Starting in 1988, Korea approaches and then exceeds the success rate for All-Ex-US filers for most years thereafter. Starting in 1992, Taiwan approximately matches the benchmark but occasionally falls below it thereafter. Starting in 1996, Israel approximately matches the benchmark but periodically falls significantly below it.[53] Since 2011, all tiger countries have exhibited comparable uncorrected success rates as compared to the benchmark. While Israel's lower success rate compared to Korea and Taiwan should raise some concern, this has not been the case since 2011 and citation frequency data discussed below generally place the patent quality of Israeli filers above that of Korea and Taiwan.[54] Additionally, the lower success rate for Israeli applications may reflect the fact that a significant percentage of Israel's patent application portfolio consists of life sciences applications, which tend to have a lower success rate as compared to other technology classes.[55]

two years earlier throughout, most likely due to the fact that I measure success rate by reference to the year of the filing, not the year of issuance.

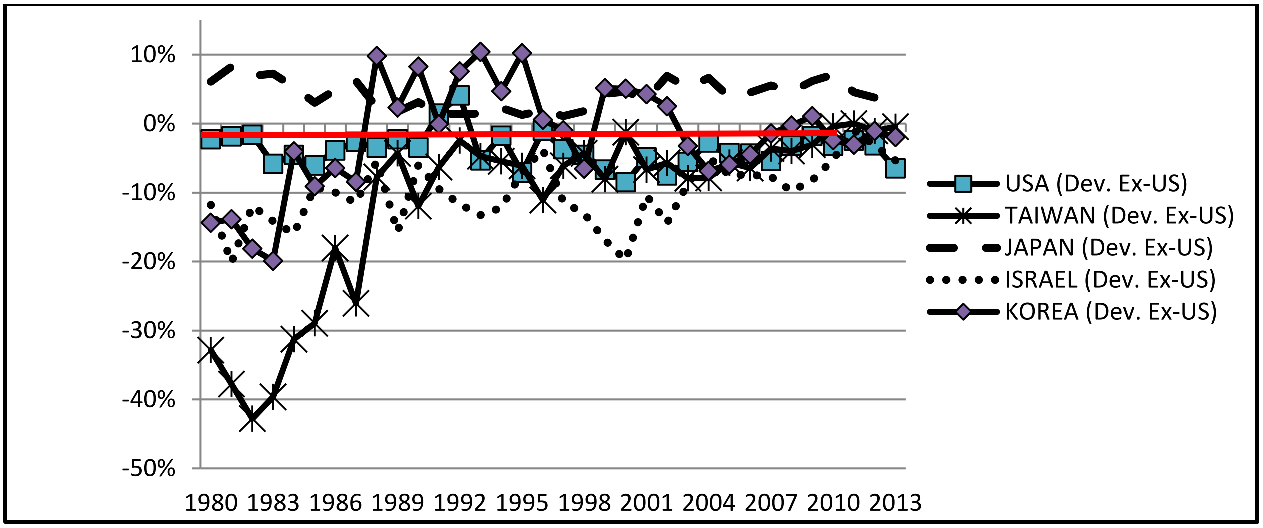
[52] For a similar assumption, see WILLIAM KINGSTON & KEVIN SCULLY, PATENTS AND THE MEASUREMENT OF INTERNATIONAL COMPETITIVENESS 8 (2006).

[53] In related data from an earlier period (1968-1997), a study found that Israeli and Taiwanese applications at the USPTO had lower success rates compared to "G7" countries. *See* Trajtenberg (1999), *supra* note 6, at 12 Tbl. 2.

[54] *See infra* Part IV.A.2.

[55] *See* Hedge et al., *supra* note 50, at 21 Tbl. A5.

Figure X: Performance Relative to Uncorrected Average Annual Success Rate for USPTO Utility Patent Applications by Non-U.S. Filers (1980-2013)[56]



c. Benchmark II: U.S. Filers

Given the selection effect described above, it is useful to assess whether the tiger countries *exceed* U.S. success rates. The graph below shows percentage deviations in the average annual uncorrected success rate for each selected country above relative to the average annual uncorrected success rate for U.S. filers. Consistent with the selection effect, Korea has outperformed or matched the U.S. benchmark in all but one year starting in 1988. Since 1993, Taiwan has approximately matched or, consistent with the selection effect, slightly exceeded the U.S. rate with the exception of a single year. Israel's performance is more variable: since 1988, it has periodically approached, matched, and sometimes underperformed the U.S. benchmark, although since 2011, it has matched the U.S. benchmark. While the mixed performance of Israeli patents may raise some quality concerns, that concern does not apply after 2011 and citation frequency data discussed subsequently suggest that patents issued to Israeli filers are of especially high quality.[57]

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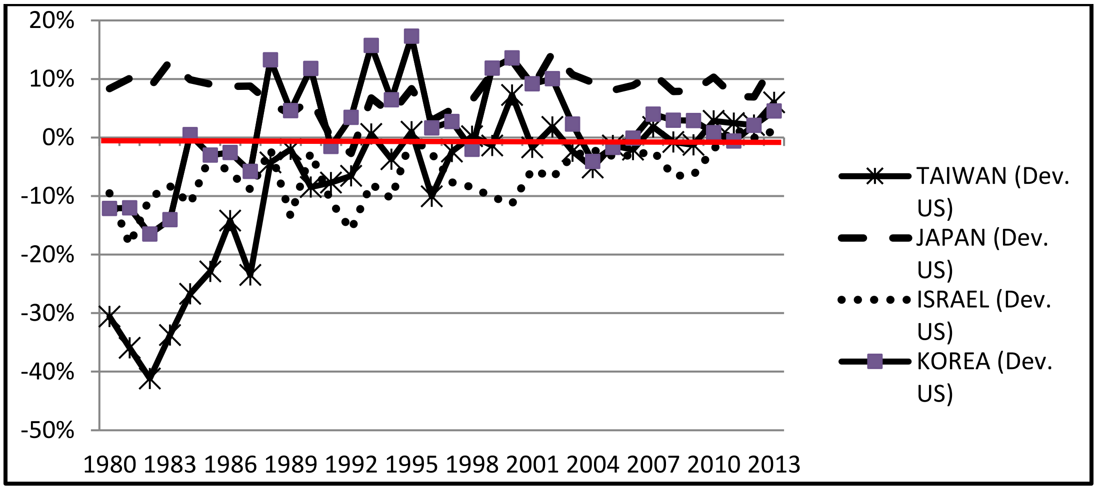
56 Parenthetical abbreviation refers to "Deviation from Ex-US filers' average annual uncorrected success rate".

57 On Israeli' patents' high citation frequency, see *infra* Part IV.A.2. There is another factor that may account for the superior performance of patents issued to Korean filers, as compared to patents issued to Israeli and Taiwanese filers. The reason is that inventors resident in Israel and Taiwan appear to often use the U.S. as the first office in which a patent application is filed. In the case of Israel and Taiwan, existing data on filing behavior by foreign small entities during 1994-2003 showed that USPTO applications constituted the filer's first application anywhere in the world about 60% of the time in the case of Israel and almost 92% of the time in the case of Taiwan. *See* KINGSTON & SCULLY, *supra* note 52, at 12, 95. While this data relates solely to small entities (and cannot necessarily be generalized to all patenting activity by filers from these countries), the observed pattern is not surprising since each country's domestic market is commercially insignificant in relative terms (within the global market) and therefore, filers may conclude that it is not worthwhile to expend filing fees on a local application. By contrast, Korea, which does have a sizable domestic market, apparently follows the more typical pattern: in the case of small entities during 1994-2003, the U.S. application was the filer's first application in less than 19% of all cases (*see* KINGSTON & SCULLY, *supra* note 52).

Figure XI: Performance Relative to Uncorrected Average Annual Success Rate for USPTO Utility Patent Applications by U.S. Filers (1980-2013)[58]



2. Citation Rates

A commonly used measure to assess patent quality is citation rates. Specifically, researchers use the number of times a particular patent is cited by other patentees (so-called "forward citations") as prior art as evidence of the patent's value. Citation data support a fairly consistent catch-up pattern in the case of each of the three tiger countries, which mimics the catch-up pattern identified above using the success ratio measure. While these countries initially lagged behind the patents of developed countries to some extent (with variation across technology sectors), it is currently the case that tiger countries' patents are typically comparable in quality to the patents of inventors from the U.S. and match or exceed the quality of other large industrialized countries.

a. General Citation Studies

A study released by the U.S. Office of Technology Policy found that, during 1982-1996, the citation quality (as measured by a "Current Impact Index") of USPTO patents issued to Israeli and Taiwanese filers in the information technology sector approximately matched or exceeded the citation quality of USPTO patents issued to U.S. filers, although Taiwanese and Korean (but not Israeli) patents trailed U.S. patents in citation quality in the advanced materials and biopharmaceutical sectors.[59] The most comprehensive and updated study examined citation counts during 1980-2011. The authors found that patentees from Israel, Taiwan and especially Korea initially lagged significantly behind U.S. patentees in terms of citation count but had almost matched the quality of U.S. patentees by the 1990s

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58 Parenthetical abbreviation refers to "Deviation from US filers' average annual uncorrected success rate".

59 *See* MICHAEL B. ALBERT, THE NEW INNOVATORS: GLOBAL PATENTING TRENDS IN FIVE SECTORS 31, Fig. 7 (2000). The "Current Impact Index" measures citation quality by comparing the citation count for a particular country's patents in a particular sector during a rolling five-year period against the expected citation count of all patents in that sector during the same period. As compared to other citation measures, the index is intended to correct for the fact that citation frequency can differ across industry sectors.

and, with a modest reversal in the case of Korea and Taiwan, continued at that level through the 2000s. [60] (Note that no country in the 15-country sample (which included Japan and other major developed countries) exceeded the U.S. citation count.) Consistent with the pattern observed in the uncorrected success rates presented above, it appears that the tiger countries acquired over time R&D (and patent prosecution) skills as they entered the patenting market and then matched or approached the patent quality (as measured by citation counts) of developed countries once those skills had been acquired.

b. Small-Entity Patentee Study

A study commissioned by the World Intellectual Property Organization examined patenting behavior by foreign small entities at the USPTO during 1994-2003.[61] In the case of Israel and Taiwan, this represents more than half of the patents issued to residents of those countries by the USPTO during this period (specifically, 56% of patents issued to Taiwanese filers and 52% of patents issued to Israeli filers). For Korea, this represented only 14.4% of patents issued to Korean filers during this period[62], so the results may not be indicative of the quality of patents issued to Korean filers generally. The study compared the citation frequency of patents issued by the USPTO to small entities from the U.S. and other countries. For these small entity patents, the tiger countries performed as follows: during 1994-2002, 27.9% of Israeli small entity patents, 21.4% of Korean small entity patents, and 27.5% of Taiwanese small entity patents issued during that period were cited at least three times.[63] While this compares unfavorably with U.S. small firm patents (37.9% were cited at least three times), it compares favorably in the case of Israel and Taiwan with all other significant users of the USPTO system, including Japan (26.8%), Canada (30.4%) and Western European countries (ranging from 17% in the case of Spain to 27.9% in the case of Ireland).[64]

B. **Innovation Inputs**

While imperfect, data on success rates and citation frequency bolster confidence that the tiger countries' high levels of USPTO patenting activity largely reflect innovative activity, rather than strategic actions for litigation, bargaining or other "unproductive" purposes. To gain further insight, I review below evidence on the "innovative health" of the tiger countries. Specifically, I review data relating to two key inputs into any innovation economy: (i) human capital and (ii) the R&D investment that cultivates human capital in order to generate innovative output. On both parameters, the tiger countries perform well, matching or exceeding all other intensive users of the USPTO. Additionally, I review

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60 *See* Soonwoo Kwon, Jihong Lee and Sokbae Lee, *International Trends in Technological Progress: Evidence from Patent Citations, 1980-2011*, ECON. J. (2015).

61 *See* KINGSTON & SCULLY, *supra* note 52. Small entities were entities that filed for patents under "small entity" status, which is typically reserved for nonprofit organizations and entities that meet the Small Business Size Standards established by the Small Business Administration. Generally, the "SBA" definition captures entities with less than 500 employees, but firms in some industries are subject to different numerical or financial thresholds. For a summary, see KINGSTON & SCULLY, *supra* note 52, at 15.

62 *See id.*, at 15, 93.

63 For figures relating to Israeli and Korean patents, *see id.*, at 64; for Taiwan, *see id.*, at 98. Note that the distribution of citation counts is highly skewed—meaning, most patents are rarely cited or only cited once or twice. *See* ALBERT, *supra* note 59.

64 *See* KINGSTON & SCULLY, *supra* note 52.

evidence on the technology balance of payments for each country; Israel does well on this measure, but Korea and Taiwan do not.

1. **Human Capital**

A critical element in any robust innovation ecosystem is a pool of human capital with skills suited for technological innovation and commercialization. This can be assessed in terms of inputs and outputs. The data support a simple conclusion: the tiger countries invest heavily in higher education and scientific research institutions and, as a result, produce a significant volume of scientific research and qualified technical personnel.

a. Inputs – Educational Institutions

Inputs can be measured by the number of students enrolled in higher education and specifically, fields of study relating to science and engineering. As of 2015, the OECD and Taiwan reported the following figures for the number of students who completed higher education degrees as a percentage of adults aged 25-64 years: (i) Israel – 49%; (ii) Korea – 45%; and (iii) Taiwan (25 and over, as of 2014) – 35.59%.[65] This compares favorably with Japan (28%); and (ii) the U.S. (44%).[66] For a more up-to-date view, it may be more appropriate to focus on the population aged 30-34 years old. Again as of 2015, the tiger countries continue to compare favorably: (i) Israel (54%); (ii) Korea (69%); (iv) Japan (37%, for ages 25-34 years old); and (v) U.S. (47%).[67] If we examine data (as of 2002 and 2012, respectively) on the percentage of students entering higher education institutions in engineering and science-related fields, the tiger countries excel, as compared to the U.S.: (i) Korea (39%, 32%) (highest in the world); (ii) Japan (26%, 23%); (iv) Israel (22%, 19%); and (iv) the U.S. (16%, 16%).[68] The tiger countries compare favorably if we examine data (as of 2012) on the percentage of GDP invested in educational institutions: (i) Korea (6.7%); (ii) Israel (6.5%); (iii) the U.S. (6.4%); and (iv) Japan (5%).[69]

b. Outputs – Scientific Publications; R&D Personnel

The tiger countries' investment in higher education yields favorable outputs in terms of the quality of higher education institutions, the volume of scientific publications and the number of R&D personnel. According to the OECD's 2013 ranking of the top 50 universities, only 7 countries can claim universities in this elite group, of which the United States has 34, Taiwan has 2, and Israel has 1.[70] In 2012, the OECD reported the following figures for the number of full-time researchers per thousand employment: Israel – 17.4 (highest in the world); Korea – 12.8; USA – 8.7; Japan – 10; and Taiwan –

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65 OECD, EDUCATION AT A GLANCE 2015. SOURCE FOR TAIWAN: STATISTICAL YEARBOOK OF THE REPUBLIC OF CHINA (2014).

66 OECD, EDUCATION AT A GLANCE 2015. The data for Japan excludes "short cycle" tertiary education, which may account for Japan's surprisingly low rates on this measure.

67 *See id.* Information not available for Taiwan.

68 OECD, SCIENCE, TECHNOLOGY AND INDUSTRY SCORECARD 2015: INNOVATION FOR GROWTH AND SOCIETY (2015), at Ch. 2. Information not available for Taiwan.

69 OECD, EDUCATION AT A GLANCE 2015, Tbl B2.1, p.233. Information on Taiwan not available.

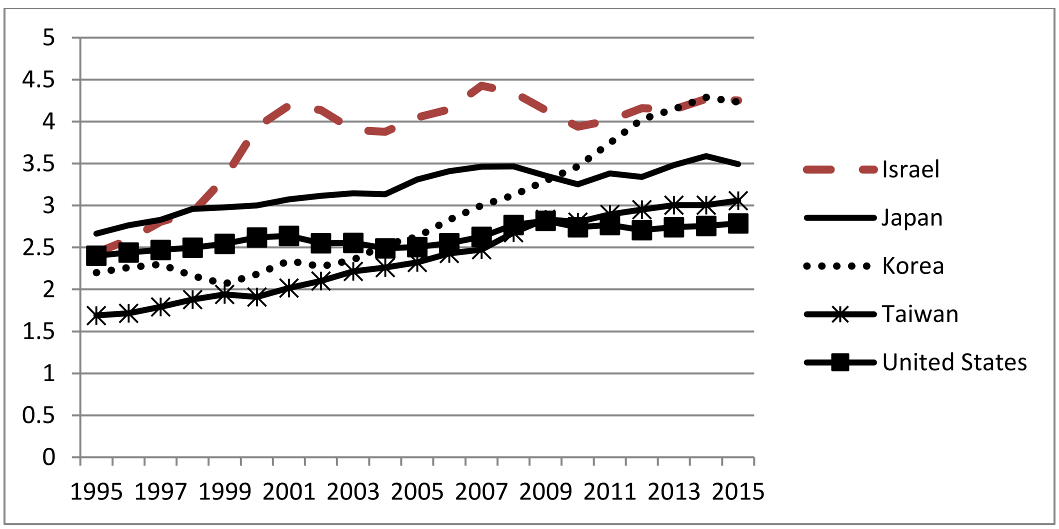
70 OECD, SCIENCE, TECHNOLOGY AND INDUSTRY SCORECARD 2013: INNOVATION FOR GROWTH (2013). The other countries with universities in the top 50 are the United Kingdom (8), Switzerland (2) and Denmark (1).

12.9.[71] Based on a ranking of countries by the annual volume of papers in the "top quartile" of scientific journals, the tiger countries excel: as of 2013, Israel had more publications per million USD GDP than the U.S., Taiwan and Korea had slightly less, and all three patent tigers exceeded Japan.[72] Based on a ranking of citations per scientific article during 1996-2014, Israel ranks highly (10th in the world), although Korea and Taiwan do not (29th and 30th in the world).[73]

2. R&D Intensity

Clearly a necessary input in any innovation economy is a high level of R&D investment, typically measured by R&D intensity (defined as R&D expenditures as a percentage of GDP) to permit comparison across jurisdictions of varying size. The graph below displays rankings for the tiger countries, along with the U.S. and Japan, during 1995-2015. The tiger countries score favorably compared to the U.S. and Japan. Based on R&D expenditures per GDP, Israel leads all five countries during 1999-2015 (except in 2014, when it is slightly overtaken by Korea). During much of the period, Taiwan approaches the U.S.'s R&D intensity levels and then exceeds it starting in 2009. Clearly, the tiger countries' high and increasing levels of USPTO activity are accompanied by high and increasing levels of R&D intensity.

Figure XI: National R&D Expenditures as Percentage of GDP (1995-2015)[74]



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71 OECD, MAIN SCIENCE AND TECHNOLOGY INDICATORS: VOLUME 2015/2. Researchers are defined as "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, as well as the management of the projects concerned." In the case of Israel, the employment figures exclude all or most defense-related R&D positions.

72 OECD, SCIENCE, TECHNOLOGY AND INDUSTRY OUTLOOK 2014. Specifically, Israel had .04 publications per million USD GDP (8th in the world), the U.S. had .03 publications (21st in the world), Taiwan had .02 publications (22nd in the world) and Korea had .02 publications (27th in the world).

73 *See* GUILLERMO LEMARCHAND, ERAN LECK AND APRIL TASH, MAPPING RESEARCH AND INNOVATION IN THE STATE OF ISRAEL 110 (UNESCO 2016).

74 OECD (2017), GROSS DOMESTIC SPENDING ON R&D (INDICATOR) (accessed Feb. 23, 2017).

3. Technology Balance of Payments

The technology balance of payments refers to the difference between (i) payments made by firms in country *X* to use or acquire IP rights held by firms located outside that country and (ii) payments received by firms in country *X* to use or acquire their IP rights from firms located outside that country.[75] Where outgoing payments exceed incoming payments, then an IP trade deficit results; in the converse case, the country enjoys an IP trade surplus. For 2014 (the last year for which the OECD makes data available for all five countries under discussion), Israel, like the U.S. and Japan, enjoyed a significant IP trade surplus ($9.96 billion, representing 3.23% of Israel's nominal 2014 GDP).[76] This further confirms the view that Israel's intensive patenting at the USPTO reflects underlying innovative strength. For the same year, however, both Korea and Taiwan showed IP trade deficits: respectively, $5.78 billion in the case of Korea (representing 0.41% of nominal 2014 GDP) and $4.26 billion in the case of Taiwan (representing .8% of nominal 2014 GDP).[77] This should raise some concern as to the extent to which Korea's and Taiwan's high levels of patenting intensity fully reflect underlying innovative strength. However, it should be noted that these countries' IP trade deficits may reflect the fact that, unlike Israel, these countries maintain significant hardware manufacturing operations located at the intermediate point of the global technology supply chain and therefore rely on technology inputs sourced from upstream R&D suppliers. I will return to this point in the case study below of Taiwan.

IV. How Patents Support Global Supply Chains

We have now established three important points: (i) over approximately the past three decades, there has been a significant increase in foreign use of the USPTO, in particular by East Asian countries and Israel, which are substantially responsible for the first "explosion" in patent issuance at the USPTO in the 1990s; (ii) the tiger countries (and Japan) are currently the most intensive foreign users of the USPTO as measured by patents issued per capita or per GDP (or, in some cases, absolute numbers of patents issued); and (iii) subject to limited qualifications, the tiger countries' intensive levels of patent acquisition appear to reflect underlying (and growing) strengths in innovative capacity and performance. In this Part, I propose an economic rationale behind the tiger countries' intensive patenting strategies. Specifically, I argue that U.S. patents have enabled the tiger countries—and, more generally, any country with strong innovation capacities but limited internal access to commercialization inputs and limited domestic consumer markets (or some combination thereof)--to overcome the transactional hazards involved in accessing the commercialization inputs and consumers located in foreign markets.

A. **Transactional Hazards in Innovation Economies**

Following Michael Porter's canonical contribution on comparative national advantage, we can situate national economies at three possible stages of development: *Factor*; *Efficiency*; and *Innovation*.[78]

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75 For a fuller definition, see OECD, MAIN SCIENCE AND TECHNOLOGY INDICATORS §1.1 (2016). "IP rights" are understood to include "patents, licenses, trademarks, designs, inventions, know-how and closely related technical services."

76 Author's calculations, based on technology payments and technology receipts reported in OECD, MAIN SCIENCE AND TECHNOLOGY INDICATORS (accessed Feb. 28, 2017). GDP figures sourced from International Monetary Fund, World Economic Outlook Database, April 2015.

77 *See id.*

78 *See* MICHAEL E. PORTER, THE COMPETITIVE ADVANTAGE OF NATIONS 546-556 (1990).

Factor economies compete on the basis of abundant natural resources and low-cost labor; *Efficiency* economies compete on the basis of process efficiencies that counteract depleting natural resources and rising labor costs; *Innovation* economies compete on the basis of innovation by developing new products, processes or both, counteracting even further depleted natural resources and even higher labor costs. In Porter's theory, successful economies convert "selective disadvantages" into "selective advantages". That is: an economy implicitly pursues competitive advantage at a particular stage of development, based on the economy's factor *dis*advantage.[79] To use one of Porter's examples: Dutch entrepreneurs addressed year-round domestic demand for fresh flowers by developing greenhouse methods for growing plants indoors, thereby overcoming a selective natural-resource disadvantage due to Holland's winter climate. Subsequently, the industry extended its newly-acquired selective advantage through investment in specialized research institutes and additional innovation in long-distance transport and refrigeration, which enabled it to dominate foreign markets for the same product.[80]

In technology-intensive markets, Porter's theory requires modification because it does not address the transactional hazards encountered by an economy that seeks to move into the *Innovation* stage. Specifically, it does not address the transactional hazards inherent to exchanges involving informational assets that move between entities located at different levels of a technology supply chain. As the literature on technology transfer has observed, any upstream-downstream interaction in a disaggregated supply chain may involve the transmission of valuable informational assets, which could then be used by the recipient firm (especially, a well-resourced and sophisticated recipient firm) to the competitive disadvantage of the firm that conveyed that asset.[81] Those hazards are compounded in the case of a firm located in a smaller economy that can only extract the full value of its R&D investment by delivering goods incorporating innovation inputs to larger foreign target markets, which raises additional logistical and transactional complications. Doing so requires either capital-intensive and knowledge-intensive forward vertical integration or contractual interactions with third parties that are the most efficient sources of the capital, infrastructure and expertise required to penetrate target foreign consumption markets. If the former option is not feasible due to capital and expertise constraints, then the latter represents the only feasible pathway to market.

It is precisely at this point that patents (and specifically, patents issued by the target consumption market) can play a critical role in enabling an economy—and especially, a smaller economy—to move toward the *Innovation* stage. Let's suppose a firm located in a small foreign economy has developed a new technology and wants to maximize returns on its investment by selling its technology, or products and services incorporating its technology, in the U.S. market. To do so, the firm must successfully execute a host of commercialization tasks, such as testing and regulatory approval, production, distribution, marketing and post-purchase support. With respect to each commercialization task, the firm can choose to execute that task either "in house"—*make*—or "on the market"—*buy*. Applying the logic

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79 *See id.*, at 81-85.

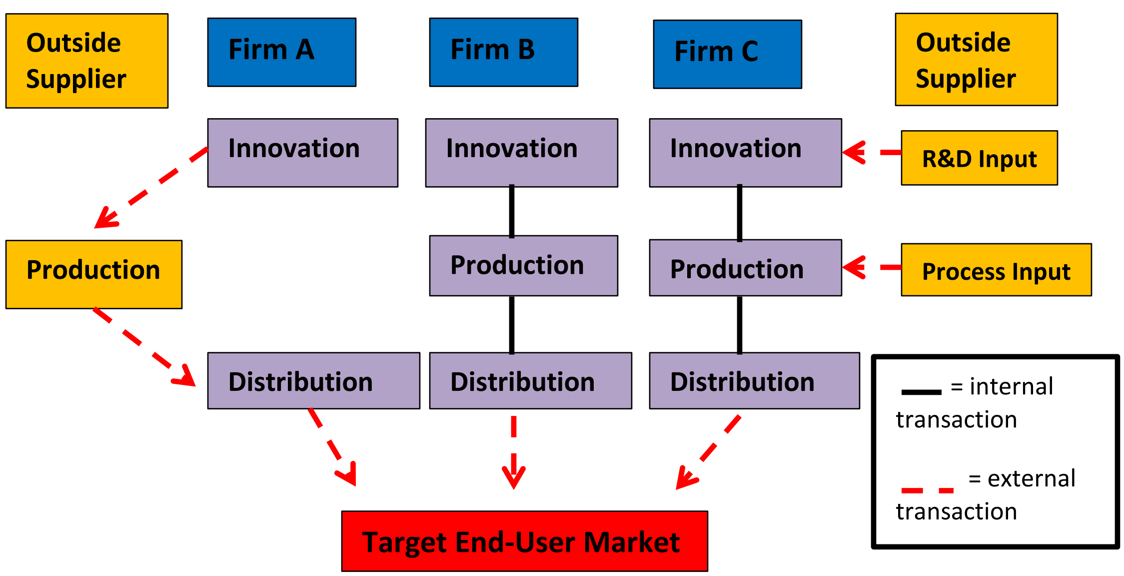
80 *See id.*, at 85.

81 *See* Timothy J. Sturgeon & Ji-Ren Lee, *Industry Co-Evolution: A Comparison of Taiwan and North American Electronics Contract Manufacturers,* in GLOBAL TAIWAN: BUILDING COMPETITIVE STRATEGIES IN A NEW INTERNATIONAL ECONOMY 42-43 (2005); John M. De Figueredo & David J. Teece, *Mitigating Procurement Hazards in the Context of Innovation,* 5 IND. & CORP. CHANGE (1996)*;* David J. Teece, *The Market for Know-How and the Efficient International Transfer of Technology,* 458 ANNALS OF THE ACADEMY OF POLITICAL AND SOCIAL SCIENCE (1981).

of Ronald Coase, if we assume away transaction costs, the firm's make/buy choice with respect to each commercialization task would simply reflect a cost comparison between internal and external entities that could execute that task (assuming comparable quality levels).[82] As Coase emphasized, however, moving functions out of the firm and into the market typically involves transaction costs that may render doing so uneconomical, in which case the firm retains that function in-house. Generically, those transaction costs involve search, negotiation, drafting, monitoring and enforcement costs inherent to arm's-length contractual relationships. In the case of transactions involving informational assets, a firm often faces additional types of costs associated with protecting those assets against expropriation, both during the commercialization stage leading to market release and in the distribution stage after market release.

Specifically, firms and other entities in technology markets face three categories of transactional hazards in delivering an innovation from the "lab" to the target consumption market. Each type of hazard arises as a function of the transactional structures selected by a firm to reach market. The graphic below depicts the transactional paths followed by three paradigm firms (A, B, C). Whatever the transactional path selected, the firm must execute three categories of supply-chain functions: (i) innovation; (ii) production; and (iii) distribution. Each firm can elect to execute each of these functions internally (*make*) or externally (*buy*). The combination of make/buy decisions determines the transactional path to market. If a firm selects the *buy* option with respect to any particular function, it must anticipate how to agree upon the terms of access with outside suppliers and then monitor and enforce compliance with those terms.

Figure XII: Alternative Supply Chains in Technology Markets



82 *See* Ronald H. Coase, *The Nature of the Firm*, 4 ECONOMICA 386 (1937).

Outsourcing Hazards: Firm A has developed an innovation and now must set up a production and distribution infrastructure to monetize it. Suppose the firm can execute the production function most efficiently by contracting with outside suppliers. Or suppose (not shown graphically above) that the firm's technology is a component designed to be incorporated into an existing technology system or some other existing, larger and more complex product. In either case, the upstream R&D firm must protect against the expropriation risk posed by its potential downstream partners, who will require access to at least some of the firm's knowledge assets during the negotiation and implementation process.

Insourcing Hazards: Firm C has developed an innovation and now seeks to monetize it through production and distribution. Production of the innovation on a mass scale and a cost-effective manner raises technological and logistical obstacles that Firm C has no capacity to resolve feasibly. Or suppose that Firm C has no innovation capacities but has sophisticated production capacities. In either case, Firm C requires access to outside suppliers' process technologies (the first case) or product technologies (the second case) to earn any positive return on its specialized expertise. To implement this structure, Firm C must credibly commit to outside suppliers of those product or process technologies that it will not use the suppliers' process or product technologies except upon agreed terms of use and associated payment obligations.

Distribution Hazards. Firm B has developed an innovation, executed production, and is now ready to distribute it into the target market. Even though it has executed all functions in-house, Firm A still faces an expropriation hazard: namely, it must protect its technology against expropriation by imitative competitors following release of its product into the target consumption market. Assuming low reverse-engineering costs, those competitors will have an inherent advantage since they have presumably not borne much of the firm's product development and commercialization costs.

Understanding the menu of informational hazards faced by firms in technology markets—and, in particular, disaggregated technology markets—provides the basis for appreciating the role of patents in enabling those supply chains to operate efficiently. Specifically, reliably enforceable patents combined with contractual agreements can mitigate transactional hazards by limiting expropriation opportunities and thereby enabling parties to regulate the flow and use of informational assets among transacting parties. In the case of outsourcing hazards, patents regulate information flow between, on the one hand, an innovator-firm and, on the other hand, the supplier of a production or distribution input required in the commercialization process. Without patents, it is difficult for the outside supplier to commit credibly against expropriating information disclosed to it. While reputational forces may constrain supplier opportunism in certain settings, it is not a fail-safe deterrent, especially in transactions involving non-repeat-play counterparties, technologically sophisticated counterparties, or large commercial stakes.[83] In the case of insourcing hazards, a patent provides the legal foundation behind a licensing transaction that regulates information flow between, on the one hand, the innovator-firm and, on the other hand, the holder of the required product or process technology input. The same informational hazard persists but operates in the opposite direction: that is, without patents, it is difficult for the *innovator-firm* to commit

83 For fuller analysis of this point, see Jonathan M. Barnett, *Three Quasi-Fallacies in the Conventional Understanding of Intellectual Property*, 12 J. L. ECON. & POL'Y. 1, 10-12 (2016).

credibly against expropriating the informational assets provided to it beyond any agreed-upon terms of use. Finally, in the case of distribution hazards, patents perform their conventional function by impeding reverse engineering in the target consumption market and providing the innovator-firm (or a commercialization entity that holds an interest in the innovation asset) with a time window in which it can earn a return on the research and commercialization efforts that stand behind the new product.

B. Patents and Specialization in Global Technology Supply Chains

If patents mitigate transactional hazards that would otherwise frustrate exchanges between the suppliers of innovation and non-innovation inputs in the commercialization process, it then follows more generally that patents may facilitate the ability of innovators and other firms to craft and adjust supply-chain structures in order to execute the innovation and commercialization process as efficiently as possible. In particular, scholars have argued that patents sometimes enable innovation to take place in smaller specialized R&D entities that contract with specialized financing, production and distribution partners for required commercialization inputs.[84] Three bodies of evidence support this proposition most directly. First, extensive studies of late 19th-century technology markets in the U.S. found that the availability of secure patent rights facilitated the formation of small R&D-intensive entities (equivalent to today's "startups"), which then contracted with venture capitalists and other financing sources to secure the funding required to commercialize those entities' innovations.[85] Second, scholars have found repeatedly that transactional structures are sensitive to differences in the strength of patent protection across countries. In countries with strong patent rights, firms tend to structure their foreign direct investments through a contractual relationship with a local partner, rather than through a directly-owned subsidiary. The effect is reversed in countries with weak patent rights.[86] Consistent with the proposition above, it appears that expropriation risk precludes or counsels against undertaking commercialization on the open market, compelling firms to select *make* even if *buy* would be the lower-cost option in a zero transaction-cost environment. Third, studies of the biotechnology industry have established that upstream R&D suppliers—typically, scientist-founded startups—are especially dependent on patents, which are

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84 *See* Jonathan M. Barnett, *Intellectual Property as a Law of Organization*, S. CAL. L. REV. (2011); Paul J. Heald, *A Transaction Costs Theory of Patent Law*, 66 OHIO ST. L. J. 473 (2005); Robert P. Merges, *A Transactional View of Property Rights*, 10 BERKELEY TECH. L. J. 1477 (2005); Ashish Arora & Robert P. Merges, *Specialized supply firms, property rights and firm boundaries*, 13 IND. & CORP. CHANGE 451, 472 (2004).

85 *See* Naomi R. Lamoreaux & Kenneth L. Sokoloff, *Inventors, Firms, and the Market for Technology in the Late Nineteenth and Early Twentieth Centuries*, in LEARNING BY DOING IN MARKETS, FIRMS AND COUNTRIES 19-57 (eds. Naomi Lamoreaux et al.) (1999); Naomi Lamoreaux & Kenneth L. Sokoloff, *The Market for Technology and the Organization of Invention in U.S. History*, in ENTREPRENEURSHIP, INNOVATION AND THE GROWTH MECHANISM OF THE FREE-ENTERPRISE ECONOMIES (eds. Eytan Sheshinski et al. 2007); Kenneth L. Sokoloff & B. Zorina Khan, *The Democratization of Invention During Early Industrialization: Evidence from the United States*, 1790-1846, 50 J. ECON. HIST. 363 (1990).

86 *See* Joanne E. Oxley, *Institutional Environment and the Mechanisms of Governance: the Impact of Intellectual Property Protection on the Structure of Inter-Firm Alliances*, 38 J. ECON. BEHAV. 283 (1999); Bharat Anand & Tarun Khanna, *The Structure of Licensing Contracts*, 48 J. Ind. Econ. (2000). Other studies similarly find that weak-patent jurisdictions attract firms that confine knowledge production and exchange within the firm, *see* Minyuan Zhao, *Conducting R&D in Countries with Weak Intellectual Property Rights Protection*, 56 MGMT. SCI. 1185 (2006). Similarly, another study finds that firms tend to export to, or manufacture (but decline to conduct R&D) in, jurisdictions with weak IP rights, *see* Beata K. Smarzynska, *Composition of Foreign Direct Investment and Protection of Intellectual Property Rights: Evidence from Transition Economies,* WORLD BANK POLICY RESEARCH DEPT. WORKING PAPER NO. 2768 (2002).

then used to enter into transactions with larger pharmaceutical companies that have comparative advantages in financing and executing the testing, production and distribution functions required to reach market.[87]

Existing theoretical discussions, and related empirical evidence, support the view that patents expand markets' ability to design structures for allocating innovation and commercialization functions to the set of least-cost providers, both at the levels of transactional design and organizational design. That is: patents are an enabling mechanism behind the division of labor, and associated efficiencies, that underlie the technology-intensive segments of a well-functioning market economy. This logic can be extended a step "higher" to the level of a national economy. If patents enable markets to construct disaggregated transactional and organizational structures for executing innovation and commercialization functions (*a transaction-level effect*), which in turn enables the viability of stand-alone R&D suppliers (*a firm-level effect*), then patents may facilitate the specialization by entire countries (or large portions of the economies of those countries) in the development and supply of particular inputs in a technology supply chain (*an economy-level effect*). From a development perspective, this is a potentially critical achievement: reducing the transaction costs of information exchange facilitates the ability of an emerging economy to enter the global technology market without having to incur the enormous costs, and acquire the complex knowledge base, required to construct and operate a fully integrated and stand-alone international supply chain to reach target consumption markets.[88]

In particular, patents may enable two paradigm types of specialized innovation economies that can make surgical entries into discrete points on a global technology supply chain. First, patents may enable upstream innovation economies that specialize in the development of product technologies that operate as R&D inputs for the development, production and distribution stages located downstream on the technology supply chain. As will be discussed in the following Part, this largely describes the Israeli innovation economy. Second, patents may enable "midstream" innovation economies that specialize in process technologies that incorporate R&D inputs into larger technology bundles for consumption by intermediate or end-users in foreign target consumption markets. As will be discussed in the following Part, this largely describes the Taiwanese innovation economy. In other cases, patents may enable mixed-type economies populated by entities that operate in multiple segments of a technology supply chain. This is the case in the Korean innovation economy, in which large vertically integrated firms (especially, the Samsung, LG, Hynix, Daewoo and Hyundai corporate groups) are prominent users of the USPTO system. These firms can typically execute all steps of the innovation and commercialization process through market release. However, in some cases, these integrated firms provide "mid-stream" commercialization

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87 *See* Toby E. Stuart et al., *Vertical alliance networks: The case of university-biotechnology-pharmaceutical alliance chains*, 36 RES. POL'Y 477 (2007); Josh Lerner & Robert P. Merges, *The Control of Strategic Alliances: An Empirical Analysis of Biotechnology Collaboration* (NATIONAL BUREAU OF ECONOMIC RESEARCH WORKING PAPER NO. 6014, 1997); Gary P. Pisano, *The Governance of Innovation: Vertical Integration and Collaborative Agreements in the Biotechnology Industry*, 20 RES. POL'Y 237 (1991).

88 The economics of development literature has observed how improvements in communications and transportation technology has enabled emerging markets to avoid the costs involved in establishing a self-contained supply-chain infrastructure. *See, e.g.*, Richard Baldwin, *Global supply chains: why they emerged, why they matter, and where they are going*, in GLOBAL VALUE CHAINS IN A CHANGING WORLD 24 (eds. Deborah K. Elms & Patrick Low 2013). I extend this point by showing that intellectual property rights play a role in mediating the expropriation risks that would otherwise raise an obstacle to that development strategy.

inputs (in Samsung's case, it provides chip fabrication services to firms such as Apple[89]), while research entities such as Korea's Electronics and Telecommunications Research Institute (one of Korea's leading USPTO users) act solely as upstream suppliers of R&D inputs.[90]

IV. Case Studies: Israel and Taiwan

The following case studies of Israel and Taiwan each represent a preliminary effort to apply the theoretical framework proposed above to two specific innovation economies.[91] I rely on USPTO data to identify each economy's leading users of the USPTO system, other data to identify those firms' position in the technology supply chain, and existing historical and empirical research on these countries' technology markets, to assess the extent to which USPTO patents enable firms in these countries to access the pipeline required to embed innovation inputs into viable consumption goods for the U.S. market. Despite important differences in each country's primary point of specialization on the global technology supply chain, a common narrative emerges from each case study. In a relatively short period of time, each country has become one of the world's exceptional innovation economies. Following Porter's framework, these economies were burdened (or blessed) with a dual selective disadvantage in the form of meager natural resources and (unlike Korea) a small domestic consumer market. In response, both economies cultivated selective advantages in the form of the technological capacities required to build and maintain an *Innovation* economy. While further inquiry is warranted in each case[92], USPTO patents, combined with contractual agreements, appear to have provided an important tool for each economy to capture returns on these human and intellectual capital investments through relationships with third-party holders of complementary innovation and non-innovation inputs.

A. Case Study I: Israel

While Israel's leadership in the world technology market has received significant attention in the business press, it has received little dedicated attention in the scholarly literature.[93] Despite having land territory approximately equal to, and population slightly smaller than, New Jersey, it was the fourth-

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89 *See* Quinten Plummer, *Apple Taps Samsung to Make A9 Chips for Next Generation iPhones and Other Devices*, TECH TIMES, April 6, 2015.

90 It should be noted that, based on USPTO data, these large integrated firms represent less than 10% of total USPTO patents issued to Korean inventors during 2000-2015. Hence, further study might reveal significant patenting activity by smaller and medium-sized entities in the Korean economy.

91 Korea is omitted from this Part due to space constraints.

92 In particular, a more complete discussion of the role of USPTO patents in each country's innovation environment would provide closer analysis of firms other than the top 15 assignees in each country's USPTO patentee population (the focus in the discussion below) and analysis of the interaction between the USPTO system and each country's local patent system.

93 For some exceptions, see Shiri M. Breznitz, *Cluster Sustainability: The Israeli Life Sciences Industry*, 27 ECON. DEVELOPMENT Q. 29 (2013); Jerome S. Engel and Itxaso del-Palacio, *Global Clusters of Innovation: The Case of Israel and Silicon Valley,* 53 CAL. MGMT. REV. 27 (2011); Gil Avnimelech and Morris Teubal, *Creating venture capital industries that co-evolve with high tech: Insights from an extended industry life cycle perspective of the Israeli experience*, 35 RESEARCH POLICY 1477 (2006); Erran Carmel and Catherine de Fontenay, *Israel's silicon wadi: the forces behind cluster formation*, in BUILDING HIGH-TECH CLUSTERS: SILICON VALLEY AND BEYOND 40-77 (eds. Timothy F. Bresnahan & Alfonso Gambardella 2004); Trajtenberg (2000), *supra* note 6; Trajtenberg (1999), *supra* note 6.

largest national recipient of venture capital funding outside of the United States during 2006-2013[94], has more firms listed on Nasdaq than any country other than the U.S. and China[95], and, as noted, is the third-largest national recipient of USPTO patents on a per capita basis.[96] Technological leadership has been accompanied by economic growth: for example, in 1980, it had a per capita GDP of $6,018, as compared to $8,355 for Italy; in 2014, it had a per capita GDP of $36,990, as compared to $35,823 for Italy.[97] Israel's rise to leadership in the world innovation economy has coincided with a jump in R&D investment: Israel's business R&D (excluding defense-related R&D) increased from 2.8% of GDP during the 1980s to 4.8% of GDP during the 1990s[98] and, since 1999, its total R&D intensity has been the highest in the world.[99] Given the absence of a large domestic market (as of 2014, it was the 41st largest consumer market in the world, representing .33% of world household consumption[100]) and the presence of high labor costs (two selective disadvantages in Porter's terminology), the country's technology firms must rely on foreign markets to extract a return from these R&D investments.

1. Background

Israel's innovation economy has been promoted by three primary forms of government intervention. First, the government's heavy investment in defense (representing 5.9% of GDP in 2014, as compared to 3.5% for the United States and 1% for Japan)[101] has spawned spillover effects in the civilian market.[102] Relatedly, compulsory military service provides potential entrepreneurs with practical training in advanced technologies. Second, the Office of the Chief Scientist provides grants for technology startups.[103] Third, the Israeli government established in the early 1990s the "Yozma" program, in which the government acted as a quasi-venture capitalist in the local technology industry. This successfully triggered a robust VC market. During 2005-2011, Israel received the fourth-largest share of total VC investment worldwide, after the U.S., Europe, and China, representing 8% of all VC investments in the

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94 WORLD ECONOMIC FORUM, *Which countries have the most venture capital investments?* (citing Ernst & Young, Venture Capital Insights – 4Q14 (Jan. 2015)). For this purpose, the report treats the European Union as a single country.

95 *See* Ari Rabinovitch, *Nasdaq expects increase in IPOs from Israeli firms*, Reuters, May 11, 2014.

96 *See supra* Figure VII.

97 Source: INTERNATIONAL MONETARY FUND, WORLD ECONOMIC OUTLOOK DATABASE, APRIL 2015. Figures expressed in current prices.

98 *See* DAPHNE GETZ & VERED SEGAL, THE ISRAELI INNOVATION SYSTEM: AN OVERVIEW OF NATIONAL POLICY AND CULTURAL ASPECTS, SAMUEL NEAMAN INSTITUTE, TECHNION-ISRAEL INSTITUTE OF TECHNOLOGY 7 (2008).

99 *See supra* Figure XI.

100 THE WORLD BANK, HOUSEHOLD FINAL CONSUMPTION EXPENDITURE (constant 2005 US$) (current as of 2014, based on World Bank and OECD national accounts data), avail. at http://data.worldbank.org/indicator/NE.CON.PRVT.KD.

101 THE WORLD BANK, MILITARY EXPENDITURE (% OF GDP), avail. at http://data.worldbank.org/indicator/MS.MIL.XPND.GD.ZS.

102 *See* Orna Berry & Daniel Wasserteil, *Israel: the technology industry as an economic growth engine creating a nationwide Cluster of Innovation*, in GLOBAL CLUSTERS OF INNOVATION: ENTREPRENEURIAL ENGINES OF ECONOMIC GROWTH AROUND THE WORLD 190 (ed. Jerome S. Engel 2014); GETZ & SEGAL, *supra* note 98, at 7.

103 For detailed description of these programs, s*ee* DAPHNE GETZ, DAN PELED, TZIPY BUCHNIK, ILIA ZATCOVETSKY, ERAN LECK & ELLA BARZANI, SCIENCE, TECHNOLOGY AND INNOVATION: AN INTERNATIONAL COMPARISON, SAMUEL NEAMAN INSTITUTE, TECHNION-ISRAEL INSTITUTE OF TECHNOLOGY 43-45 (4th ed. 2013); Trajtenberg (2002), *supra* note 93, at 88-89; Avnimelech & Teubal, *supra* note 93.

top six country-level recipients of VC investment.[104] As of 2013, VC investments represented .31% of Israel's GDP, the highest VC/GDP ratio in the world and significantly exceeding the second and third-highest countries, the United States (.17%) and Canada (.08%).[105]

2. Patent Data: Firm and Market Characteristics

a. Patent Assignee Population

When a patent is issued by the USPTO, it will state, if applicable, the first-named assignee of the patent. When this appears, it is typically the inventor's employer, with whom the inventor has entered into a pre-assignment contract. Data on the first-named assignees of patents issued to Israeli inventors provide a window into the primary types of entities that undertake R&D (or at least, patentable R&D) in the Israeli economy.[106] For this purpose, I examined a pool consisting of first-named assignees identified by the USPTO in its country-based breakdown of utility patent grants (which includes all such assignees other than entities that were first-assigned fewer than five USPTO patents during 1969-2015).[107] This "identified first-named assignees" pool represents a significant majority (73%) of USPTO patents issued to Israeli filers during 2000-2015.[108] If we consolidate parents and subsidiaries within this assignee pool[109], there are 648 unique identified first-named assignees of patents issued to Israeli filers during this period. From the perspective of entity type, the assignee population falls into three major categories: (i) academic research institutions; (ii) local subsidiaries of large multinational firms; and (iii) local technology firms. As discussed further below, local subsidiaries of foreign multinationals often started as local firms that were acquired by the multinational. From the perspective of industry type, the assignee population falls mostly into three categories: (i) ICT (defined broadly to include software, hardware and telecommunications); (ii) life sciences (defined broadly to include biopharmaceuticals and medical devices); and (iii) defense or military systems. This industry type distribution tracks other data on the patent classes favored by Israeli USPTO filers (during 2000-2015, Israeli filers patented most heavily in

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104 Author's calculations, based on data in: ERNST & YOUNG, GLOBALIZING VENTURE CAPITAL: GLOBAL VENTURE CAPITAL INSIGHTS AND TRENDS REPORT 10 (2011). The top 6 countries (as of 2011) are: the U.S., Europe, China, Israel, India and Canada.

105 OECD, SCIENCE, TECHNOLOGY AND INDUSTRY OUTLOOK 2014.

106 Note that this pool does not prominently reflect certain internet and software companies that do not rely heavily on patent protection, areas in which Israel has recognized innovative capacities.

107 USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION. This five-patent limitation appears to be the reason why the pool of patents for which the USPTO identifies first-named assignees (as well as individually owned patents that do not name any such assignee) is smaller than the total pool of patents issued to Israeli filers during this period as reported elsewhere by the USPTO (see USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT).

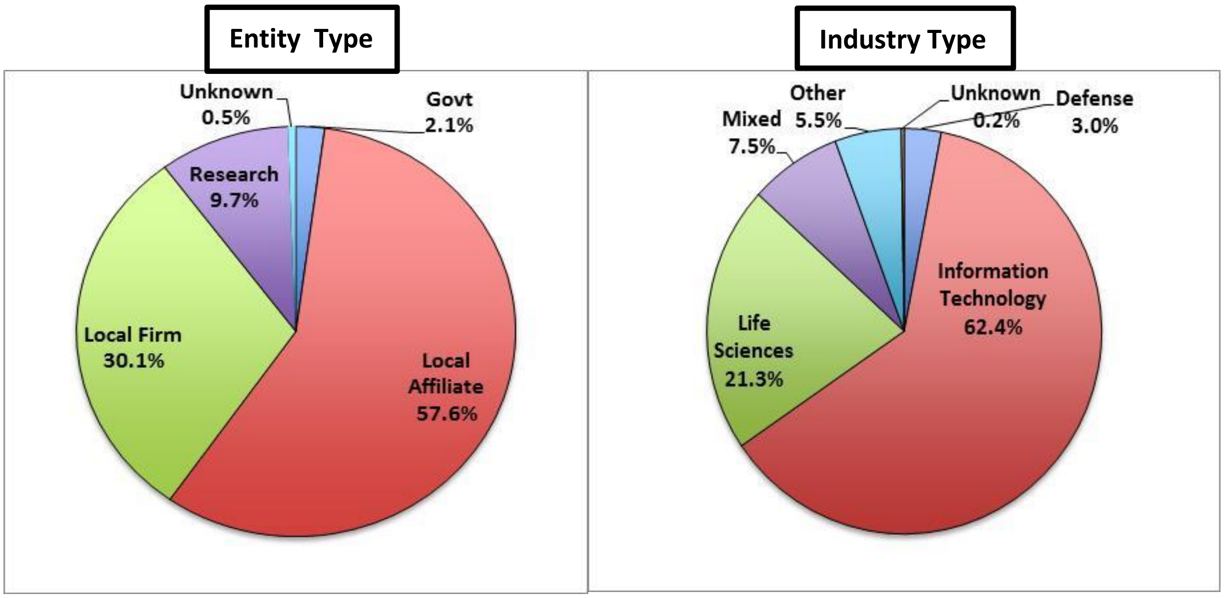
108 Author's calculations, based on USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION (providing information on first-named assignees, with country breakdown) and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT (providing information on total utility patents, with country breakdown).

109 Consolidation of parents and subsidiaries was based on commonality of names, supplemented by information in companies' annual reports, company websites, and the Hoover's company database. In cases not involving commonality of names, additional parent-subsidiary relationships were identified through data collected on acquisitions of Israeli firms by foreign multinationals (for methodology and sources, see *infra* note 130). These methods may still have overlooked some parent-subsidiary relationships.

patent classes relating to pharmaceuticals, surgical devices, digital communications, image analysis and data transfer).[110]

The charts below show, respectively, during 2000-2015: (i) the percentage that each entity type represents out of the total pool of identified first-named assignees of USPTO patents issued to Israeli filers; and (ii) the percentage that each industry type represents out of that same pool.

Figure XIII: Type Distribution of Identified First-Named Assignees of USPTO Patents Issued to Israeli Filers (2000-2015)[111]



We can observe further detail by examining more closely the top 15 first-named assignees of USPTO patents issued to Israeli filers during 2000-2015. Collectively these assignees represent 29% of

110 Specifically, among all patents issued to Israeli filers during 2000-2015, the following patent classes were designated most frequently: (i) drugs, bio-affecting and body-treating compositions (5.95% of all patents issued to Israeli filers); (ii) multiplex communications (4.57%); (iii) surgery (3.95%); (iv) organic compounds (2.75%); (v) image analysis (2.71%); (vi) pulse or digital communications (2.31%); (vii) chemistry: molecular biology (2.29%); (viii) telecommunications (2.24%); (ix) tools (2.12%); and (x) multicomputer data transfer (2.08%). Source: Author's calculations, based on USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY TECHNOLOGY CLASS.

111 I obtained the names of first-named assignees of patents issued to Israeli filers at: USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION. I then obtained data on assignees' entity and industry type, and any parent-subsidiary relationship, by consulting the website and annual report (if available) of each entity, or the Hoover's company database. In some cases, additional information relating to entity type was obtained by reviewing a sample of the entity's patents. For purposes of computing percentages, parents and subsidiaries were treated as a single entity (even if they were listed separately as patent filers in the USPTO data). The "Mixed" category refers to entities engaged in both IT and life sciences activities (in almost all cases, these are academic research institutions).

all patents issued to Israeli filers during this period.[112] Leading assignees include a mix of academic research institutions, local firms, and local affiliates of foreign firms. With the exception of HP and IBM, all foreign parents maintain R&D expenditures in excess of 12% of sales.[113] These assignees mostly provide R&D inputs for the ICT sector, with additional significant representation in the life sciences and medical device markets. As reflected by employee numbers (for operations in Israel only), these entities are small to medium-size entities that, with some exceptions, lack significant local manufacturing capacities. This R&D focus obviously characterizes the R&D centers maintained by large foreign corporations (which, with the exception of Intel, do not maintain production facilities in Israel) and the technology transfer entities of academic research institutions. Israeli universities, which (as shown above) represent almost 10% of all USPTO patents issued to Israeli filers during 2000-2015, are especially vigorous patentees: in 2015, three of its universities were ranked among the top 100 university patentees at the USPTO.[114]

Table I: First-Named Assignees of USPTO Patents Issued to Israeli Filers (Top 15, 2000-2015)[115]

Legend: LA = Local affiliate of foreign firm; TT = technology transfer office of academic research institution; LF = local firm; ICT = information and communications technology; LS = life sciences; G = government/military

Assignee	Entity Type	Industry Type[116]	Employees in Israel[117]	Significant Mfg Facilities in Israel	First-Assigned Patents Issued to Israeli Filers (2000-2015)	Percent of Patents Issued to Israeli Filers (2000-2015)[118]	R&D Intensity (2015 or most recent year available)[119]
IBM	LA	ICT	1,336	N	1,497	5.50%	6.42%
Intel	LA	ICT (Semi)	8,826	Y	1,194	4.39%	21.91%

[112] Author's calculations, based on data in USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT.

[113] Author's calculations based on most recent annual SEC filings (2014 or 2015, as available) for each company.

[114] *See* ACADEMY OF INVENTORS, TOP 100 WORLDWIDE UNIVERSITIES GRANTED U.S. UTILITY PATENTS (2015).

[115] I relied on USPTO data for all patent-related information. With respect to all other information, I searched the company's most recent annual report filed with the SEC. If the filing did not disclose information or the company was private, I relied on information in the Hoover's company's database or the company's website, except as otherwise indicated. Note that parent and subsidiaries were consolidated even if listed as separate filers in the USPTO data. Unless otherwise indicated below, all information is current as of September 2016.

[116] "Semi" indicates that the company has significant business in some part of the semiconductor industry.

[117] Employees refer to technical and non-technical employees. In the case of technology transfer entities of academic research institutions, employees refer to number of research faculty at the university, as stated on the university's website.

[118] This refers to the percentage constituted by (i) identified first-assigned patents issued to Israeli filers during 2000-2015 out of (i) all USPTO patents issued to Israeli filers during that period. Sources: USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT.

[119] R&D intensity is not applicable or not available in the case of research entities and private companies.

Assignee	Entity Type	Industry Type[120]	Employees in Israel[121]	Significant Mfg Facilities in Israel	First-Assigned Patents Issued to Israeli Filers (2000-2015)	Percent of Patents Issued to Israeli Filers (2000-2015)[122]	R&D Intensity (2015 or most recent year available)[123]
HP	LA	ICT	1,830	N	654	2.40%	3.1%
Marvell	LA	ICT (Semi)	970	N	611	2.24%	31.41%
SanDisk[124]	LA	ICT	562	N	483	1.77%	14.29%
Yeda R&D (Weizmann Institute)	R	ICT, LS	654	N	477	1.75%	n/a
Tel Aviv Univ.	R	ICT, LS	over 2,200	N	409	1.50%	n/a
Yissum R&D (Hebrew Univ.)	R	ICT, LS	1,000	N	356	1.31%	n/a
Teva Pharmaceuticals	LF	LS	6,967	Y	341	1.25%	7.76%
Cisco	LA	ICT	over 1,000[125]	N	329	1.21%	12.63%
Applied Materials	LA	ICT (Semi)	1,000	Y	325	1.19%	15.53%
Technion Foundation	R	ICT, LS	620	N	321	1.18%	n/a
Broadcom	LA	ICT (Semi)	278	N	320	1.18%	15.37%
Iscar (Berkshire Hathaway)	LA[126]	Other (precision tools)	3,000	Y	251	0.92%	n/a
Biosense (Johnson & Johnson)	LA	LS (medical device)	200	N[127]	234	0.86%	n/a

120 “Semi” indicates that the company has significant business in some part of the semiconductor industry.

121 Employees refer to technical and non-technical employees. In the case of technology transfer entities of academic research institutions, employees refer to number of research faculty at the university, as stated on the university’s website.

122 This refers to the percentage constituted by (i) identified first-assigned patents issued to Israeli filers during 2000-2015 out of (i) all USPTO patents issued to Israeli filers during that period. Sources: USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT.

123 R&D intensity is not applicable or not available in the case of research entities and private companies.

124 In May 2016, SanDisk was acquired by Western Digital.

125 Bloomberg, *Cisco to Buy Israel’s Leaba Semiconductor for About $320 Million,* Mar. 2, 2016 (states “over 1000” employees at Cisco Israel).

126 Iscar is marked as “LA” because it was acquired by Berkshire Hathaway in 2013. However, it might more appropriately be classified as “LF” because it is generally recognized as one of Israel’s leading indigenous commercial enterprises. Additionally, I did not include R&D intensity for Iscar because, while Berkshire Hathaway, is publicly traded, its R&D intensity would not be reflective of Iscar’s activities since the parent is not a technology-focused company.

127 Company website describes the Israeli facility as an R&D and manufacturing site. However, other sources indicated that it is primarily an R&D facility.

b. **R&D Affiliates**

Patenting data demonstrate the prominent role in the Israeli innovation economy of local R&D centers maintained by large multinational technology firms. While these R&D centers (264 in total according to a recent report[128]) are affiliated with a foreign parent, they often if not typically represent local technology generation by firms that had been acquired by the parent.[129] Considering the top 15 foreign-owned R&D centers in Israel based on total USPTO patents first-assigned to the center's parent (or affiliates) during 2000-2015, I found that, with two exceptions, each parent had acquired several Israeli targets (ranging from 3 (HP) to as many as 14 (Microsoft)) during that period.[130] Based on patenting and other data (as shown above for some of these R&D centers), it appears that these foreign-owned R&D centers operate primarily as knowledge generation centers that employ relatively small numbers of personnel (in all but three cases as shown above, less than 2,000 total employees), usually do not operate production facilities (the most notable exception being Intel), and supply R&D inputs for the parent's global manufacturing and distribution operations.[131] Some of these centers have been responsible for key ICT innovations, such as (among others) the Pentium MMX and Centrino microprocessors developed at Intel's Israeli R&D facility[132], the USB flash memory storage technology, initially developed by M-Systems, an Israeli startup acquired by SanDisk in 2006[133], and the "ICQ" instant messaging technology, developed by Mirabilis, an Israeli startup acquired by AOL in 1998.[134]

3. **Evaluation: The Role of U.S. Patents in Israel's Innovation Ecosystem**

The data presented above provide a foundation for a preliminary understanding of the functions played by U.S. patents in Israel's innovation economy, especially in the market segment occupied by the top 15 first-named assignees in the Israeli USPTO population during 2000-2015. There appear to be three functions, each corresponding to a different type of expropriation risk at different points on the technology supply chain. First, USPTO patents mitigate "outsourcing hazards" that might frustrate transactions between Israeli holders of R&D inputs and third-party (typically, foreign) holders of commercialization inputs. This applies most clearly in the case of Israeli research universities engaged in technology transfer in the IT and life sciences markets. Second, USPTO patents mitigate "insourcing hazards" that might discourage corporate-control transactions that enable local R&D firms to permanently

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128 *See* LEMARCHAND ET AL., *supra* note 73, at 39 (citing Israel Venture Capital Database).

129 A UNESCO report finds that, for the period 1990-2010, "at least 1360 distinct inventions" were transferred from Israeli companies to Israeli R&D affiliates of foreign parents as a result of acquisition or merger transactions. *See* LEMARCHAND ET AL., *supra* note 73, at xv.

130 Source for data on acquisitions of Israeli firms: Zephyr database, SDC Platinum M&A databases, SEC filings, and company press releases. Specifically, I found that these "top 15" foreign parents acquired the following numbers of Israeli targets during 2000-2015: IBM (11); Intel (8); HP (3); Marvell (4); SanDisk (3); Broadcom (9); Cisco (7); Applied Materials (3); Microsoft (14); Apple (4); EMC (8); Qualcomm (5); Johnson & Johnson (Biosense) (1); Berkshire Hathaway (Iscar) (1).

131 Source for patenting information: USPTO, PATENT COUNTS BY COUNTRY, STATE AND YEAR - UTILITY PATENTS (DEC. 2015). For this purpose, I consolidated first-assigned patents issued to entities affiliated with the same parent. Source for information relating to employee numbers and manufacturing operations: company annual reports, company website, or the Hoover's company database. Employees include both technical and non-technical employees.

132 *See* David Shamah, *Israel Inside: A history of Intel's R&D in Israel,* ZDNet, Aug. 28, 2012.

133 *See* Lucas Mearian, *Why Israel is a hotbed for flash storage innovation,* May 17, 2012.

134 *See AOL Buys Israel's Mirabilis*, INTERNETNEWS.COM, June 8, 1998.

access a larger foreign (usually, U.S.) firm's commercialization infrastructure through an acquisition transaction. Third, USPTO patents mitigate "distribution hazards" that arise once an IT or life sciences firm distributes into the U.S. market products and services that embody R&D inputs developed in Israel.

a. Outsourcing Hazards

The USPTO infrastructure may mitigate outsourcing hazards to the extent it enables Israeli firms and research institutions to safely export technology assets to foreign partners, which then embed that technology into commercially valuable products and services and distribute those products and services in the target U.S. market. Israeli firms often lack adequate (or, in the case of a research institution, any) production, distribution and marketing capacities to achieve worldwide distribution rapidly or efficiently. Hence, those entities outsource downstream functions to third-party partners that excel in those functions. The obstacle to these transactions is that the third-party partner poses an expropriation threat to the Israeli firm that holds a valuable R&D input, either at the time of negotiation or during the course of a business relationship. Consider the Weizmann Institute, Israel's most prolific academic patentee (during 2000-2015, it received more USPTO patents than all but 26 U.S. universities[135]) and one of the world's most commercially successful technology transfer entities.[136] Weizmann's technology transfer entity would naturally be reluctant to enter into a testing, production and distribution agreement with a pharmaceutical firm if it could not protect its intellectual assets with some combination of contract and patent rights. Equipped with a U.S. patent portfolio (consisting of 477 USPTO patents issued during 2000-2015), Weizmann can enter into commercialization transactions with corporate partners and extract returns on the institution's intellectual capital. For example, in 1987 Weizmann licensed to Teva Pharmaceuticals patents relating to the "Copaxone" treatment for multiple sclerosis, which ultimately earned $4 billion in sales in 2014.[137]

b. Insourcing and Distribution Hazards

The USPTO infrastructure may mitigate insourcing hazards that would otherwise discourage foreign firms from acquiring local Israeli firms, which are then converted into R&D centers. As noted above, large foreign (mostly U.S.) technology firms regularly acquire Israel startups[138], which then continue to acquire USPTO patents as an R&D center within the parent organization. A USPTO patent portfolio mitigates an internal transactional hazard that might otherwise discourage foreign firms from acquiring and maintaining R&D operations in Israel. Namely: the founder and senior executives of the acquired firm, or any other employee of the post-acquisition R&D entity, may pose a post-acquisition expropriation threat to the foreign firm. Patents can mitigate the expropriation threats that are posed by departing employees and cannot be reliably controlled by contractual limitations on employee mobility.[139]

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135 Author's calculations, based on USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION.

136 See Gali Weinreb, *Yeda earns $50-100M annually*, GLOBES, July 28, 2013.

137 *See id.*

138 *See supra* note 130.

139 *See* Jonathan M. Barnett and Ted Sichelman, *Revisiting Employee Mobility in Innovation Markets* (Working Paper 2016). In Israel, practitioners report that courts rarely enforce noncompete agreements. *See* Heather A. Stone, Yael Dolev and Yael Ben Naim, *In the Start Up Nation Where Know How Is Everywhere – Is It Protected?*, Apr. 16, 2014 (American Bar Association, Section of Labor and Employment Law, International Labor and Employment Law Committee), at 17-20.

Given the parent's ownership of a USPTO patent portfolio, presumably combined (as is typical) with a pre-assignment and non-disclosure agreement[140], the target founders and executives, or post-acquisition employees, can more credibly commit against using the firm's R&D assets to found a competing startup or join a competing firm.[141] Additionally, consistent with the function typically attributed to patents, any patents acquired by the target firm, or the R&D center into which the target firm is converted following acquisition, mitigate distribution hazards in the target U.S. market and promote the parent's ability to capture returns on the amounts expended in the acquisition transaction and the amounts it continuously invests in its R&D operations in Israel. The same function is at play in the case of integrated Israeli firms (most notably, Teva Pharmaceuticals[142]) in the biopharmaceutical and medical devices markets that couple patent-protected R&D with in-house production and distribution capacities.[143]

B. **Case Study II: Taiwan**

Like Israel, Taiwan's rise to prominence is remarkable given its small size: despite having land territory approximately equal to the Netherlands and a population about a fifth of that of Japan, it is the third-largest center for the production of information technology equipment, the fourth-largest source of semiconductor chips[144], and, as noted, currently the top country-level recipient of U.S. patents on a per capita basis. Even more dramatically than Israel, Taiwan has enjoyed a remarkable jump in economic development: for example, in 1980, it had a per capita GDP of $2,368, as compared to $8,336 for Italy; in 2014, it had a per capita GDP of $22,598, as compared to $35,823 for Italy.[145] Like Israel, Taiwan suffers from a selective disadvantage in the form of a small domestic market, which has always compelled Taiwan to enter into trade relationships with large foreign markets. Unlike Israel, Taiwan initially enjoyed a selective advantage in the form of low labor costs, which it used to enter global technology markets by offering manufacturing and assembly services to U.S. and Japanese firms in the PC and

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140 Non-disclosure and non-use agreements are typically enforced by Israeli courts. Non-solicitation agreements are typically not enforced. *See id.*, at 6-7, 20.

141 For an example of how a leading Taiwanese chip firm brought patent litigation in a *U.S.* court (and the ITC) to address patent infringement claims relating to the departure of employees to a competitor, see *infra* notes 190-192 and accompanying text. A related explanation is that the patent may signal to potential investors the quality of a startup's claimed technological innovation. Assuming a patent is costly to obtain and defend in court, the patent can be used to screen out false claims of technological novelty and support a higher valuation of the startup from investors. For a theoretical model and supporting evidence from samples of Israeli startups, see Annamaria Conti, Jerry Thursby, and Marie C. Thursby, *Patents as Signals for Startup Financing,* NBER Working Paper No. 19191 (June 2013); Gilli Greenberg, *Small Firms, Big Patents? Estimating Patent Value Using Data on Israeli Startups' Financing Rounds,* 10 EURO. MGMT. REV. 183 (2013).

142 While Teva is the world's largest generic pharmaceutical firm, it maintains a significant proprietary drug business: as of 2015, it constitutes 51% of Teva's total revenues. *See* TEVA PHARMACEUTICALS, FORM 20-F (2015), at 7, 20.

143 Based on USPTO data, at least some Israeli medical device firms maintain significant USPTO patent portfolios and couple R&D capacities with in-house manufacturing and distribution functions. An example is Medinol, a first-named assignee of 77 USPTO patents during 2000-2015 (source: USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION). Medinol developed a leading type of stent for cardiovascular treatment and maintains both R&D and manufacturing operations (source: company website).

144 *See* Bor-Shiuan Cheng, *Dragon appearing in the field: the legend of the semiconductor industry in Taiwan*, in TERENCE TSAI AND BOR-SHIUAN CHENG, THE SILICON DRAGON: HIGH-TECH INDUSTRY IN TAIWAN 8 (2006).

145 Source: INTERNATIONAL MONETARY FUND, WORLD ECONOMIC OUTLOOK DATABASE, APRIL 2015. Figures expressed in current prices.

consumer electronics markets. By the mid-1990s, Taiwan ranked first or second in the world in the production of multiple categories of consumer electronics, a position it largely continues to hold today (even though Taiwanese firms have mostly moved operations to other countries).[146] As Taiwan developed, it lost its labor-cost advantage. Taiwanese firms responded by developing "foundry" services for chip design firms and integrated chip manufacturers and entering into the chip design and electronics component design segments.[147] The result is a mixed technology economy that supports "lower value" contract manufacturing by OEMs, "intermediate value" foundry production for foreign and domestic chip design firms, and "higher value" technology development in the chip design and electronics components markets.[148] Below I show how patents, together with limited government intervention, appear to support this market structure.

1. Background

The rise of Taiwan as a technology leader has its roots in three policy actions by the Taiwanese government. First, in 1973, the Taiwanese government established the Industrial Technology Research Institute ("ITRI"), a research institute tasked with pursuing industrial priorities for the economy.[149] ITRI (including its subsidiary, the Electronics Research and Service Organization, known as "ERSO") surveyed foreign markets for technologies required to establish a semiconductor industry in Taiwan and reduce the country's reliance on commodity contracting work for branded electronics firms.[150] In some cases, ERSO obtained licenses to patents, or purchased patents covering, targeted technologies, which it then transferred to Taiwanese firms for commercial development.[151] Second, in 1980, the government established the Hsinchu industrial park, where technology firms were given tax and other incentives to set up operations.[152] Third, in 1987, 1992 and 1994, the government enacted reforms to its local patent

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146 *See* Kenneth L. Kraemer et al., *Entrepreneurship, Flexibility and Policy Coordination: Taiwan's Computer Industry,* 12 THE INFORMATION SOCIETY 215 (2006).

147 *See* Shin-Horng Chen, *Global Production Networks and Information Technology: The Case of Taiwan,* 9 Industry and Innovation 249 (2002); Chintay Shih, Kung Wang and Yi-Ling Wei, *Hsinchu, Taiwan: Asia's Pioneering High-Tech Park,* in MAKING IT: THE RISE OF ASIA IN HIGH TECH 102-09 (eds. Henry S. Rowen, Marguerite Gong Hancock and William F. Miller 2007).

148 *See* JOHN A. MATHEWS & DONG-SUNG CHO, TIGER TECHNOLOGY: THE CREATION OF A SEMICONDUCTOR INDUSTRY IN EAST ASIA 272-73 (1999).

149 *See* Chao-Tung Wen & Jun-Ming Chen, *Taiwan: linked-based Clusters of Innovation – the case of Taiwan's IT industry,* in GLOBAL CLUSTERS OF INNOVATION: ENTREPRENEURIAL ENGINES OF ECONOMIC GROWTH AROUND THE WORLD 224 (ed. Jerome S. Engel 2014); Dan Breznitz, *Development, flexibility and R&D performance in the Taiwanese IT industry: capability creation and the effects of state-industry coevolution,* 14 Ind. Corp. Change 153, 159 (2005) [hereinafter Breznitz (2005)].

150 *See* Cheng, *supra* note 144, at 12-13. ITRI continues to engage in these types of activities today. *See* ITRI, 2014 ANNUAL REPORT; Matthews, *supra* note 152; Po Young Chu, Yu Ling Lin, Hsing Hwa Hsiung, and Tzu Yar Liu, *Intellectual capital: an empirical study of ITRI,* 73 TECH. FORECASTING & SOCIAL CHANGE 886 (2006).

151 *See* MATHEWS & CHO, *supra* note 148, at 190; Kraemer, *supra* note 146, at 230; An-Chi Tung, *Taiwan's Semiconductor Industry: What the State Did and Did Not Do,* 5 Rev. Dev. Econ. 266 (2001). Soo-Hung Terence Tsai and Chang-hui Zhou, *Science Parks in Taiwan: HSIP and TSIP*, in TERENCE TSAI AND BOR-SHIUAN CHENG, THE SILICON DRAGON: HIGH-TECH INDUSTRY IN TAIWAN 58 (2006), observe that ERSO used foreign technology as the basis for internal research, or reverse engineered existing technology, which, upon completion, it then transferred to private industry for commercial application. For further discussion, see Wen & Chen, *supra* note 149.

152 *See* John A. Matthews, *A Silicon Valley of the East: Creating Taiwan's semiconductor industry,* 39 CALIF. MGMT. REV. (Summer 1997).

system to increase protection, lengthen the patent term and improve enforcement.[153] While my analysis focuses on the effect of the U.S. patent system on Taiwanese firms' patenting behavior, this background fact is relevant insofar as it signaled an institutional commitment to IP rights in a country that had previously been known for widespread piracy.

2. Patent Data: Window into Firm and Market Characteristics

Data on the first-named assignees of patents issued to Taiwanese filers provide a window into the primary types of entities in Taiwan's innovation economy. For this purpose, I examined a pool consisting of first-named assignees identified by the USPTO in its country-based breakdown of utility patent grants (which includes all such assignees other than entities that received fewer than five USPTO patents during 1969-2015).[154] This "identified first-named assignees" pool represents a significant majority (75%) of USPTO patents issued to Taiwanese filers during 2000-2015.[155] If we consolidate parents and subsidiaries within this assignee pool[156], there are 1,325 unique identified first-named assignees of patents issued to Taiwanese filers during this period. The assignee population falls into three major categories: (i) ITRI, the government research institute mentioned above; (ii) academic research institutions; and (iii) local technology firms. In turn, local technology firms fall into three broad categories: (i) a handful of large foundries that provide chip manufacturing services to other firms; (ii) a handful of large branded consumer electronics manufacturers; and (iii) a large population of differently sized entities that specialize in the design, manufacture and assembly of PCs, smartphones and electronics components. This industry type distribution is consistent with data on the patent classes favored by Taiwanese filers, who, during 2000-2015, patented most heavily in patent classes relating to semiconductors, electrical systems, and information storage.[157]

The charts below show, respectively, during 2000-2015: (i) the percentage that each entity type represents out of the total pool of identified first-named assignees of USPTO patents issued to Taiwanese filers; and (ii) the percentage that each industry type represents out of that same pool.

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153 For detailed discussion, see Chih-Hai Yang, *The Effects of Strengthening Intellectual Property Rights in NIEs: Evidence from Taiwan's 1994 Patent Reform,* 26 CONTEMPORARY ECON. POL'Y 259 (1994).

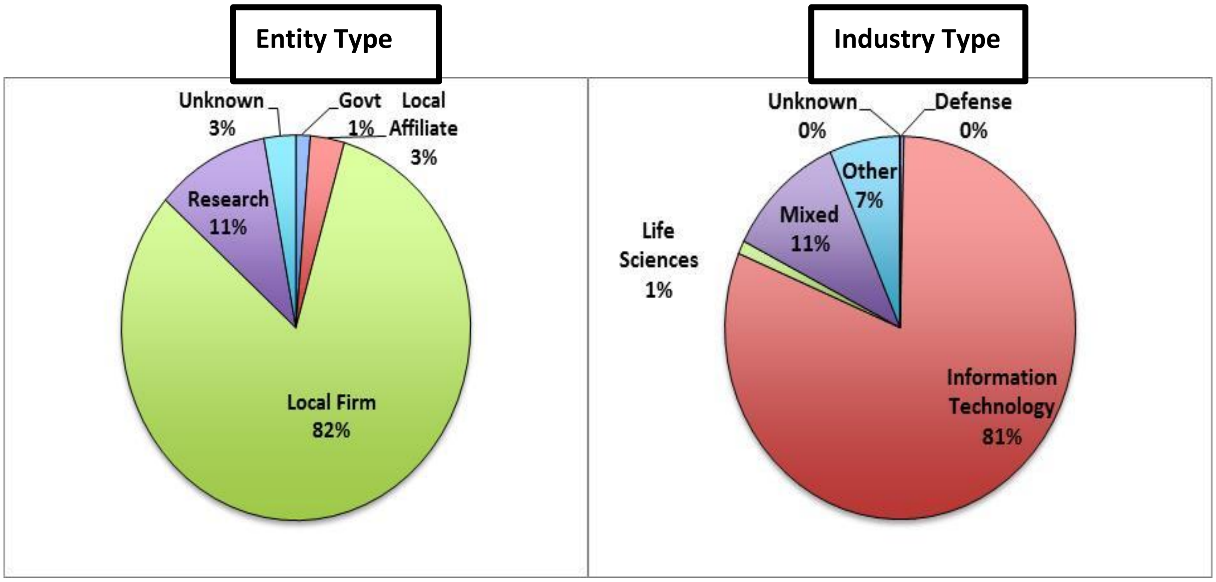
154 USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION. This five-patent limitation appears to be the reason why the pool of patents for which the USPTO identifies first-named assignees (as well as individually owned patents that do not name any such assignee) is smaller than the total pool of patents issued to Taiwanese filers as reported elsewhere by the USPTO (see USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT).

155 Author's calculations, based on USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION (providing information on assignees, with country breakdown) and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT (providing information on utility patent grants, with country breakdown).

156 For my methodology in identifying parent-subsidiary relationships, *see supra* note 109.

157 Specifically, Taiwanese filers patented most heavily in the following classes: (i) semiconductor device manufacturing (8.77% of all patents issued to Taiwanese filers during 2000-2015); (ii) solid-state devices (e.g., transistors) (6.7%); (iii) electrical connectors (4.84%); (iv) electrical systems and devices (3.73%); (v) illumination (3.02%); (vi) computer graphics processing (2.59%); (vii) information storage (1.59%); (viii) optical: systems and elements (1.5%); (ix) tools (1.45%); and (x) miscellaneous electrical devices (1.19%). Source: Author's calculations, based on USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY TECHNOLOGY CLASS.

Figure XIV: Type Distribution of Identified First-Named Assignees of USPTO Patents Issued to Taiwanese Filers (2000-2015)[158]



We can observe further detail by examining the top 15 first-named assignees of USPTO patents issued to Taiwanese inventors during 2000-2015. Collectively these assignees hold 37% of all USPTO patents issued to Taiwanese filers during this period.[159] Within this top 15 group, five entities account for 19% of all patents issued to Taiwanese filers during 2000-2015[160]: (i) Hon Hai Precision Co. (also known as "Foxconn"), the largest electronics components assembler in the world; (ii) ITRI, the government research and commercialization institute described above; (iii) TSMC and UMC, the world's largest semiconductor foundries; and (iv) AU Optronics, the world's leading manufacturer of liquid crystal displays ("LCDs"). The remainder of the "top 15" group is constituted by hardware firms and the Taiwan university system. Taiwanese universities have recently performed especially strongly at the USPTO: in 2015, five of its universities were among the top 100 university patentees.[161]

As noted earlier, Taiwan's IP trade deficit raises concerns over the quality of Taiwan's patenting activities[162], although Taiwan's improving success ratio, which now matches U.S. filers[163], allays those

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158 I obtained names of assignees through the USPTO database. I then obtained data on assignees' entity and industry type, and any parent-subsidiary relationship, by consulting the website and annual report (if available) of each entity, the Hoover's company database, or the EMIS database. In some cases, additional information relating to entity type was obtained by reviewing a sample of the entity's patents. For purposes of computing percentages, parents and subsidiaries were treated as a single entity (even if they were listed separately as patent filers in the USPTO data). For my methodology in identifying parent-subsidiary relationships, *see supra* note 109.

159 Author's calculations, based on data in USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT.

160 For sources, *see id*.

161 *See* ACADEMY OF INVENTORS, TOP 100 WORLDWIDE UNIVERSITIES GRANTED U.S. UTILITY PATENTS (2015).

162 *See supra* note **Error! Bookmark not defined.** and accompanying text.

163 *See supra* Part IV.A.1.

concerns to a certain extent. Other commentators have expressed similar concerns[164], although this seems to be based on an equation of patent quality with product innovation, rather than the process innovation in which Taiwanese firms appear to typically specialize. To address this concern further, I calculated the R&D intensities of the 15 Taiwanese non-governmental entities that were first-assigned the most USPTO patents during 2000-2015. All firms that are primarily involved in chip fabrication and chip design exhibit high R&D intensity rates (as of 2015 or 2014), in excess of 7% in the case of the foundries and in excess of 20% in the case of the chip design firms. This compares favorably with other Asian IT hardware firms such as Panasonic (5.93%), Samsung (7.43%), Sony (5.65%), Toshiba (5.18%) and LG (4.21%) and, in the case of the chip design firms, compares favorably with U.S. semiconductor firms such as Intel (21.91%) and Broadcom (15.37%).[165] Hon Hai and three IT hardware firms show low R&D intensity rates compared to other Asian IT hardware firms, which may therefore account in part for Taiwan's IP trade deficit.[166] In the aggregate, these data suggest, consistent with the trajectory of Taiwanese inventors' success ratios, that, at least in recent years, Taiwanese patents are reflective to a significant extent of underlying innovative capacity and activity.

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164 *See* Suzanne Berger and Richard K. Lester, *Globalization and the Future of the Taiwan Miracle*, in GLOBAL TAIWAN: BUILDING COMPETITIVE STRENGTHS IN A NEW INTERNATIONAL ECONOMY 15 (eds. Suzanne Berger and Richard K. Lester 2005).

165 Author's calculations, based on financial statements for each company as filed in its 2015 annual SEC filing (in the case of Samsung, the data are current as of 2014).

166 In companies that exhibit a combination of high patenting rates and low R&D intensities (compared to industry peers), there is a legitimate concern that patenting is being driven in significant part by an effort to reduce licensing rates paid to external technology suppliers. This type of patenting strategy would not be reflective of innovation activities.

Table II: First-Named Assignees of USPTO Patents Issued to Taiwanese Filers (Top 15, 2000-2015)[167]

Legend: G = governmental research entity; LF = local firm; R = research institution; ICT = information and communications technology; F = foundry; CD = chip design (fabless); H = hardware (incl. assembler); M = mixed

Assignee	Entity Type	Industry Type	Employees (Total)[168]	Mfg Facilities in Taiwan?	First Assigned Patents Issued to Taiwanese Filers (2000-2015)	Percent of Patents Issued to Taiwanese Filers (2000-2015)[169]	R&D Intensity (2015 or earliest year available)
Taiwan Semiconductor Manufacturing	LF	ICT (F)	43,591 (39,386 TW only)	Y	9,437	7.93%	7.77%
Hon Hai Precision	LF	ICT (H)	830,174 (est. 46,000 TW only)[170]	Y	8,324	6.99%	1.17%
Industrial Technology Research Institute	G	ICT	11,149 (TW only)	Y	5,128	4.31%	n/a
United Microelectronics	LF	ICT (F)	18,538	Y	3,262	2.74%	8.41%
AU Optronics	LF	ICT (H)	67,833 (24,155 TW only)	Y	3,106	2.61%	2.47%
Mediatek	LF	ICT (CD)	15,754	Y	2,541	2.13%	23.23%
Macronix Intl	LF	ICT (CD)	4,221	Y	2,129	1.79%	23.73%
Innolux	LF	ICT (H)	80,645	Y	1,475	1.24%	3.96%

167 I relied on USPTO data for all patent-related information. With respect to all other information, I searched the company's most recent annual report filed with the SEC. If the filing did not disclose information or the company was private, I relied on information in the Hoover's company database or the company's website, except as otherwise indicated. It was not possible in most cases to determine a firm's employees located only in Taiwan; hence worldwide employee figures are provided. In the limited number of cases in which there was reliable information on a firm's employees located in Taiwan, that information was included in parentheses as shown above. Note that parent and subsidiaries were consolidated under the parent's name even if listed as separate filers in the USPTO data. Unless otherwise indicated below, all information is current as of September 2016.

168 Employees refer to technical and non-technical employees. In the case of technology transfer entities of academic research institutions, employees refer to the number of research faculty at the university. Note that I list total employee figures for each company, rather than only employees in Taiwan, because it was typically not possible to reliably determine employees in Taiwan only.

169 This refers to the percentage constituted by (i) identified first-assigned patents issued to Taiwanese filers during 2000-2015 out of (ii) all USPTO patents issued to Taiwanese filers during that period. Sources: USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT.

170 As of 2014, based on: Lorraine Luk, *Hon Hai Beefs Up Hiring in Taiwan*, Wall St. J., Mar. 10, 2014.

Assignee	Entity Type	Industry Type	Employees (Total)	Mfg Facilities in Taiwan?	First Assigned Patents Issued to Taiwanese Filers (2000-2015)	Percent of Patents Issued to Taiwanese Filers (2000-2015) [171]	R&D Intensity (2015 or earliest year available)
Wistron Corp.	LF	ICT (H)	n/a[172]	Y	1,448	1.22%	2.15%
Delta Electronics	LF	ICT (H)	n/a[173]	Y	1,395	1.17%	7.11%
Univ. System of Taiwan[174]	R	M	2,321 (TW only)[175]	n/a	1,317	1.11%	n/a
Via Technologies	LF	ICT (CD)	1,728	Y	1,262	1.06%	20%
Republic of China	G	M	n/a	n/a	1,183	0.99%	n/a
Inventec	LF	ICT (H)	49,118		952	0.80%	2.23%
Realtek Semiconductor	LF	ICT (CD)	2,465	Y	927	0.78%	n/a[176]

3. Evaluation: The Role of USPTO Patents in Taiwan's Innovation Economy

The data presented above provides a foundation for a preliminary understanding of the functions of USPTO patents in Taiwan's innovation ecosystem, especially in the market segment occupied by the top 15 first-named assignees in the Taiwanese USPTO population during 2000-2015. There appear to be three primary functions, each corresponding to a different type of expropriation risk. First, as is discussed in the existing literature, patent licenses mitigated "insourcing hazards" and thereby enabled Taiwanese entities to initially secure access to foreign technology from Japanese and U.S. firms, which was used to enter, and subsequently undertake R&D in, the electronics component and chip production markets.[177] Relatedly, ITRI obtained licenses to secure foreign technology for applied research purposes, which it then transmitted to local firms (especially chip foundries). Second, patents mitigate "outsourcing hazards" and thereby enable "fabless" chip design firms to enter into mutually profitable production

[171] This refers to the percentage constituted by (i) identified first-assigned patents issued to Taiwanese filers during 2000-2015 out of (ii) all USPTO patents issued to Taiwanese filers during that period. Sources: USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION and USPTO, EXTENDED YEAR SET – PATENT COUNTS BY COUNTRY/STATE AND YEAR, UTILITY PATENTS REPORT.

[172] This figure could not be reliably determined due to a discrepancy between the Hoover's company database, which indicates 6,074 employees, and the company website, which indicates over 60,000 employees worldwide.

[173] This figure could not be reliably determined due to a discrepancy between the Hoover's company database, which indicates 5,868 employees, and the company website, which indicates over 60,000 employees worldwide.

[174] This is an entity that integrates certain resources of four research universities in Taiwan. It appears to operate as a technology transfer entity for these universities.

[175] This refers to the number of instructors as of 2011. Source: University System of Taiwan.

[176] Last annual report in English issued in 2004.

[177] *See* Sturgeon & Lee, *supra* note 81, at 51. For discussion of a Taiwanese firm's innovations in electronic component design (specifically, scanners), see SAXENIAN, *supra* note 6, at 166. On the importance of technology in-licensing transactions in fostering the development of the Taiwanese TFT-LCD (display panel) industry, which was then followed by R&D and patenting by the Taiwanese partner firms, see Mei-Chih Hu, *Industry and Knowledge Evolution: The Case of Taiwan's Flat Panel Display Industry,* in TAIWAN'S ECONOMIC TRANSFORMATION IN EVOLUTIONARY PERSPECTIVE (ed. Fu-Lai Tony Yu 2007).

relationships with Taiwanese foundries. Third, patents enable Taiwanese foundries and other firms to protect innovations (principally process innovations) in chip fabrication and other IT production segments and earn a return on their R&D investments. To structure the analysis, I focus below on semiconductor design and manufacturing.[178]

a. The Foundry Model

Patents enabled Taiwan's initial insourcing of technological knowledge from foreign firms, primarily through ITRI. These critical technology transfers laid the foundation for Taiwan's foundries and subsequent leadership in semiconductor production.

- In 1976, RCA and ITRI entered into a license agreement permitting ITRI to make use of RCA's semiconductor process technology.[179] Specifically, the license enabled IRTI to enjoy access to RCA's patented "CMOS" (complementary metal-oxide-silicon) technologies (plus related know-how and training provided by RCA). On that basis, ERSO constructed a pilot IC production facility.[180] Thereafter ITRI spun off the facility to a newly-formed private entity, United Microelectronics Corporation ("UMC").[181]

- In approximately 1983, ITRI licensed "VLSI" ("Very Large Scale Integration") technology from a small California-based firm.[182] ERSO later transferred its rights in VLSI technology to a stand-alone foundry, the Taiwan Semiconductor Manufacturing Corporation ("TSMC"), established in 1986 as part of a joint venture with Philips.[183] Philips contributed cash and certain chip fabrication patents as well as Philips' rights under cross-licensing agreements with other major semiconductor producers.[184]

TSMC pioneered the "pure play" foundry model (as contrasted with the vertically integrated model used by Intel and other incumbents in the chip industry), in which stand-alone production services are provided to chip design firms that lack the billions of dollars required to construct a fabrication

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178 My discussion identifies key transactions in which patent licensing facilitated the voluntary transmission of knowledge inputs from U.S., European and Japanese firms to Taiwanese firms, which in turn seeded indigenous R&D in the Taiwanese chip production and design industries. Given the widespread piracy that characterized Taiwan at least until the enactment of patent reforms starting in the late 1980s (*see supra* note 153), a fuller study of Taiwan's innovation economy would consider whether other segments may have benefited from the involuntary (as distinguished from the negotiated) transmission of knowledge inputs held by foreign firms.

179 *See* SAXENIAN, *supra* note 6, at 140; Tung, *supra* note 151; Shih et al., *supra* note 147, at 110.

180 *See* JOHN A. MATTHEWS AND DONG-SUNG CHO, TIGER TECHNOLOGY: THE CREATION OF A SEMICONDUCTOR INDUSTRY IN ASIA 158-59 (2007); Shih et al., *supra* note 147, at 110; Tung, *supra* note 151; Wen & Chen, *supra* note 149, at 225; Matthews, *supra* note 152, at 26, 34.

181 *See* SAXENIAN, *supra* note 6, at 140; Wen & Chen, *supra* note 149, at 225; Shih et al., *supra* note 147, at 110.

182 *See* MATTHEWS AND CHO, *supra* note 180, at 169; Matthews, *supra* note 152, at 26, 36; *see also* SUNG GUL HONG, THE POLITICAL ECONOMY OF INDUSTRIAL POLICY IN EAST ASIA 54 (1997) (noting a joint research agreement between ERSO and Vitelic to develop VLSI technology).

183 *See* Tung, *supra* note 151; Hong, *supra* note 182, at 55.

184 *See* MATTHEWS AND CHO, *supra* note 180, at 160, 259; Matthews, *supra* note 152, at 26, 36. For further description of the agreement and subsequent amendments, see TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY LTD., FORM 20-F (filed Dec. 13, 2004), at p.48. For the amended agreement, see TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY LTD., FORM 20-F (filed Dec. 13, 2004), EXH. 4.8.

facility or to integrated chip manufacturers in need of additional capacity.[185] Within little more than a decade after its founding in 1986, TSMC constituted the world's largest stand-alone chip foundry[186] and, as of 2014, Taiwanese firms constituted approximately 71% of the worldwide foundry market.[187] Taiwanese foundries have developed process and equipment innovations in chip manufacturing[188], which they have then sought to protect through patent portfolios as is typical in the chip industry worldwide.[189] Those patent portfolios protect the foundries' R&D investments against expropriation by competitors as well as departing employees. This is not merely theoretical: in 2003 and 2004, TSMC initiated patent and trade secret litigations against SMIC, a Chinese chip manufacturer, which involved in part the alleged disclosure of TSMC's trade secrets by employees that had departed for SMIC and the alleged use by SMIC of TSMC's patented technology.[190] Interestingly, these litigations were brought in U.S. federal court[191] and the International Trade Commission[192] (as noted earlier, a U.S. administrative entity) on the basis of TSMC's USPTO portfolio.

While Taiwanese foundries are located at the mid-stream production stage in the supply chain, it is clear that the firms must make significant R&D investments in order to reduce production costs and achieve performance targets in the competition for chip design clients.[193] The foundries' R&D efforts are reflected both in their R&D intensity (R&D expenditures as a percentage of total revenues) and patenting behavior. As of 2015, TSMC's R&D intensity was 7.77% and UMC's R&D intensity was 8.41%[194], which compares favorably with leading Asian IT hardware firms such as Samsung (7.43%), Sony (5.77%), Toshiba (5.18%) and LG (4.06%).[195] While it falls below the R&D intensity of leading U.S. semiconductor firms such as Intel (21.21%) and Broadcom (15.37%)[196], those firms have chip design capacities, which are located further "upstream" on the supply chain and may therefore demand greater R&D expenditures. For the period 2000-2015, Taiwan is tied with Japan as the single largest foreign first-named assignee of USPTO patents in semiconductor manufacturing equipment (USPTO Class 438)

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185 *See* Breznitz (2005), *supra* note 149, at 159.

186 *See* MATTHEWS AND CHO, *supra* note 180, at 179.

187 R.O.C. (TAIWAN) NATIONAL DEVELOPMENT COUNCIL, TAIWAN STATISTICAL DATA BOOK 12 (2015).

188 *See* Douglas Fuller, Akintunde Akinwande & Charles Sodini, *Leading, Following or Cooked Goose? Innovation Successes and Failures in Taiwan's Electronics Industry*, 10 INDUSTRY AND INNOVATION 179, 183 (2003).

189 On patenting practices in the semiconductor industry, see Stefan Tamme et al., *Trends and Opportunities in Semiconductor Licensing,* SEMICONDUCTOR LICENSING TRENDS (Dec. 2013).

190 *See* Sumner Lemon, *China's SMIC settles lawsuits with TMIC*, INFOWORLD, Jan. 31, 2005.

191 *See* COMPLAINT, TAIWAN SEMICONDUCTOR MANUFACTURING CO., LTD. ET AL. V. SEMICONDUCTOR MANUFACTURING INTERNATIONAL CORPORATION, N.D. CAL., DEC. 19, 2003.

192 *See* COMPLAINT OF TAIWAN SEMICONDUCTOR MANUFACTURING CO., LTD. ET AL. UNDER SECTION 337 OF THE TARIFF ACT OF 1930, INT'L TRADE CMM'N, AUG. 18, 2004.

193 *See* Tamme et al., *supra* note 189, at 220; SHIN-HORNG CHEN, PEI-CHANG WEN AND MENG-CHUN LIU, TRENDS IN PUBLIC AND PRIVATE INVESTMENTS IN ICT R&D IN TAIWAN 26 (2011); Fuller et al., *supra* note 180, at 81-82.

194 Sources: TSMC, FORM 20-F, 2012 ANNUAL REPORT; UMC, FORM 20-F, 2012 ANNUAL REPORT.

195 Author's calculations, based on SEC filings for each company, as of 2015 (or 2014 if figures not available for 2015).

196 Author's calculations, based on SEC filings for each company, as of 2015 (or 2014 if figures not available for 2015).

and is the second largest foreign first-named assignee of patents in Computer-Aided Design and Analysis of Circuits and Semiconductor Masks (Class 716).[197]

b. Fabless Chip Design

The foundry model represented an important organizational innovation that enabled smaller chip design firms to enter the market without having to fund the billions of dollars[198] required to construct a chip fabrication facility (a "fab"). As such, it has had a second favorable effect on Taiwan's innovation economy by supporting domestic IC design houses that would not otherwise have had access to manufacturing facilities.[199] Within one year of the founding of TSMC (in 1987), the number of chip design firms in Taiwan increased from 4 to 40[200] and, as of 2014, there were approximately 245 such firms based in Taiwan.[201] The result is a disaggregated market cluster of small to medium-sized chip design firms, complemented by firms that specialize in other parts of the chip testing, packaging and production process.[202] As of 2015, Taiwanese firms represented approximately 18% of the worldwide fabless industry, constituting the largest chip design source after the United States.[203]

Patents appear to have promoted this development in two respects. First, patents mediate in-licensing and joint venture relationships between U.S. and Taiwanese chip design firms, which can then use those licenses to cultivate independent design capacities.[204] Second, patents have mediated production relationships between Taiwanese chip design firms and foundries. Specifically, patents resolve a two-way expropriation dilemma. On the one hand, design firms must disclose extensive information to the foundry in the course of the production process.[205] This naturally raises (and design firms have reportedly expressed) concerns that the foundry will expropriate those designs by providing them to a competing firm.[206] On the other hand, as UMC (a leading Taiwanese chip foundry) stated in a litigation before the International Trade Commission, the foundry must disclose elements of its process technology to the design firm in order to facilitate coordination between the customer's circuit design and

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197 Author's calculations, based on USPTO, EXTENDED YEAR SET – PATENTING IN TECHNOLOGY CLASSES BREAKOUT BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY).

198 As of 2015, estimated construction cost for a new "fab" was $5-10 billion. *See* SEMICONDUCTOR INDUSTRY ASSOCIATION, BEYOND BORDERS: THE GLOBAL SEMICONDUCTOR VALUE CHAIN 22 (2015).

199 *See* MATTHEWS AND CHO, *supra* note 180, at 30, 38 Fig. 1.10; 89, 178; Matthews, *supra* note 152, at 36-37; Shin-Horng Chen, *Global Production Networks and Information Technology: The Case of Taiwan*, 9 INDUSTRY AND INNOVATION 249-265 (2002).

200 *See* Tung, *supra* note 151, at 272.

201 SEMICONDUCTOR INDUSTRY ASSOCIATION, BEYOND BORDERS: THE GLOBAL SEMICONDUCTOR VALUE CHAIN 19-20 (2015).

202 *See* CHEN ET AL., *supra* note 193, at 26.

203 *See* SEMICONDUCTOR INDUSTRY ASSOCIATION, BEYOND BORDERS: THE GLOBAL SEMICONDUCTOR VALUE CHAIN 19-20 (2015), at p.11 Fig. 8.

204 For a description of some of these partnerships, see Saxenian, *supra* note 6, at 179-180. For a discussion of the same and how Taiwanese firms subsequently secured dominant market shares in certain chip market segments, see Douglas B. Fuller, *Moving Along the Electronics Value Chain: Taiwan in the Global Economy*, in GLOBAL TAIWAN: BUILDING COMPETITIVE STRATEGIES IN A NEW INTERNATIONAL ECONOMY 145-46 (eds. Suzanne Berger and Richard K. Lester 2005).

205 *See* CHEN ET AL., *supra* note 193, at 33.

206 *See* Shin-Horng Chen, *Global Production Networks and Information Technology: The Case of Taiwan*, 9 INDUSTRY AND INNOVATION 259-60 (2002); Shahid Yusuf, *Competitiveness Through Technological Advances Under Global Production Networking*, in GLOBAL PRODUCTION NETWORKING AND TECHNOLOGICAL CHANGE IN EAST ASIA 10 (eds. Shahid Yusuf, M. Anjum Altaf & Kaoru Nabeshima 2004).

the foundry's manufacturing process.[207] This poses expropriation risk to the extent the design firm has existing or potential chip manufacturing capacity (or its employees can move to a firm with chip manufacturing capacity). Patents mitigate both sides of this expropriation dilemma by protecting the design firm against expropriation by the foundry while, in certain cases, protecting the foundry from expropriation by the design firm.

B. **Summing Up: The International Chip Supply Chain**

Patents play different functions in the innovation economies of Israel and Taiwan: while patents appear to most often protect product innovation in Israel, they appear to most often protect process innovation in Taiwan. In both cases, patents enable firms in each country to reap the benefits of comparative advantage by supplying the global IT market with the functions in which those firms excel. This allocation of supply chain functions yields an efficiency gain by minimizing the costs of sourcing R&D inputs, assembling commercialization inputs, and delivering the final product to the end-user. The relationship between patents, comparative advantage, and supply chain design can be illustrated by reference to the Marvell Technology Group Ltd. and Taiwan Semiconductor Manufacturing Corporation ("TSMC").[208]

Marvell is a large semiconductor firm that maintains its operational headquarters and an R&D center in Silicon Valley while operating additional R&D centers in China, Israel, Singapore and Switzerland. Its Israeli R&D center is a significant enterprise (consisting of 1,200 employees, out of a total global workforce of approximately 7,500 employees) that has been developed in part through the acquisitions of Israeli firms: (i) Galileo (acquired in 2001 for $2.7 billion); (ii) RadLan technologies (acquired in 2003 for $49.7 million and additional equity); (iii) DSPC (acquired in 2006 for $600 million); and (iv) Iamba Networks (acquired in 2008 for $10 million).[209] As a "fabless" firm, Marvell has no independently owned fabrication facilities and contracts for chip production services, primarily with TSMC. The firm exhibits an exceptionally high R&D intensity (31.41%), which exceeds even Intel (21.21%) and Google (14.95%).[210] That R&D investment has resulted in a significant patent portfolio, consisting of 5,300 U.S. patents (of which 83% were issued to U.S. inventors, 11% to Israeli inventors and the remainder to inventors in other countries[211], all presumably working at Marvell's R&D centers). That USPTO patent portfolio ameliorates expropriation risks that could frustrate Marvell's ability to monetize its R&D assets through a supply chain structure that is disaggregated over multiple countries but ultimately targets the U.S. market. At the same time, TSMC's large patent portfolio (consisting of 10,016

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207 *In re Certain Integrated Circuits, Processes for Making Same and Products Containing Same*, Inv. No. 337-TA-450 (Oct. 7, 2002), at 248-49 (testimony by UMC, Vice President for Field Engineering).

208 Unless otherwise indicated, all remaining information in this section is based on the most recent annual reports of Hon Hai, HP, Marvell and TSMC, in each case as filed with the SEC.

209 Source for data on patents: USPTO, EXTENDED YEAR SET, UTILITY PATENT REPORT, PATENTING BY GEOGRAPHIC ORIGIN (STATE AND COUNTRY) – BREAKOUT BY ORGANIZATION. Source for acquisitions: Nikhil Deogun and Molly Williams, *Marvell Technology Agrees to Buy Israel's Galileo in $2.7 Billion Deal,* Wall St. J., Oct. 17, 2000; Shmulik Selah, *Intel Sells DSPC for $600m 7 years after paying $1.6b,* Globes, June 27, 2006; News Release, *Marvell Acquires Radlan Computer Communications Ltd.,* Feb. 6, 2003.

210 Source: companies' annual reports filed with the SEC.

211 Author's calculations, based on USPTO data, and information disclosed in Marvell's 2015 annual report. For purposes of calculating the firm's USPTO patents, I included any patent assigned to Marvell as a first-named assignee since 1995. This assumption is overinclusive to the extent that Marvell did not maintain in force all of the patents assigned to it during that time.

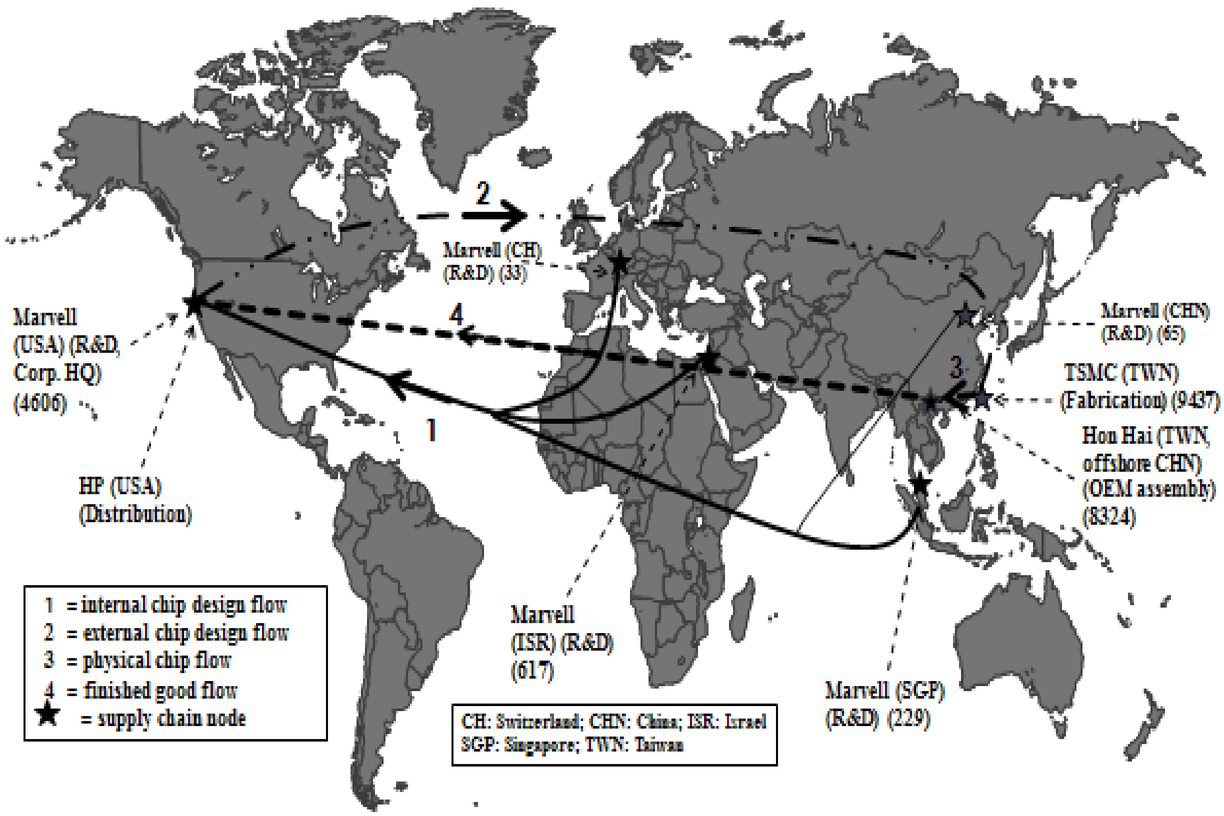
U.S. patents[212]) provides some protection against expropriation of TSMC's process technologies, whether by competitors or departing employees.

The map below depicts a "sample" supply chain in which four firms—Marvell, TSMC, Hon Hai and HP—must interact, and exchange knowledge assets, in order to deliver an IT good to the target U.S. market. At each sensitive point of knowledge exchange, USPTO patents, presumably in conjunction with licensing and employment agreements, regulate information flow and allow the supply chain to move forward efficiently. In simplified form, the sequence consists of four information-intensive transactions. First, in the upstream market for R&D inputs, the patent portfolio regulates information flow between Marvell and its R&D centers in Israel, Switzerland, Singapore and China, whose employees may pose an internal expropriation threat. Second, in the intermediate market for chip production services, the patent portfolio regulates information flow between Marvell and TSMC (and, by implication, TSMC's other customers). Additionally, TSMC's patent portfolio enables it to overcome expropriation risks and reveal design inputs and process technologies to its customers and employees. Third, in the intermediate market for assembly services, Marvell's patent portfolio protects against expropriation risk from OEMs such as Hon Hai (which operates an offshore production facility in China in the supply chain shown below)[213], who receive the chips from Marvell for use in devices assembled for foreign branded manufacturers (in the sample supply chain, HP) located in the U.S. market.

[212] Author's calculations, based on USPTO data, and information disclosed in TSMC's annual report. For purposes of calculating the firm's USPTO patents, I included any patent assigned to TSMC as a first-named assignee since 1995. This assumption is overinclusive to the extent that TSMC did not maintain in force all of the USPTO patents assigned to it during that time. Based on TSMC's 2015 annual report, it holds almost 20,000 patents issued by other countries; these too may mitigate expropriation risk following the reasoning set forth above.

[213] Certainly, a U.S. patent only protects against expropriation risk at a production facility in a weak-IP regime such as China to the extent that it can potentially block importation into the U.S. market.

Figure XV: International Semiconductor Supply Chain (Simplified)[214]



Conclusion

It is often argued that the patent system stands in tension with growth and innovation in developing countries. This paper identifies a notable exception to this argument. In the case of at least three emerging markets, extensive use of the U.S. patent system appears to have supported innovation and been accompanied by significant movement up the growth ladder. Within a few decades, Israel, Korea and Taiwan have invested heavily in cultivating a rich stock of human and intellectual capital and obtaining USPTO patents to extract a return from those investments. The result is impressive: these small and (especially in the case of Israel and Taiwan) relatively isolated markets now outperform every country aside (sometimes) from the U.S. and Japan on both per-capita and per-GDP measures of USPTO patent grants. While further inquiry is warranted, the result does not seem accidental. Existing theory and empirics support the view that patents are especially valuable as entry tools for smaller R&D-intensive firms that lack the capital and expertise to establish the production and distribution infrastructure required to execute the commercialization process efficiently. The "patent tigers"

214 Number in parentheses following each entity indicates the number of USPTO patents first-assigned to that entity during 2000-2015. In the case of patents that are assigned to Marvell, I assume that any such patent that is issued to an inventor resident in a foreign country was patented by an employee at Marvell's R&D center in that country. For simplicity, some steps in an actual semiconductor supply chain have been omitted.

phenomenon suggests that this effect extends from the firm level to the country level. Jurisdictions with rich human and intellectual capital but small domestic markets can extract returns from R&D investments through transactions with third parties that facilitate the pathway to larger foreign markets. The property rights umbrella supplied by the U.S. patent system provides a critical tool to achieve that objective.