US Patents and Global Performance: Analyzing the Impact of Local Patent Protection on Firms’ International Operations

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US Patents and Global Performance:
Analyzing the Impact of Local Patent Protection
on Firms’ International Operations

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Abstract

This paper examines how US patent protection affects the global scale and supranational distribution of firms’ operations. After presenting a simple theoretical model, I exploit exogenous variation in patent examiner leniency to estimate the impact of US patent protection on firms’ aggregate sales in both the US and various foreign countries. In addition, to consider how US patents affect firms’ production location decisions, I estimate the impact of firm-level US patent protection on US and foreign subsidiary sales. Lastly, I evaluate how institutional factors contribute to across-country heterogeneity in the relationship between US patents and foreign subsidiary sales. I find that US patent protection increases firms’ US sales at the aggregate and subsidiary levels. Furthermore, US patent protection increases firms’ aggregate sales in foreign countries. Nonetheless, the impact of US patent protection on foreign subsidiaries’ sales depends upon country-specific levels of intellectual property rights (IPR) protection, property rights, judicial independence, and political transparency. Altogether, these findings suggest that US patent protection not only grants substantial domestic market power to innovative firms, but also may incentivize them to expand their foreign operations.

Keywords: Intellectual Property Rights (IPR), Patent, Subsidiary
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1 Introduction

In 2019, US Secretary of Defense Mark Esper warned that China’s acquisition of foreign companies’ intellectual property through forced technology transfer and espionage represented “the greatest intellectual property (IP) theft in human history.” While some might view Esper’s remarks as hyperbole, it is undeniable that the scope and costs of Chinese IP imitation have presented significant challenges for both policymakers and foreign companies. Indeed, a 2018 CNBC survey found that one in five North American companies reported Chinese IP theft within the past year,\(^1\) while a 2017 report by the US Commission on the Theft of American Intellectual Property estimated that Chinese IP theft had cost the country an annual total of $225-$600 billion. Nonetheless, despite the substantial risks and costs of Chinese IP infringement, in recent years innovative companies ranging from Daimler to Apple have only become more reliant on their Chinese sales and operations to ensure their growth.

The continued presence of foreign companies in the Chinese market, despite the material risk of IP imitation, raises pertinent questions for both policymakers and economists. First, policymakers might wonder why foreign companies that hold patented IP in advanced economies might continue to maintain and even expand their Chinese operations. In addition, economists might more generally speculate on how patent protection in one geographic market affects firms’ operations both within the local market and across various foreign markets, where a local patent’s enforcement may not be guaranteed.

Addressing these questions, this paper considers the implications of local patent protection on the scale and distribution of a firm’s global operations. First, I consider how local patent protection might theoretically affect a firm’s domestic and foreign sales in a simple model. Next, by employing (i) patent data from the United States

\(^{1}\)7 of the 30 companies represented in the survey reported Chinese IP theft over the past decade. The survey sample comprised of all companies represented in CNBC’s global CFO council.
Patent and Trademark Office (USPTO), (ii) firm-level financial data from Compustat North America, and (iii) subsidiary-level data from Bureau Van Dijk, I empirically estimate the impact of US patent protection on various facets of a firm’s global operations. First, combining the Compustat and USPTO data, I evaluate how US patent protection might influence a firm’s aggregate sales within the US and across different foreign markets. Next, by adding subsidiary-level data from Bureau Van Dijk, I investigate how a firm’s US patent holdings might influence the sales of its US and foreign subsidiaries. Lastly, I examine the extent to which country-level variables such as intellectual property rights (IPR) quality, property rights, judicial independence, and political transparency explain across-country heterogeneity in the relationship between US patent protection and foreign subsidiary sales. For these analyses, I employ country-level data on IPR, property rights, judicial independence, and political favoritism from the World Bank’s GovData360 database.

To begin, this paper’s theoretical model highlights a fundamental trade-off that a profit-maximizing firm faces when deciding to sell or produce a locally-patented product abroad. On the one hand, potential profits from foreign sales may incentivize the firm to introduce a locally-patented product into a foreign market, even if the local patent does not protect the product abroad. Furthermore, the potential to eliminate export-related transport costs and benefit from lower marginal costs of production abroad may motivate a firm to produce the patented product within the foreign market. On the other hand, if a local patent only protects a product in the local market, a firm might be disincentivized from selling and producing the product abroad due to the threat of competitor imitation. Analyzing this fundamental trade-off, the model predicts, under certain assumptions, that local patent protection should increase a firm’s local and foreign sales. However, the model also predicts that the impact of local patent protection on a firm’s production location decisions remains ambiguous. Specifically, it conjectures that a firm’s decision on where to
locate production of its patented good relies on the across-market heterogeneity in marginal production costs, transport costs, and imitation threats.

Next, to build upon the theoretical intuition provided by the model, I provide empirical analyses on the causal relationship between local patent protection and firms’ global operations. Throughout these analyses, I employ an instrumental variables approach to identify the causal impact of US patent protection on firms’ global operations. Restricting my data to patent-holding firms, I exploit quasi-random variation in USPTO patent examiner leniency, which exogenously shocks a firm’s US patent holdings. To justify this approach, I discuss how (i) assignment to a more lenient USPTO examiner increases an individual US patent application’s probability of success and (ii) having more lenient USPTO examiners on average increases the total number of patents held by a given firm in a given year. Also, I include industry-year fixed effects in all my analyses to account for the possibility of nonrandom assignment of patent examiners across technological sectors and time. Lastly, I complement my instrumental variables analyses with fixed effect analyses. Although they might present more biased estimates of the causal impact of US patents on firms’ global operations, the fixed effect analyses allow me to estimate the relationship between US patents and global operations over a larger sample of firms.

Implementing these two empirical approaches, I first evaluate the impact of US patents on firms’ US and global aggregate sales. In my preferred specification, I find that, on average, an additional patent increases a firm’s aggregate global sales by 0.26%, while an additional patent increases a firm’s aggregate US sales by 0.20%. While these estimates may initially appear modest, they would suggest that a US patent generates millions of dollars in additional sales, especially since the total sales reported by the publicly-traded companies in my sample are often over $1 billion. Furthermore, an additional US patent appears to increase firms’ aggregate sales in
various foreign countries. Altogether, these results appear consistent with the model, which suggests that patent protection would increase both US and foreign sales.

In addition, to understand how US patents might affect the spatial distribution of a firm’s production, I consider the impact of firm-level US patent protection on the sales of its US and foreign subsidiaries. Within the US, I find that an additional US patent at the parent company level increases a US subsidiary’s sales by $1.1 million on average. In contrast, I find the impact of firm-level US patent protection on foreign subsidiaries’ sales to be ambiguous. To illustrate, after conducting regression analyses on a country-by-country basis, I find that an additional firm-level US patent increases the sales of a firm’s subsidiaries located in countries including France, Britain, and Germany. However, I also find that an additional US patent decreases sales for subsidiaries located in other countries such as China, India, and Russia. Discarding all restrictions on subsidiary location, I find that an additional US patent increases a subsidiary’s sales by $1.28 million. Nonetheless, the aforementioned country-by-country analysis suggests that significant across-country heterogeneity in the causal relationship between US patent protection and foreign subsidiary sales exists.

Accordingly, I employ country-level data on IPR quality, property rights, judicial independence, and political transparency to determine whether such variables help to explain the across-country heterogeneity in the relationship between US patents and foreign subsidiary sales. First, using fixed effect regressions, I find that an increase in the quality of IPR protection in a given country is associated with a positive increase in the correlation between US patents and subsidiary sales in that country. That is, firm-level US patent protection is more positively correlated with higher subsidiary sales in countries with high-quality IPR protection than in countries with low-quality IPR protection. Likewise, US patent protection is more positively correlated with

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2 I investigate the impact of US patent protection on aggregate sales in Canada, the UK, China, Japan, Germany, and other countries. A full list of countries is provided in section 4.
3 That is, I regress subsidiary sales on US patents while restricting my data to subsidiaries located in a specific country. Refer to section 5 for the complete set of country-by-country results.
higher subsidiary sales in countries where the quality of property rights protection, the extent of judicial independence, and the degree of political transparency are higher. In addition, using my leniency instrument in additional 2SLS regressions, I find more limited evidence suggesting that country-level increases in IPR protection quality, property rights protection quality, judicial independence, and political transparency increase the causal impact of US patent protection on subsidiary sales across countries and time. That is, the impact of US patent protection on subsidiary sales will be larger in countries with stronger IPR protections, stronger property rights, more independent judiciaries, and less political favoritism. Lastly, additional empirical tests appear to suggest that within-firm adjustment of subsidiary sales serve as the primary catalyst behind these results, whereas across-firm selection into markets with high vs. low IPR quality play at best a secondary role.

This paper contributes to the economics literature in various ways. First, while much empirical work on the relationship between IPR and international trade has been conducted at the industry or product level,\textsuperscript{4} this paper considers the relationship between patent protection and international trade at the \textit{firm} level. Previous theoretical work including Helpman (1993) and Lai (1998) posits that firms play a critical role in determining the relationship between local patent protection and international trade flows. Indeed, a 2013 UN report showed that multinational corporations generate nearly 80% of global trade value, while a USPTO annual report in 2015 showed that US and foreign firms accounted for over 90% of new US patent grants that year. However, the body of empirical work on the firm-level interaction between IPR and trade remains somewhat modest. The relatively modest number of firm-level empirical studies in prior years may have resulted from the relative paucity of disaggregated firm-level data in earlier years.\textsuperscript{5} However, the emergence of large disaggregated firm-level data in recent years has rendered firm-level studies more fea-

\textsuperscript{4}Such work includes Doanh and Heo (2007), Awokuse and Yin (2010), and Delgado et al (2013).

\textsuperscript{5}Previous firm-level analyses include Branstetter et al (2006) and De Rassenfosse et al (2019).
sible. Accordingly, this paper adds to the relatively less explored literature on the firm-level relationship between local patent protection and international trade.

In addition, this paper extends prior literature on the firm-level impact of patent protection on trade beyond the conventional North-South context. To elaborate, prior empirical work on the firm-level impact of patents on international trade such as Branstetter et al (2006) has generally considered how improved patent protection in developing (Southern) countries impacts the local sales and foreign direct investment of foreign multinationals. These multinationals are usually headquartered in developed (Northern) economies. Fittingly, for causal identification, these previous empirical studies have relied upon country-level patent system reforms as a source of exogenous variation in an event study or differences-in-differences approach.

While these empirical analyses effectively identify the impact of patent protection on trade in the North-South context, the smaller number of recent patent system reforms in “Northern” countries render such difference-in-difference approaches less feasible outside of the North-South context. Furthermore, previous analyses’ North-South focus limits their external validity when considering whether a more generalizable relationship between foreign patent protection and international trade exists. Nonetheless, the emergence of examiner-level US patent data enables me to construct a measure of patent examiner leniency as an instrumental variable for this paper’s empirical analyses. Thus, equipped with such an instrument, this paper builds off prior work by evaluating the impact of local patent protection on international sales and production across advanced economies, instead of just in the North-South context. Although leniency instruments have been widely used in other areas of applied microeconomics, this paper, to the best of my knowledge, is one of the first to employ such an instrument in the subfield of international trade and investment.

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6This is likely due to the longer history of robust patent systems in developed economies. For example, the modern USPTO was founded in 1975, and the first US patent system formed in 1790.
7Refer to Dobbie et al (2018), Sampat and Williams (2019), and Maestas et al (2013) for examples.
Lastly, and perhaps most importantly, this paper contributes to the literature by considering the impact of local patents on a firm’s international operations beyond a patent’s jurisdiction. Indeed, this paper, to the best of my knowledge, is one of the first to consider the potential spillover effects of local patent protection on firms’ foreign operations. Prior literature on international trade and technology transfer has often considered how country-level improvements in patent and IPR protection may stimulate firm-level sales and investment within a country.\[^{8}\] Furthermore, the innovation economics literature has also examined the impact of patents on firm operations within a patent’s jurisdiction.\[^{9}\] However, the literature on how local patent protection may alter firms’ international operations beyond a patent’s area of jurisdiction remains fairly modest. Nonetheless, the rapid globalization of firms’ supply chains and customer markets over the past quarter century has only rendered such questions more relevant. As many globally-expanding firms may seek to forego the substantial costs of ensuring patent protection for all their innovations in all geographic markets, understanding how patent protection in one “local” market affects a firm’s operations in foreign markets appears increasingly critical for understanding the international flow of goods, capital, and technology.

The rest of this paper is structured as follows. Section 2 provides institutional background on international trade and patent protection, as well as a brief literature review. Section 3 presents a theoretical model to illustrate the impact of local patent protection on a firm’s global sales and production location, while section 4 describes my data. Section 5 details the paper’s regression specifications, focusing in particular on the instrumental variables identification strategy. Section 6 presents the empirical results, while section 7 discusses the ways in which the results might corroborate and extend the theoretical model presented in section 3. Lastly, section 8 concludes.

\[^{8}\text{Refer to Branstetter et al (2006) and De Rassenfosse et al (2019) for examples.}\]

\[^{9}\text{See Kogan et al (2017) and Farre-Mensa et al (2018) for examples.}\]


2 Background

Any analysis of how US patent protection might affect a company’s US and overseas operations requires a basic understanding of the institutions governing local patent protection and international trade. Accordingly this section overviews the existing institutions and academic knowledge behind international innovation, patenting, and trade. First, I provide a brief background on the recent history and current composition of international trade and patenting. I use this background information to frame why international spillovers of local patent protection might intuitively be relevant and beneficial to firms’ international operations. Second, I review previous work discussing the interplay between IPR, firm strategy, and international trade and investment. In particular, I examine prior studies on two topics: (i) the impact of foreign IPR protection on firms’ sales and FDI, and (ii) the impact of patent protection on a firm’s local performance and market value.

2.1 International Trade and Patent Policy

Fueling the rapid growth in international trade over the past 40 years, the global expansion of innovative “superstar firms” has heightened the importance of IPR protection in international trade policy over the same period. Starting in the 1980s, developing countries’ rapid economic growth, coupled with the gradual decrease in global tariff rates, raised firms’ economic incentives to sell goods and relocate production abroad. Furthermore, technological advances during the same period catalyzed the rise of new superstar firms such as Apple and Qualcomm. Intensifying domestic competition between these new entrants and incumbents such as IBM, Ericsson, and Siemens only raised the allure of expanding sales and production abroad. In result, as average tariff rates across the globe gradually fell,\(^\text{10}\) global merchandise exports

\(^\text{10}\)For example, the average weighted tariff rate in the US decreased from 3.91% in 1989 to 2.1% in 2000. The average weighted tariff rate is weighted by the per-product value of imports into the
more than doubled from $3.037 trillion in 1981 to $6.499 trillion in 2000.\textsuperscript{11}

While the combination of lowered tariffs and technological innovation incited the rapid expansion of firms’ international operations from 1980-2000, the threat of foreign IP imitation continued to deter certain firms from expanding operations within developing economies. Thus, to better harmonize international standards of IP protection and facilitate international trade, 123 countries signed the TRIPS agreement in 1993, after the GATT-sponsored Uruguay round of trade negotiations.\textsuperscript{12} Complementing the 1970 Patent Cooperation Treaty (PCT), which established a standardized international patent application process, the TRIPS agreement established minimum international standards of patent protection, notably enforcing a minimum patent term length of 20 years. However, even after the TRIPS agreement came into effect in 1995, concerns over the enforcement of IPR across countries, as evidenced by the current US-China trade dispute, have persisted to this day.

The current tensions surrounding international IP transfer could perhaps be partially attributed to the lack of a global patent office. Although the TRIPS agreement helped to ensure more comparable levels of patent enforcement across countries, it did not expand the system governing international patent applications first established by the PCT. Indeed, in the present day, patent application approval remains administered by national patent offices. While the PCT system facilitates the process by which a single patent application is submitted to multiple patent offices, the prerogative to grant or reject the patent applications over a specific geographic jurisdiction remains entirely with the national or regional patent offices themselves.\textsuperscript{13}

Accordingly, under the current PCT system, a firm with a new innovation would

\begin{flushright}
\textsuperscript{11}These values are measured in current USD. All tariff and export figures are drawn from the World Bank’s National Accounts data set.

\textsuperscript{12}TRIPS stands for Trade-Related Aspects of Intellectual Property Rights. GATT stands for the General Agreement on Tariffs and Trade, the predecessor of the World Trade Organization.

\textsuperscript{13}Most patents are granted at the national level. However, some, such as the European patents granted by the European Patent Office, are granted at the regional level.
\end{flushright}
be obliged to submit a patent application in every country where it wishes to protect its innovation from imitation. Of course, the firm may choose to file a PCT patent application to facilitate its application’s submission into various national patent offices. Nonetheless, the World Intellectual Property Organization (WIPO), which controls the PCT application process, cannot legally approve a patent for any applicant alone. Instead, final approval of the patent application must be independently determined by national patent offices which receive the patent application. Indeed, upon completing a preliminary patentability review with the WIPO, a firm must refile its application to patent offices in all markets where it wishes to acquire patent protection. Furthermore, the firm’s application must pass examination in each patent office separately for patent protection to be granted within each jurisdiction.

Since a patent with global jurisdiction does not exist, the firm-driven global growth in patent applications over the past decades has primarily resulted in an increase in filings to national patent offices.\textsuperscript{14} To illustrate, in a 2019 report, the World Intellectual Property Office (WIPO) found that 3.326 million patent applications were filed in 2018. This figure represented a 5.2% increase from 2017, and 2018 also marked the 9th consecutive year of global patent application growth.\textsuperscript{15} Of these 3.326 million patent applications, 73.8% were filed in China, the US, or Japan, even as over 100 patent offices exist in the world. As these global patenting statistics might suggest, international growth in patent filings has been primarily driven by increased filings to a few national patent offices which serve large countries/markets.

Thus, without the existence of a globally-enforced patent, it remains difficult for firms to protect their IP across all geographic markets in which they operate. Furthermore, since it may be infeasible and costly for firms to file over 100 patent applications for the same invention to multiple regional patent offices to ensure the invention’s

\textsuperscript{14}Firms generally represent the largest source of patent applications and grants for patent offices across the world. For example, a USPTO report in 2016 found that 44.7% patents granted in 2015 were filed by US companies, while 48.5% were filed by foreign companies.

\textsuperscript{15}The last year in which there was a decline in patent applications was 2009, during a global recession.
global protection, firms may more selectively choose where exactly to protect their IP with a patent. Nonetheless, as firm-level sales, supply chains, and competition become increasingly globalized, a local patent may confer a global competitive advantage to a firm by protecting a nontrivial portion of its sales and production processes from imitation. Since a local patent legally imposes market power by prohibiting local competitor imitation, it should enable a patent-holding firm to increase sales and attain monopoly profits on its patented good within the local market. Furthermore, by prohibiting competitor entry into the local market, a firm’s local patent decreases its competitors’ expected global profits from imitation, thus lowering their incentive to imitate. By globally reducing the threat of imitation, local patent protection might raise a firm’s expected foreign profits and sales. Thus, local patent protection may benefit firms not only within the patent’s jurisdiction, but also abroad.

2.2 Literature Review

The ongoing policy discussions on the interplay of patent protection, and international trade parallel academic debates on the same topics. Given the instrumental role of firm-driven international trade, innovation, and technology transfer in raising global welfare and growth, economists often consider how local patent protection impacts firms’ innovative and international activities. By considering the potential global spillovers of local patent protection, this paper builds upon various insights from the international trade and innovation literatures. First, the paper builds off prior work which examines the impact of IPR protection quality on international trade. Second, by examining how individual firms respond to patent protection, this paper extends previous work in the innovation economics literature that discusses the impact of patent to a firm’s market value and local performance.

To begin, by analyzing the cross-border spillovers of local patent protection, this paper builds off existing literature on international trade. Economists have found that
the interaction between trade and innovation works in both directions: innovation and patent protection stimulate trade, while trade-induced competition stimulates innovation and patenting. First, prior theoretical and empirical studies have established that bilateral trade generally stimulates firm-level innovation within a domestic market. On the one hand, as Bloom et al (2013) note in a “trapped factors” model of innovation, increased foreign import competition might stimulate firm-level innovation and patenting by reducing the opportunity cost of reallocating productive factors away from the production of current goods into the innovation of new goods. On the other hand, as Autor et al (2019) note, import competition could alternatively reduce firm-level innovation by reducing domestic firms’ profitability and capacity for productive investment. Nonetheless, although the impact of import competition on innovation might be theoretically ambiguous, most empirical work finds a positive relationship between import competition and domestic innovation/patenting.\footnote{Such work includes Pavcnik 2002, Teshima 2008, and Bloom et al 2016.}

In addition, as Aghion et al (2018) note, foreign exporting opportunities may also stimulate domestic firms’ innovation. In particular, an increase in export opportunities raises a firm’s return on innovation by expanding the total market demand for the firm’s innovations. Although increased international competition amongst firms might theoretically counteract the market size effect, Aghion et al (2018) empirically find that export shocks increase domestic innovation, especially for more productive firms. Altogether, previous studies such as Aghion et al (2018), Bloom et al (2013), and Autor et al (2019) establish that causality between patenting and trade works in both directions. This fact motivates my 2SLS identification strategy, used to disentangle the impact of patenting on foreign sales from the opposite causal relationship.

Conversely, prior theoretical and empirical work has also examined how higher levels of foreign patent protection and firm innovation might impact sales and investment within foreign markets. To begin, Melitz (2003) predicts that more productive
firms will be more likely to expand into foreign markets, since they can predict with greater certainty that foreign entry will be profitable. Accordingly, innovation may catalyze an expansion in firms’ international operations to the extent that it bolsters firm-level productivity. In addition, Helpman (1993) and Lai (1998) predict that strengthening IPR protection in developing economies should increase multinational corporations’ activities within those economies. Although Helpman (1993) and Lai (1998) disagree on the global welfare implications of strengthening IPR protection,17 both papers deduce that stronger IPR protections in a developing country catalyze multinational corporations to expand their operations within the country by lowering the expected probability of imitation. Specifically, by lowering the probability of imitation, stronger IPR protection in a developing market raises the expected profits of selling in the market for foreign firms, thus incentivizing foreign expansion.

Corroborating theoretical conjectures, prior empirical studies have generally found that strong foreign patent protection stimulates foreign sales and FDI on the firm level. For example, Branstetter et al (2006) find that strengthened IPR protection in foreign countries increases US firms’ sales, FDI, and technology into these countries. Likewise, building on the analysis by Branstetter et al (2006), De Rassenfosse et al (2019) find that French firms with greater level of patent protection within specific foreign countries are more likely to export more to those same countries. Altogether, these theoretical and empirical analyses inform this paper’s theory and empirical analysis on the impact of US patent protection on sales within the US market. Furthermore, in its across-country subsidiary-level analyses, this paper considers how country-level improvements in IPR protection might increase the scope of firm operations within a country. Nonetheless, this paper also seeks to extend previous work by considering the impact of local patent protection across geographic markets.

Helpman (1993) claims that stronger IPR protection in developing economies will increase global innovation and welfare by fostering FDI and increased technology transfer in developing countries. In contrast, Lai (1998) concludes that stronger IPR protection in developing countries will decrease global welfare by excessively concentrating market power in foreign multinationals.
Lastly, by considering the potential international spillovers of local patent protection, this paper builds off prior studies in innovation economics which estimate the firm-level ramifications of corporate patents. To begin, Hall et al (2005) find that an additional patent citation is associated with an increase a firm’s stock market value by 3% on average. In addition, in their attempt to quantify a patent’s economic value, Kogan et al (2017) find that a US patent grant tends to raise a firm’s stock price.

Complementing the literature discussing the impact of patents on firms’ market value, a closely related literature also examines the impact of patents on the scale of firms’ operations. Balasubramanian and Sivadasan (2011) find that a firm’s US patent count is associated with an increase in its productivity, sales, and output. In addition, Farre-Mensa et al (2018) and Gaule (2018) investigate the impact of US patent protection on the venture capital-driven funding and expansion of start-up companies. Employing patent examiner leniency measures in an instrumental variables identification strategy, both papers find that US patent acquisition has a positive effect on expanding start-up operations and funding. However, since both studies focus on start-ups, their estimates do not directly apply to much larger publicly-traded multinational firms. Furthermore, relatively small start-up companies typically locate a larger portion of their sales and production within a single geographic market than a publicly-traded multinational corporation. Accordingly, this paper extends these prior studies by more closely examining how US patent protection might affect large multinational firms’ operations across different geographic regions, instead of just at the aggregate global or US market level.

Altogether, this paper builds upon insights from both the innovation economics and international trade literature. First, by analyzing how the impact of US patent protection on foreign sales might change in response to stronger foreign IPR protection and property rights, it extends prior literature in international trade on the impact of foreign IPR quality on firms’ foreign operations. Furthermore, by consider-
ing how US patent protection might expand a firm’s international operations, it builds upon prior studies discussing the impact of innovation on a firm’s propensity to enter a foreign market. Lastly, by considering how a local patent might both expand the global scale and shift the regional distribution of a firm’s operations, it also builds upon work in innovation economics on how patent protection affects a firm’s global scale and value. Nonetheless, to the best of my knowledge, the paper is one of the first to consider how local patents affect firm operations beyond their jurisdiction.

3 Theory

Having examined the existing academic literature on trade, innovation, and patenting, in this section I present a simple theoretical model to frame how local patent protection in a “domestic” market might affect a firm’s domestic and international sales, as well as their production location decisions. I first consider the trade-offs behind a firm’s decision to (i) produce and (ii) acquire patent protection for a newly innovated good within a single domestic market. Next, I analyze how a firm’s decision to patent a newly-innovated good in the domestic market might affect its foreign expansion, sales, and profits from that good. Lastly, I examine how a local patent might alter a firm’s production location decision. The model suggests that local patent protection will increase a firm’s profits and aggregate sales in a domestic market, while it will also increase profits and aggregate sales in a foreign market. However, the impact of patent protection on a firm’s production location decision is ambiguous. Under certain assumptions, I predict that domestic patent protection will increase a firm’s profits from domestically-produced goods. Nonetheless, its effect on the profits drawn from production abroad remains ambiguous. Lastly, while this section covers the model more intuitively, Appendix A provides a more mathematical formalization of the intuition presented in the following pages.
3.1 Patents and Profits in a Single Market

First, I analyze the trade-offs behind a firm’s decision on whether to produce and patent a newly-innovated good within a single “domestic” market. Consider some firm $i$ operating in a single domestic market $d$. Firm $i$ possesses a newly-innovated good $g \in G$, which it can produce at constant marginal cost $c_d$. $i$ must decide (i) whether to commercialize $g$, and (ii) whether to acquire patent protection for $g$. To commercialize product $g$ for sale, firm $i$ must undertake some firm-specific fixed cost $F_i$, while firm $i$ must also incur fixed cost $F_p$ to acquire patent protection for product $g$ in market $d$. I assume that patents in market $d$ are perfectly and costlessly enforced; with patent protection, firm $i$ will be the only firm that can produce product $g$. If firm $i$ does not acquire patent protection, another firm, $j$, can costlessly imitate firm $i$’s innovation with probability $\psi \in [0,1]$. Conditional on its successful imitation, firm $j$ also faces a firm-specific fixed cost $F_j$ to commercialize its imitated version of product $g$ as it chooses whether to enter the market for product $g$. Upon entry, I assume that firm $j$ splits monopoly profits with firm $i$ by producing good $g$ at the same constant marginal cost $c$. I assume that a firm can directly observe its own fixed commercialization cost, but not its competitor’s. That is, $F_j$ is a known constant from the perspective of firm $j$, while it is a random variable from the perspective of firm $i$.

Thus, the expected profits of firm $i$ hinge upon whether it acquires patent protection. Equation 1 below characterizes firm $i$’s expected profits with patent protection:

$$E[\Pi_i|PATENT] = \pi_d^M - F_i - F_p = (p_d^* - c_d)D_d(p_d^*) - F_i - F_p$$

(1)

In this equation, $\pi_d^M = (p_d^* - c_d)D_d(p_d^*)$ represents monopoly profits in market $d$. Decomposing $\pi_d^M$, $p_d^*$ represents the optimal monopoly price in market $d$, while $D_d(p_d^*)$

18 $G$ refers to the set of firm $i$’s products, which is greater than 1 if $i$ is a multi-product firm. I assume that all cross-price elasticities between good $g$ and the other goods produced by $i$ are equal to 0. Refer to Appendix A Assumption 1 for more mathematical details.
represents market demand in market $d$ at the optimal monopoly price. Lastly, $F_i$ and $F_p$ are defined in the previous paragraph.

In contrast, choosing not to acquire patent protection will allow firm $i$ to avoid paying fixed cost $F_p$, but it would introduce firm $i$’s sale of product $g$ to the threats of imitation and market entry by firm $j$. Thus, the expected profits of firm $i$ without patent protection are displayed in equation (2) below:

$$E[\Pi_i | NOPATENT] = (1 - \lambda \psi)\pi^M_d + \lambda \psi (\frac{1}{2}\pi^M_d) - F_i$$  

(2)

In the equation above, all variables except for $\lambda$ are defined in previous paragraphs. Intuitively, $\pi^M_d = (p^*_d - c_d)D_d(p^*_d)$ represents the expected profits from sales of product $g$ that firm $i$ would receive if competitor $j$ does not enter market $d$.\(^{19}\) Likewise, since monopoly profits are split upon firm $j$’s entry, $\frac{1}{2}\pi^M_d$ represents firm $i$’s expected profits from sales of product $g$ if firm $j$ does successfully enter into the market for good $g$ in the domestic country $d$. $1 - \lambda \psi$ represents the probability that firm $j$ does not enter the market for good $g$ in the domestic country $d$, while $\lambda \psi$ represents the probability that firm $j$ enters the market. The $\psi$ in $\lambda \psi$ represents the exogenous probability that firm $j$ is able to successfully imitate firm $i$ in producing its innovated good $g$.

I now discuss the parameter $\lambda$ in greater detail. Intuitively, $\lambda \in [0, 1]$ represents the probability that firm $j$ will choose to sell product $g$ in the market $d$, conditional on its successful imitation of product $g$ from firm $i$. More formally, from the perspective of firm $i$, $\lambda$ can be described as follows:

$$\lambda = Pr(F_j < \frac{1}{2}\pi^M_d)$$  

(3)

To reiterate, since firm $i$ cannot directly observe $F_j$ like firm $j$ can, firm $i$ treats $F_j$ as a random variable. This allows $\lambda$ to be defined as in equation (3). In Appendix A\(^{19}\) I do not account for the fixed entry/commercialization cost $F_i$ in $\pi^M_d$. 

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Proposition 1, I derive equation (3) by modeling firm $j$’s market entry decision, in a situation where it does in fact successfully imitate firm $i$.

From equations (1) and (2), if patent acquisition is costless or exogenous (i.e. $F_p = 0$), it is clear that firm $i$’s expected profits are higher with patent protection than without.\textsuperscript{20} Indeed, firm $i$ chooses to patent when the following condition holds:

$$\frac{1}{2} \lambda \psi \pi^M_d > F_p$$

Intuitively, the condition displayed in equation (4) states that firm $i$ will only patent if the patent-induced increase in expected profits outweighs the fixed cost of patenting. Comparative statics show that this condition becomes less binding as $\lambda$ and $\psi$ increase, indicating that firm $i$ will be more likely to patent when the threats of imitation and competitor entry are higher. This is because the probability of imitation is driven to 0 by law in market $d$ with a patent. Lastly, since firm $j$ can split monopoly profits with firm $i$ upon entry, one can find that exogenous and costless patent protection will weakly increase firm $i$’s total sales of product $g$ as well as its profits. Appendix A Proposition 3 derives this assertion in greater mathematical detail.

### 3.2 Patents and Profits in Two Markets

I now proceed to extend the analysis of firm $i$’s patenting decision to a global economy with two markets, “domestic” market $d$ and “foreign” market $f$. In this extended model, I assume that firm $i$ faces imitation and market entry threats from firm $j$ in both markets, and that it can nullify the imitation threat via patent protection at fixed cost $F_p$ in the domestic market $d$. However, I assume that firm $i$ is unable to attain patent protection in the foreign market, so it may never fully eliminate the threat of imitation from firm $j$ abroad. Upon successful imitation, firm $j$
can split market-specific monopoly profits with firm $i$ in both the domestic market $d$ and the foreign market $f$. Furthermore, for this subsection, I assume that all of firm $i$’s production occurs in the domestic market at marginal cost $c_d$.\textsuperscript{21}

In this two-market scenario, I allow the imitation parameter $\psi$ from section 3.1 to vary across market, so that firm $i$ faces an imitation probability of $\psi_d \in [0, 1]$ from firm $j$ when it operates in market $d$ and $\psi_f \in [0, 1]$ when it operates in market $f$. For mathematical tractability, I assume that $\psi_d$ and $\psi_f$ are independent. That is, if firm $i$ sells product $g$ in both markets, the probability that firm $j$ imitates product $g$ from firm $i$ via foreign market sales is independent of the probability that firm $j$ imitates firm $i$ via domestic market sales. However, upon imitation in either market, firm $j$ may sell into any market without patent protection. The remaining parameters in the two-market model are directly carried over from section 3.1.

Accordingly, if firm $i$ decides to patent product $g$, it will not face the threat of imitation and entry in the domestic market $d$, although it will continue to face imitation and entry threats in the foreign market. Thus, firm $i$’s expected profits with domestic patent protection for good $g$ are as follows:

$$E[\Pi_i|PATENT] = \pi^M_d + (1 - \lambda \psi_f)\pi^M_f + \lambda \psi_f \left(\frac{1}{2}\pi^M_f\right) - F_i - F_p$$

(5)

$\pi^M_d$, $F_i$, and $F_p$ have all been defined in prior equations, while $\psi_f$ was defined in the previous paragraph. $\pi^M_f = (p^*_f - c_d)D_f(p^*_f)$ represents optimal monopoly profits in the foreign market $f$. $p^*_f$ represents a monopolist’s optimal price in market $f$,\textsuperscript{22} and $D_f(p^*_f)$ represents foreign market demand at the optimal monopoly price. Intuitively, when firm $i$ acquires patent protection in domestic market $d$, $\pi^M_d$ represents firm $i$’s expected profits from domestic market sales, while $(1 - \lambda \psi_f)\pi^M_f + \lambda \psi_f \left(\frac{1}{2}\pi^M_f\right)$ represents firm $i$’s expected profits from foreign market sales.

As in section 3.1, $\lambda \in [0, 1]$ represents the probability that firm $j$ will enter the

\textsuperscript{21}This assumption is relaxed in section 3.3.

\textsuperscript{22}The price is optimal given a constant marginal cost of $c_d$. 

24
foreign market conditional on its successful imitation of product $g$ from firm $i$. When firm $i$ acquires patent protection in market $d$, $\lambda$ can be characterized as follows:

$$\lambda = Pr(F_j < \frac{1}{2} \pi_f^M)$$  \hspace{1cm} (6)$$

This definition of $\lambda$ mirrors the definition presented in section 3.1. However, firm $j$ cannot earn profits or sell in the domestic market, where firm $i$ has patent protection. Thus, $\pi_j^M$ replaces $\pi_d^M$ in equation (6). Appendix A Proposition 4 includes a more complete mathematical derivation for this definition of $\lambda$.

Next, I consider firm $i$’s expected profits if it does not acquire domestic patent protection for good $g$. In this situation, firm $i$ faces an imitation and entry threat in both markets. Equation (7) characterizes firm $i$’s resulting expected profits:

$$E[\Pi_i|NOPATENT] = (1 - \lambda' \rho)(\pi_d^M + \pi_f^M) + \lambda' \rho(\frac{1}{2}(\pi_d^M + \pi_f^M)) - F_i$$  \hspace{1cm} (7)$$

In the equation above, all parameters except for $\lambda'$ and $\rho$ have been previously defined. First, $\rho = 1 - (1 - \psi_d)(1 - \psi_f)$ represents the probability that imitation by firm $j$ occurs in either the foreign or the domestic market. Second, similarly to $\lambda$ from equation (6), $\lambda'$ intuitively represents the probability that firm $j$ chooses to enter both markets conditional on its successful imitation of firm $i$. Mathematically, when firm $i$ does not acquire patent protection, $\lambda'$ can be characterized as follows:

$$\lambda' = Pr(F_j < \frac{1}{2} \pi_f^M + \frac{1}{2} \pi_d^M)$$  \hspace{1cm} (8)$$

Appendix A Proposition 4 derives this definition of $\lambda'$ from firm $j$’s market entry decision, conditional on its successful imitation of firm $i$.

When firm $i$ does not possess domestic patent protection, it is noticeable that (i) the overall probability of imitation by firm $j$ and (ii) the probability of firm $j$’s market

\[23\]Since firm $j$ is allowed to imitate firm $i$’s production of good $g$ in both markets, imitation in either market provides firm $j$ with the possibility of entry into both markets without patent protection.
entry conditional on successful imitation both increase. Mathematically, $\lambda' > \lambda$, while $\rho > \psi_f$. The decreased probabilities of firm j’s imitation and entry that result from domestic patent protection increase firm i’s expected profits from both domestic and foreign market sales. However, the mechanisms through which domestic patent protection affects these domestic and foreign profits differ.

With domestic patent protection, the probability of competitor imitation and entry within the domestic market is legally enforced to be zero. Such legally enforced market power directly raises firm i’s profits from domestic sales. In contrast, domestic patent protection does not bar competitor imitation and entry within the foreign market. However, since firm j is allowed to imitate firm i from its sales in both the domestic and foreign markets when firm i does not possess domestic patent protection, firm j will be more likely to successfully imitate firm i without patent protection due to an expansion of the geographic area over which imitation can occur. That is, $\rho > \psi_f$. In addition, since firm j can enter only the foreign market post imitation when firm i has a domestic patent, the probability that firm j chooses to enter the foreign market for good $g$ decreases when firm i acquires domestic patent protection. That is, although a domestic patent does not prohibit firm j from entering the foreign market, it decreases firm j’s profit-related incentives to do so, as $\lambda' > \lambda$. In all, by decreasing the likelihood of imitation and entry by firm j, a domestic patent increases firm i’s expected foreign profits. Nonetheless, since firm j might still enter the foreign market, the patent-induced relative increase in firm i’s expected foreign profits would likely be smaller than the relative increase in its expected domestic profits.

To mathematically interpret the intuition above, equations (9) and (10) on the next page demonstrate that firm i’s profits from domestic and foreign sales are both higher with domestic patent protection. Given these equations, one can also deduce

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24See Appendix A Proposition 4 for a formal mathematical derivation.
25The probability of competitor entry in the foreign market remains positive unless $\psi_f = 0$ or $\lambda' = 0$.
26Firm j can enter both markets post imitation when firm i does not have domestic patent protection.
27See proposition 4 for a proof of this claim.
that domestic patent protection would increase both domestic and foreign sales, as long as firm $j$ is able to hypothetically split monopoly profits with firm $i$ from sales in both markets, conditional upon its entry.\footnote{This is more formally derived in Appendix A Proposition 5.}

\[
\pi_d^M - [(1 - \lambda'\rho)\pi_d^M + \lambda'\rho\frac{1}{2}\pi_d^M] = \pi_d^M - (1 - \frac{1}{2}\lambda'\rho)\pi_d^M \geq 0 \tag{9}
\]

\[
(1 - \lambda\psi_f)\pi_f^M + \lambda\psi_f\frac{1}{2}\pi_f^M - [(1 - \lambda'\rho)\pi_f^M + \lambda'\rho\frac{1}{2}\pi_f^M] \geq 0 \tag{10}
\]

Equations (9) and (10) together imply that a domestic patent would raise firm $i$’s total profits if its acquisition were costless. Thus, firm $i$ would seek to acquire a domestic patent as long as the additional global profits gained from the patent outweigh the fixed cost of domestic patent acquisition $F_p$.\footnote{The additional global profits gained from patent protection can be captured by summing the left hand side terms in equations (9) and (10).}

### 3.3 Patents and the Location of Production

I now remove the assumptions made in section 3.2 that (i) all of firm $i$’s production of good $g$ occurs in the domestic market $d$ and (ii) firm $i$ can costlessly export good $g$ across markets. Dropping these assumptions allows me to consider how a domestic patent impacts firm $i$’s decisions on where to produce good $g$. The set up of a mathematical model to describe firm $i$’s behavior remains largely the same from section 3.2. However, a few new parameters must be introduced. First, since exports are no longer costless, firm $i$ must pay fixed cost $E$ if it exports product $g$, either from the domestic to the foreign market or vice versa. In addition, I allow marginal costs of production to vary across market, although they remain constant over the local quantity produced within a market. $c_d$ represents the marginal cost of production in market $d$, while $c_f$ represents the marginal cost of production in market $f$.

In addition to previously used sales imitation parameters $\psi_d$ and $\psi_f$, firm $i$ now...
faces additional production imitation probabilities $\phi_d, \phi_f \in [0, 1]$ from firm $j$ in the domestic and foreign markets respectively.\textsuperscript{30} Intuitively, I add these parameters because firm $j$ can potentially imitate firm $i$’s innovated good $g$ through both its production process and its sale.\textsuperscript{31} Accordingly, $\psi_d$ and $\psi_f$ now represent the probability of imitation by firm $j$ when firm $i$ sells good $g$ in the domestic or foreign market. Upon imitation, firm $j$ faces the same market-specific marginal costs and exporting costs as firm $i$; however, its fixed commercialization cost $F_j$ remains potentially different.

I begin by considering the intuition behind firm $i$’s production location decision without domestic patent protection.\textsuperscript{32} Assuming that firm $i$ finds it profitable to sell product $g$ in both markets,\textsuperscript{33} firm $i$ could choose to locate production in one of three ways. First, it could produce $g$ exclusively in the domestic market $d$. Second, it could produce $g$ exclusively in the foreign market $f$. Third, it could produce all units of product $g$ sold in domestic market $d$ within the domestic market, while selling all units of product $g$ sold in the foreign market $f$ within market $f$.\textsuperscript{34} Firm $i$ chooses the option which maximizes its expected global profits. Various parameters determine which option firm $i$ finds most profitable. Ceteris paribus, the third option’s (local production’s) expected profitability increases as the fixed export cost $E$ increases. Likewise, ceteris paribus, the second option’s (foreign production’s) expected profitability decreases as the foreign marginal cost $c_f$ and foreign production imitation probability $\phi_f$ increase. Lastly, ceteris paribus, the first option’s (domestic production’s) expected profitability decreases as domestic marginal cost $c_d$ and domestic production imitation probability $\phi_d$ increase. Thus, assuming that it profitably sells good $g$ in both markets, firm $i$’s production location decision will depend on the fol-

\textsuperscript{30}Like $\psi_d, \phi_d$ goes to 0 when firm $i$ acquires domestic patent protection.
\textsuperscript{31}Section 7.1 details this phenomenon more thoroughly.
\textsuperscript{32}Discussion of firm $i$’s production location decision will remain intuitive in this section. Refer to Appendix A Proposition 6 for more mathematical details.
\textsuperscript{33}The general logic remains the same if firm $i$ chooses not to enter one of the two markets.
\textsuperscript{34}Without patent protection in either market, firm $i$ never does the inverse of the third option, as at least one of the three options described would prove more profitable.
lowing parameters: the export cost \((E)\), market-specific marginal costs \((c_d \text{ and } c_f)\), and market-specific probabilities of imitation via production \((\phi_d \text{ and } \phi_f)\).

I now consider the impact that patent protection might have on firm \(i\)'s production location decision. With patent protection, the probability of imitation from sales and production in the domestic market, represented by \(\psi_d\) and \(\phi_d\) respectively, are reduced to 0. This is because domestic imitation of any form is prohibited by the patent, which I assume to be perfectly and costlessly enforced. Furthermore, given its inability to sell or produce in the domestic market, firm \(j\)'s probability of foreign market entry (which I refer to as \(\lambda^*\)) decreases, like in section 3.2. The reductions in \(\psi_d\) and \(\lambda^*\) raise firm \(i\)'s expected profits regardless of its production location decision. However, the reduction in \(\phi_d\) raises firm \(i\)'s expected profits only if it produces good \(g\) domestically. Thus, in relative terms, domestic patent protection will increase firm \(i\)'s expected profits the most when it produces all units of \(g\) domestically. More generally, since firm \(i\)'s production location decision depends on its expected profits from domestic vs. foreign production, domestic patent protection increases firm \(i\)'s propensity to produce good \(g\) in the domestic market. Conversely, domestic patent protection decreases the likelihood that firm \(i\) produces good \(g\) in the foreign market.

To conclude this section, I summarize the model’s main conjectures. This model shows that domestic patent protection increases an innovating firm’s domestic, foreign, and global profits and sales on the aggregate level. The increase in domestic profits and sales is largely generated by the domestic monopoly market power that a domestic patent ensures. In contrast, a domestic patent will increase foreign profits and sales by decreasing the probability of competitor imitation and competitor entry conditional upon successful imitation. In addition to aggregate profits and sales, the model predicts under certain additional assumptions that domestic patent protection will raise an innovating firm’s incentive to concentrate production of good \(g\) in the domestic market. Combining higher aggregate profits and sales with an increased
incentive to produce domestically, domestic patent protection accordingly raises the profits and sales generated from production in the domestic market $d$. However, the impact of domestic patent protection on the profits and sales generated from foreign market production is theoretically ambiguous. On the one hand, domestic patent protection increases total global profits and sales. Since all sold goods must be produced somewhere, this increases the total profits and sales generated from global production. Thus, this “profit expansion” effect works to increase profits and sales generated from foreign (and domestic) production. On the other hand, domestic patent protection incentivizes a reallocation of production away from the foreign market into the domestic market. This “reallocation” effect works to decrease sales generated from foreign production. Ultimately, the magnitude of parameters such as the probability of imitation via foreign production ($\phi_f$), export costs ($E$), and foreign market marginal cost ($c_f$) determine which of the two effects empirically dominates.

4 Data

To determine whether the theoretical predictions from section 3 are supported by empirical analyses, this paper draws upon various sources for data. First, I collect consolidated firm-level financial data from Compustat North America. These data record the global sales figures of all companies that were publicly traded in a North American stock exchange at any time during 1970-2018. I complement these data with geographic segment data from Compustat. The segment data provide firm-level sales within different geographic markets, so that I may discern a firm’s region-specific sales across various international markets. Next, I collect subsidiary-level data from Bureau Van Dijk, which contain subsidiary-level sales figures from 2007-2018. Furthermore, since the data identify subsidiary location, I am able to use subsidiary sales as a proxy for the sales generated from a firm’s production within a given country.
In addition, to quantify the extent of a firm’s US patent protection, I collect patent data from the United States Patent and Trademark Data (USPTO) on US patent applications and grants from 1910-2018. Focusing on patents that were in force at any time after 2006, I use these data to identify the number of patents held by a given firm in a given year. Employing previous concordances created by Autor et al (2019) and others, I match USPTO patents to firms in Compustat North America, as well as firms in Compustat to subsidiaries in Bureau Van Dijk. Lastly, so that I can consider how the impact of US patents on firms’ foreign subsidiary operations might vary across countries, I obtain country-level survey data from the World Bank’s GovData360 database. These data quantify the quality of intellectual property rights protection, the quality of property rights, the degree of judicial independence, and the extent of political favoritism in a country. Sections 4.1-4.4 discuss the data and my matching procedures in greater detail.

4.1 Firm and Subsidiary Data

This paper’s firm-related data comes from two sources: Compustat and Bureau Van Dijk. First, I gather data from 2007-2018 on company-level annual sales from Compustat North America. The Compustat North America data contain annual global sales for all companies publicly traded on some North American stock exchange from 1970-2018. However, to maximize overlap with the subsidiary data from Bureau Van Dijk, I restrict these data to observations during the 2007-2018 period. The resulting data set contains 131,546 observations unique at the firm-year level. Around 10,500-11,500 unique firms are represented in a given year within the data, and a total of 19,550 firms are represented across the entire 2007-2018 sample. Figures 1a-1b (on the next page) show the number of firms and average annual global sales in the sample by year, while rows 1 and 2 of Table D1 (see Appendix D) provide the corresponding summary statistics on firm count and average global sales.
Building off these data, I also include segment-level data from Compustat onto the data on firms’ aggregate global sales. Through these data, I am able to observe firms’ aggregate sales in the US and various foreign countries for a subset of firms in the original Compustat data. Specifically, I observe firm-level market sales in following countries/regions: Canada, Europe, China, Japan, Germany, France, Mexico, Korea, Taiwan, Australia, Brazil, and India.35 These data cover the years 2010-2018, and like the global sales data, all market sales are reported in current US dollars (USD). To link these data to the base data set on global sales, I standardize the geographic market segment names reported by individual firms in the data. For example, firm-reported segment names of “US” and “United States of America” are both matched to a standardized country name of “United States”. Due to variation in firm activity and sales reporting across different geographic markets, the number of observations in the segment data vary significantly across different markets. Table 1 (on the next page) displays the segment-level data’s summary statistics across different geographic markets. As Table 1 displays, firms’ market sales are somewhat correlated with a region’s economic size, while firms that report non-US sales are larger on average than those that report US sales. In addition, Appendix D table 3 shows the concordance

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35I would have selected more countries and regions from these segment data if feasible. However, reporting of segment sales within other geographic markets proved to be sparse.
between firm-reported region names and the standardized names which I use.

Table 1: An Overview of Compustat Segment Data

<table>
<thead>
<tr>
<th>Region Name</th>
<th>Observations</th>
<th>Average Global Sales</th>
<th>Average Market Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>60,287</td>
<td>4649.019</td>
<td>2905.683</td>
</tr>
<tr>
<td>Canada</td>
<td>11,566</td>
<td>5446.346</td>
<td>662.304</td>
</tr>
<tr>
<td>Europe</td>
<td>10,695</td>
<td>8055.277</td>
<td>1691.915</td>
</tr>
<tr>
<td>China</td>
<td>8,995</td>
<td>7792.073</td>
<td>2885.748</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>6,215</td>
<td>10640.81</td>
<td>1332.991</td>
</tr>
<tr>
<td>Japan</td>
<td>4,240</td>
<td>12473.74</td>
<td>3336.186</td>
</tr>
<tr>
<td>Germany</td>
<td>4,180</td>
<td>14267.70</td>
<td>2185.358</td>
</tr>
<tr>
<td>Mexico</td>
<td>3,195</td>
<td>6806.553</td>
<td>510.907</td>
</tr>
<tr>
<td>Brazil</td>
<td>2,945</td>
<td>11289.21</td>
<td>2465.893</td>
</tr>
<tr>
<td>Australia</td>
<td>2,731</td>
<td>8133.191</td>
<td>512.488</td>
</tr>
<tr>
<td>France</td>
<td>2,400</td>
<td>15491.42</td>
<td>2010.193</td>
</tr>
<tr>
<td>Korea</td>
<td>1,971</td>
<td>5597.423</td>
<td>1511.612</td>
</tr>
<tr>
<td>India</td>
<td>1,782</td>
<td>6400.339</td>
<td>515.982</td>
</tr>
<tr>
<td>Taiwan</td>
<td>1,512</td>
<td>3539.154</td>
<td>601.956</td>
</tr>
</tbody>
</table>

NOTES: Average global and market-specific sales are both measured in millions of current US dollars. Both global and market sales are averaged across all firms that report market sales in a specific region-year. Market sales measure total sales within a pre-specified country or region, and market sales figures include both sales by foreign subsidiaries as well as sales from exports.

While data from Compustat enable this paper to empirically analyze the impact of US patent protection on aggregate firm sales across geographic markets, subsidiary-level sales data from Bureau Van Dijk (BVD) allow me to consider the impact of US patent protection on firm production within different geographic markets. Whereas I use reported segment sales to consider a firm’s total sales within a geographic market, I use subsidiary sales to proxy for the sales value of a firm’s production within a geographic market. Thus, I collect data on companies’ first-level subsidiaries from Bureau Van Dijk’s Amadeus and Orbi data sets. These data record subsidiary sales and location, as well as the parent company’s total ownership share in a subsidiary. Specifically, the sales of European subsidiaries are found in BVD’s Amadeus database, while the sales of non-European subsidiaries are found in BVD’s Orbi database.

I proceed to link subsidiary-level data from BVD onto firm-level data from Compus-
I am able to link the two data sets through three common identifying variables: parent company stock ticker, parent company international security identification number (ISIN), and parent company name. The resulting data set contains 408,892 observations unique at the subsidiary-year level. 299,858 of these observations cover subsidiaries located in the US, while the remainder detail subsidiaries located abroad. Row 1 of Table D2 (see Appendix D) shows summary statistics on subsidiary-level sales in the merged Compustat-BVD data. Lastly, the data cover the years 2008-2018, although most observations fall during the 2014-2018 period.\footnote{The imbalance in the data is likely due to peculiarities in BVD’s data collection process on parent-company to subsidiary ownership links.}

### 4.2 Patent Data

Alongside firm and subsidiary-level sales data, I collect application-level patent data from the USPTO. I gather these US patent data to ultimately measure the scale of a firm’s US patent protection by aggregating the number of patents held by that firm in a specific year. Prior studies on firm-level patenting including Hall et al (2001) and Autor et al (2019) employ US patent data from the NBER patent data project. However, data from the NBER patent data project only contain successful patent applications, and thus the construction of patent examiner leniency measures using the NBER data would be impossible. Thus, to mitigate this concern, patent data for this paper came from two relatively new USPTO data sources: the Patent Examination Research Dataset (PERD) and the Patent Assignment Database (PAD).\footnote{Graham et al 2015 and Apple et al 2015 claim that these data cover all USPTO patent applications through 2017. Some but not all of the patent applications filed in 2018 exist in the data as well.}

The PERD data are unique at the application level, and they include identifying information on the patent examiner and owner (i.e. assignee) of a USPTO patent application. Other information in the data include the patent application’s technological class, dates for its filing, grant, and abandonment, and its status as a utility, design, trademark, or plant patent. I collect data on the around 11 million patent
applications filed from 1840 to the present. Nonetheless, I restrict my analysis to the approximately 9 million utility patent applications filed during the 2006-2018 period.

I use the PERD data to construct quantitative measures of patent examiner leniency. Specifically, I calculate a corresponding “leave-one-out” grant rate for every utility patent application found in the data. Intuitively, for a specific patent application $p$ reviewed by USPTO patent examiner $e$, the corresponding “leave-one-out” grant rate assigned to $p$ represents the number of successful patent applications reviewed by examiner $e$ divided by the total number of patent applications reviewed by examiner $e$, excluding $p$.\(^{39}\) The exclusion of application $p$ allows the corresponding examiner “leave-one-out” grant rate to be independent of $p$’s inherent quality. Thus, my “leave-one-out” patent examiner leniency measure can be considered to be independently assigned to individual patents.\(^{40}\) Figure 2a (on the next page) provides a graph which displays the distribution of this “leave-one-out” grant rate examiner leniency measure. A more rigorous mathematical definition of this patent examiner leniency measure is provided in Appendix B.

Lastly, before I merge application-level patent data onto financial data from Compustat and Bureau Van Dijk, I link the PERD data at the patent application level onto PAD data, which are recorded at the patent transaction level. Specifically, the PAD data record all patent transactions among patent assignees over time. To illustrate, suppose firm $A$ is granted patent $X$ in 2008 and sells $X$ to firm $B$ in 2009. Firm $B$ proceeds to sell $X$ to firm $C$ in 2011, and firm $A$ repurchases $X$ from firm $C$ in 2013. Lastly, firm $A$ abandons $X$ in 2018. All grants, purchases, sales, and abandonments mentioned above are recorded in the Patent Assignment Data set. The resulting merged data set contains around 30 million observations of patent applications at the transaction level, and it allows me to observe the times at which certain patents are

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\(^{39}\) The exclusion of patent $p$ is why this grant rate is termed the “leave-one-out” grant rate.

\(^{40}\) This claim underpins the conditional independence assumption behind this paper’s instrumental variable identification strategy. See section 5 for more information.
Figure 2: The Distribution of Examiner Leniency As Measured by Leave-One-Out Grant Rates at the Patent and Firm-Year Levels

NOTE: Figure 2a (on left) measures patent examiner leniency at the patent level, while figure 2b (on right) measures average patent examiner leniency at the firm-year level. That is, figure 2b shows the distribution of average examiner leniency across all patents held by a firm in a given year. Refer to section 4.3 for more information.

4.3 Firm to Patent Matching

Having collected patent data at the application and transaction level, I proceed to merge these data onto my Compustat data covering firm-level annual sales. Due to the lack of an identifying firm key in US patent data, various previous papers (e.g. Hall et al 2001, Autor et al 2019) have documented the challenges of effective firm-to-patent matching. Specifically, there exists a high potential for extensive Type II error (i.e. false negatives) in simple 1:1 matching algorithms which link a specific patent assignee name to a specific firm. This risk for extensive Type II error derives from the fact that patent assignee names in USPTO data are not standardized. For

41Figure 2b shows the distribution of the “averaged” examiner leniency measure.
example, a patent which belongs to IBM could have a corresponding assignee name of IBM, IBM Ltd., International Business Machines, Int’l Business Machines, etc..

To minimize the probability of Type II error, I adjust a firm-to-patent concordance table created by Autor et al (2019). I first perform Derwent standardization on all patent assignee names in my combined PERD-PAD patent data, as recommended by Hall et al (2001).\footnote{Derwent standardization mostly helps to standardize common company terms. For example, it replaces terms such as “Incorporated” and “Limited” with “INC” and “LTD” respectively.} Next, I implement the firm-to-patent Autor et al’s concordance table. However, instead of matching firms directly to a patent, I match firm codes to Derwent-standardized patent assignee names.\footnote{This strategy allows me to assign a total number of patent applications to a firm in a year. In contrast, a direct firm-to-patent match would only allow me to view successful patent applications by a specific firm in a given year.} This is possible because Autor et al’s concordance table contains information on firm names, patent numbers, \textit{and} the Derwent-standardized assignee names found on patent applications. Furthermore, to the best of my knowledge, Autor et al (2019) provide the most comprehensive concordance between USPTO patent assignees and Compustat firms by employing a unique web-based matching algorithm between firm names and patent assignee names. Nonetheless, I ensure that my implementation of Autor et al’s concordance yields valid firm-to-patent matches through additional automated and manual checks.

Having merged the application and transaction-level patent data from the USPTO to Compustat, I proceed to generate patent counts, examiner leniency measures, patent approval times, and patent application counts by firm-year. Specifically, from my transaction level data covering patent assignment, release, and abandonment,\footnote{Assignment refers to the office-based granting or legal acquisition of a patent. Release refers to the sale of a patent. Lastly, abandonment refers to the expiration or legal forfeiture of a patent.} I construct a count of the number of patents held by a specific firm in a specific year. Next, I average examiner grant rates across all patents held by a firm in a given year. To complement these averaged measures of examiner leniency, I also calculate the
NOTE: US Patents are residualized after controlling for average patent approval time and patent application count in all four figures above. Log-transformed patents are defined as log(1 + patents) so that firms with no patents are given a log-transformed patent count value of 0. Noise in the subsidiary-level plots could be due to across-country heterogeneity in the relationship between US patents and subsidiary sales.

average examination approval time for all patents held by a firm in a given year. Likewise, to complement my firm-level aggregate patent count, I construct a count of total patent applications submitted by a firm in a given year. Lastly, after constructing these four particular variables, I also merge BVD data on subsidiary-level sales onto the merged USPTO-Compustat data via the methods described in section 4.1.

Accordingly, Appendix D Tables 1 and 2 show summary statistics on firm-year patent counts, average examiner grant rates, average patent approval times, and patent application counts for the firm and subsidiary-level data sets respectively. Lastly, to motivate my empirical analyses, figures 3a and 3b above display visual

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45 This variable is mathematically defined in Appendix section B. Intuitively, it represents the average number of days between application filing and patent granting for a specific firm in a given year.
evidence suggesting that a linear correlation between firm-level US patents and sales at the firm and subsidiary levels exists.

4.4 Country-Level Data

Lastly, to analyze how the impact of US patents on subsidiary sales might vary across countries, I collect country-level institutional data from the World Bank’s Gov-data360 database. Specifically, I gather survey data on the following four country-level variables: (1) the quality of IPR protection, (2) the quality of property rights protection, (3) the degree of judicial independence, and (4) the extent of political favoritism. Surveys were conducted using random sampling methods among residents of the country in question.\textsuperscript{46} To determine each of the 4 aforementioned variables’ value within a country, the country-level data take average survey response scores within a country, measured on an increasing scale from 1 to 7. To explain further, a survey response score of 7 on IPR or property rights protection would indicate near-perfect protection of IPR/property rights in a country, whereas a score of 1 would indicate poor protection of IPR/property rights. Likewise, a score of 7 in judicial independence would indicate a highly independent judiciary system in a country, whereas a score of 1 would suggest a highly politicized judiciary system. Lastly, a score of 7 in political favoritism would indicate a highly transparent political system, whereas a score of 1 in political favoritism would likely indicate a highly biased political system. Lastly, I combine these data with my subsidiary-level data to consider potential across-country heterogeneity in the impact of US patents on foreign subsidiary sales.

Figures 4a-4d (on the next page) graphically display the distribution of IPR, property rights, judicial independence, and political favoritism across all countries in the world in 2018, while Figures 5a-5d (on page 41) show the geographic spread of

\textsuperscript{46}For example, data quantifying the quality of IPR protection in the United States were collected by surveying US citizens about the quality of IPR protection in the US.
Figure 4: *Country-Level Distribution of IPR Quality, Property Rights Quality, Judicial Independence, and Political Favoritism in 2018*

NOTE: IPR Quality, Property Rights Quality, Judicial Independence, and Political Favoritism/Transparency are measured on a 1-7 scale using survey data from the World Bank’s GovData360 database. The distribution draws upon unweighted country-level data, where one country’s score represents one observation.

From these figures, one can observe that there is significant heterogeneity in four country-level variables mentioned in the previous paragraph. Furthermore, even though potentially biased within-country survey responses (as opposed to an external/third-party scoring process) determine country-level scores for all four of these variables, scores assigned to particular countries generally match intuitive expectations. For example, as figure 5a displays, advanced economies tend to have higher scores in IPR protection quality than less developed economies. Lastly, Appendix D Table D2 displays the average values taken on by these four country level variables in this paper’s merged subsidiary-level data.

47 Appendix C Figures 1 and 2 likewise show average values of these variables for all countries during the 2008-2018 time period. Figure C1 uses histograms to display the distribution of these four variables, while figure C2 uses maps to display the geographic spread of the four variables.
Figure 5: IPR Quality, Property Rights Quality, Judicial Independence, and Political Favoritism By Country in 2018

NOTE: All metrics of IPR Quality, Property Rights Quality, Judicial Independence, and Political Favoritism are measured on a 1-7 scale using survey data from the World Bank’s GovData360 database. Countries with higher quality IPR protection, higher quality property rights protection, more independent judiciaries, and less political favoritism are colored in darker shades of blue in all figures above. Lastly, I sometimes refer to political favoritism as political transparency in the results section for clarity.

5 Empirical Methodology

Having collected data on firm and subsidiary-level sales, firms’ US patent holdings, and country-level institutional variables, in this section I detail the paper’s main empirical analyses. I conduct three main categories of empirical analyses in this paper. First, I examine the impact of US patents on firms’ aggregate sales at the global, US, and foreign country level. Second, shifting my analysis within firms, I test the impact of firm-level US patent holdings on subsidiary-level sales in the US and across different foreign markets. Lastly, I attempt to explain the across-country heterogeneity in the relationship between US patents and foreign subsidiary sales. Specifically, I empirically determine how the impact of firm-level US patents on foreign subsidiary sales varies as factors such as IPR protection quality, property
rights protection quality, judicial independence, and political transparency increase.\(^{48}\)

To address these empirical questions, I employ both fixed effect and instrumental variables regression specifications. Each approach has benefits. On the one hand, fixed effect regressions enable me to consider both patenting and non-patenting firms in my analyses. On the other hand, although they restrict my analyses to patent-holding firms, by employ a patent examiner leniency instrument, my instrumental variables (IV/2SLS) regressions minimize the role that reverse causality and selection bias might play in biasing my fixed effect regression estimates. The remainder of this section covers my regression specifications in more detail. Section 5.1 explains my fixed effect regressions, while section 5.2 displays my 2SLS regressions. Lastly, section 5.3 goes over the main assumptions behind my use of a patent examiner leniency instrument, and it explains why each assumption might plausibly be fulfilled.

### 5.1 Fixed Effect Regressions

I begin by running fixed effect regression specifications to investigate each of my three empirical questions. First, to investigate the relationship between US patents and aggregate sales, I implement preliminary regressions of the following general form:

\[
\log \text{SALES}_{itc} = \beta_0 + \beta_1 \text{PATENTS}_{it} + \delta \text{Z}_{it} + \gamma_{jt} + \epsilon_{it} \tag{11}
\]

In equation (11), the dependent variable \(\log \text{SALES}_{itc}\) represents the log-transformed annual sales reported by firm \(i\) in year \(t\) within geographic market \(c\), where \(c\) is fixed to represent a specific geographic market.\(^{49}\) The main treatment variable \(\text{PATENTS}_{it}\) represents the number of USPTO patents held by firm \(i\) in year \(t\). In addition, I include a vector of observable controls \(\text{Z}_{it}\) as well as industry-year fixed effects \(\gamma_{jt}\).\(^{50}\)

\(^{48}\)Political transparency refers to the same variable as political favoritism in section 4. I now refer to it as political transparency since high scores correspond to high levels of political transparency.

\(^{49}\)Before log transformation, sales are measured in millions of current USD.

\(^{50}\)I classify industry using 3-digit NAICS (North American Industry Classification Standard) codes.
Observable controls include the number of patent applications filed by firm $i$ in year $t$ as well as the average time of approval for all patents held by firm $i$ in year $t$. I include the patent application control to proxy for firms’ current amount of innovation, while I control for average patent approval time to proxy for heterogeneity in patent value.\textsuperscript{51} I conduct these empirical analyses on a country-by-country basis. That is, I fix country/region $c$ to observe sales exclusively from a single geographic market.\textsuperscript{52}

While these fixed effect regressions may provide solid evidence of a positive correlation between US patent protection and sales across various industries, certain confounding factors prevent the fixed effect regression model estimates from being a true causal effect. To begin, firm-level sorting and selection may bias our results. For example, larger firms within an industry may possess more US patents and higher sales than their smaller counterparts. However, the fixed effect regression detailed in equation (11) would not fully disentangle the impact of US patents on market sales from the impact of other characteristics of large firms, such as higher levels of capital and larger management teams. Such factors may cause equation (11)’s fixed effect estimates to be upwardly biased vis-a-vis the true causal effect.

To partially address this selection issue, I first add a firm fixed effect $\psi_i$ to the specification in equation (11). Nonetheless, while this firm fixed effect controls for unobservable differences across firms, it does not control for the possibility that firm-level increases in US patent protection over time may correspond with other sales-raising changes within a firm, such as improvements in corporate strategy or talent acquisition. In addition, adding a firm fixed effect does not account for endogeneity within the relationship between patents and sales, especially in the US context. To illustrate, firms with growing US sales may be more inclined to obtain more US patents

\textsuperscript{51}Prior research such as Budish et al (2015) has suggested that patents that take longer to approve are less valuable, since a patent’s term length is determined by its application filing date.

\textsuperscript{52}To illustrate, I first estimate the relationship between US patents and firms’ aggregate global sales. Next, I consider the relationship between US patents and aggregate sales within each country displayed in Table 1 separately on a country-by-country basis.
in order to protect global profits which are increasingly dependent on US sales. Thus, even when including firm fixed effects, such endogeneity may also bias equation (11)’s estimates upwards. To address these endogeneity concerns, I implement 2SLS regressions, which I cover in section 5.2. Lastly, although I control for approval time to proxy for heterogeneity in an individual patent’s value, it remains plausible that the value of an additional US patent to a firm exhibits decreasing marginal returns. That is, a firm’s first US patent might raise its sales by more than its 100th. Accordingly, to account for this possibility, I log-transform the treatment variable $PATENTS_{it}$ into $\log(1 + PATENTS_{it})$ as a robustness check.

In addition to considering the relationship between US patent protection and firms’ aggregate sales across different geographic markets, I also investigate the relationship between firm-level US patent protection and subsidiary-level sales across different countries. To do this, I run fixed effect regressions of the following form:

$$SALES_{sitc} = \beta_0 + \beta_1 PATENTS_{it} + \delta W + \psi_i + \gamma_{jt} + \nu_{sit}$$

(12)

In the equation above, the dependent variable $SALES_{sitc}$ represents the annual sales of subsidiary $s$ owned by firm $i$ in year $t$. The $c$ subscript identifies a subsidiary’s country-level location. It remains fixed, since I consider the relationship between US patents and subsidiary sales on a country-by-country basis. The main treatment variable $PATENTS_{it}$ again represents the number of US patents held by firm $i$ in year $t$. In a new vector of observable controls $W$, I again include average patent approval time and patent application. In addition, I also directly control for the number of subsidiaries held by firm $i$ in year $t$, as well as firm $i$’s average ownership share of its subsidiaries in year $t$. Complementing my vector of observable controls $W$, I also

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53I investigate the relationship between US patents and subsidiary sales in the US, UK, Germany, France, Belgium, the Netherlands, China, Japan, Korea, Australia, Brazil, India, Singapore, and Russia. These countries were selected to match the regions in Table 1 as closely as possible.
include firm \((\psi_i)\) and industry-year \((\gamma_{jt})\) fixed effects.\(^{54}\) Following the suggestions of Abadie et al (2017), I cluster my standard errors at the firm level, since this represents the unit over which my main treatment variable \(PATENTS_{it}\) is assigned.

Due to the presence of firm fixed effect \(\psi_i\), the regression specification detailed in equation (12) should eliminate any bias that might result from other across-firm determinants that determine subsidiary sales besides US patent protection. Nonetheless, there remain additional confounding factors which may bias equation (12)’s coefficient estimates vis-a-vis the true causal effect of US patents on subsidiary sales. Like before, concerns over endogeneity between US patents and subsidiary sales remain, especially when considering US subsidiary sales. That is, parent companies with higher subsidiary sales in the US may possess higher incentives to obtain US patent protection to build upon their US subsidiaries’ competitive advantage and profits. Furthermore, prior theoretical work such as Helpman (1984) and Melitz (2003) posit that more productive and innovative firms are more likely to expand international operations. Thus, it is difficult to disentangle the effect of US patent protection on foreign subsidiary operations from other simultaneous firm-level changes, such as in corporate strategy or employee talent. To address these confounding factors, I again rely on instrumental variables regression analyses presented in section 5.2. In addition, to account for potential diminishing marginal returns to US patents, I again log-transform the \(PATENTS_{it}\) treatment variable in a robustness check.

Lastly, to consider how the relationship between US patents and foreign subsidiary sales varies in response to certain country-level characteristics, I run fixed effect regressions of the following form:

\[
SALES_{sitc} = \beta_0 + \beta_1 PATENTS_{it} + \beta_2 IPR_{tc} + \beta_3 PATENTS_{it} \times IPR_{tc} + \delta W + \psi_i + \kappa_c + \gamma_{jt} + u_{sitc}
\]

In this regression analysis, I allow subsidiary country location, denoted by \(c\), to vary, \(^{54}\)Industry is again categorized by 3-digit NAICS codes.
although I drop US subsidiaries from my data. Instead of analyzing the impact of US patents on subsidiary sales on a country-by-country basis, I introduce a country-level institutional variable, $IPR_{tc}$. This variable is the IPR quality score found in the World Bank’s GovData360 database. I also replace $IPR_{tc}$ with the variables on property rights quality, judicial independence, and political transparency in alternate regression specifications. Since a country’s IPR protection quality might be correlated with other factors such as its level of economic development, I include a country fixed effect $\kappa_c$ to better ensure that my estimate of country-variant treatment heterogeneity $\beta_3$ is not biased by these related country-specific variables. Lastly, all other variables in equation (13) above remain identical to the ones in equation (12).

5.2 Instrumental Variables Regressions

As previously mentioned, various confounding factors threaten the internal validity of the fixed effect regression specifications detailed in section 5.1. To begin, as Helpman (1984) and Melitz (2003) both imply, more efficient and innovative firms both within and across industries prove more likely to export and maintain significant overseas operations. Even when controlling for firm and industry-year effects, it remains plausible that confounding factors such as a new corporate strategy, new management, or improved talent acquisition could be simultaneously driving international sales growth and patenting within a firm over time. Such confounding factors would likely bias the paper’s fixed effect estimates upwards. In addition, reverse causality could also cause my fixed effect specifications to overestimate the true causal effect of US patent protection on international operations. Specifically, firms with larger global operations may be more inclined to acquire US patents as a protective measure against competitor imitation. This possibility is especially applicable when considering the impact of US patent protection on aggregate and subsidiary-level sales within US subsidiaries are dropped here because they likely remain under the direct protection of their parent company’s US patents, which may not be true for foreign subsidiaries.
the US. Nonetheless, if my earlier theoretical conjecture that a US patent might reduce the likelihood of the competitor entry into foreign markets proves true, firms’ incentives to acquire US patents may also increase as their foreign operations grow.

To address these potential confounding factors, I exploit the exogenous variation in USPTO patent examiner leniency in an instrumental variables (2SLS) empirical framework. Leniency instruments have been widely employed in various subfields of applied microeconomics. For example, Dobbie et al (2018) exploit exogenous variation in judge leniency in the law and economics literature, while Maestas et al (2013) exploit exogenous variation in disability insurance application examiners in the health economics literature. After merging USPTO patent data with Compustat using the concordance table of Autor et al (2019), I construct an average patent examiner leniency measure by averaging leave-one-out grant rates across all US patents held by a firm in a given year. To recapitulate, a given patent $p$’s leave-one-out grant rate is defined as the total number of successful patent applications divided by the total number of patent applications reviewed by patent $p$’s examiner, excluding patent $p$. Since the leave-one-out examiner leniency measure does not account for whether $p$ is successful, it is not influenced by $p$’s inherent quality. Furthermore, since prior studies such as Lemley and Sampat (2010) and Sampat and Williams (2019) suggest that patent examiners are randomly assigned to patent applications within certain broad technological units, it remains plausible that average leave-one-out grant rates are as good as randomly assigned to a firm in a given year. Appendix B defines both the patent-level leave-one-out grant rate and the average leave-one-out grant rate instrumental variable more mathematically, while section 5.3 discusses the identification assumptions behind the average examiner leniency instrument in more detail.

Thus, complementing my fixed effect analyses which investigate the impact of US patent protection on aggregate sales, I run the second stage 2SLS regression displayed in equation (14). All terms in equation (14) (on the next page) are defined exactly
the same as in equation (11) in section 5.1, except for \( \hat{PATENTS}_{it} \). As in equation (11), I conduct these 2SLS regressions on a country-by-country basis, restricting observations to observe sales exclusively from a single geographic market \( c \).

\[
\log SALES_{itc} = \beta_0 + \beta_1 \hat{PATENTS}_{it} + \delta Z_{it} + \gamma_{jt} + \epsilon_{it} \tag{14}
\]

\( \hat{PATENTS}_{it} \) represents the predicted values of a firm’s US patent count in a given year. These predicted values are obtained via the following first stage regression:

\[
PATENTS_{it} = \alpha_0 + \alpha_1 AVGGRANTRATE_{it} + \delta' Z_{it} + \gamma_{jt} + \upsilon_{it} \tag{15}
\]

where \( AVGGRANTRATE_{it} \) represents the average examiner leniency measure (i.e. average leave-one-out grant rate) across all US patents held by firm \( i \) in year \( t \). The remaining terms are defined exactly the same as their counterparts in equation (11).

I also use my 2SLS regression framework to consider the impact of firm-level US patents on subsidiary sales. Specifically, I run the following 2nd stage 2SLS regression:

\[
SALES_{sitc} = \beta_0 + \beta_1 \hat{PATENTS}_{it} + \delta' W_{it} + \psi_{i} + \gamma_{jt} + \nu_{sit} \tag{16}
\]

All terms in the equation above are defined exactly the same as in equation (12) in section 5.1, except for \( \hat{PATENTS}_{it} \). As in equation (12), I conduct these 2SLS regression on a country-by-country basis. Similarly to equation (14), \( \hat{PATENTS}_{it} \) represents the predicted values derived from the following first stage regression:

\[
PATENTS_{it} = \alpha_0 + \alpha_1 AVGGRANTRATE_{it} + \delta' W_{it} + \psi_{i} + \gamma_{jt} + \upsilon_{it} \tag{17}
\]

Lastly, I apply this 2SLS framework to my analyses investigating the across-country heterogeneity in firm-level US patents’ impact on foreign subsidiary sales.
Specifically, I run second stage regressions of the following form:

\[
SALES_{sitc} = \beta_0 + \beta_1 \widehat{PATENTS}_{it} + \beta_2 \widehat{IPR}_{tc} \\
+ \beta_3 \widehat{PATENTS}_{it} \times \widehat{IPR}_{tc} + \delta W + \psi_i + \kappa_c + \gamma_{jt} + u_{sitc}
\]  

(18)

All terms in the equation above are defined exactly the same as in equation (13) in section 5.1, except for \(\widehat{PATENTS}_{it}\) and \(\widehat{PATENTS}_{it} \times \widehat{IPR}_{tc}\). To explain, instead of regressing \(SALES_{sitc}\) on \(PATENTS_{it}\) and \(PATENTS_{it} \times IPR_{tc}\) directly, I use two instrumental variables, \(AVGGRANTRATE_{it}\) and \(AVGGRANTRATE_{it} \times IPR_{tc}\) respectively, to obtain \(\widehat{PATENTS}_{it}\) and \(\widehat{PATENTS}_{it} \times IPR_{tc}\).

### 5.3 Instrumental Variables Assumptions

Having discussed my specific 2SLS regression specifications, I now explain why my average examiner grant rate instrument plausibly satisfies the fundamental instrumental variable assumptions of relevance, conditional independence, exclusivity, and monotonicity across all my regression specifications. I mention the exclusivity and monotonicity assumptions because I assume the treatment effect of US patent protection on aggregate and subsidiary sales to heterogeneously vary across different firms and subsidiaries. Lastly, after discussing why my examiner leniency measure plausibly satisfies the fundamental IV assumptions, I discuss the remaining limitations to my 2SLS empirical approach.

**Relevance:**

I first demonstrate that my examiner leniency measure, average grant rate, satisfies the relevance condition. Mathematically, the condition states the following:

\[
\text{Cov}(PATENTS_{it}, AVGGRANTRATE_{it}) \neq 0
\]  

(19)

\(AVGGRANTRATE_{it}\) is the same instrument used in equations (16) and (17), and \(AVGGRANTRATE_{it} \times IPR_{tc}\) is an interaction term between the average examiner leniency instrument and the country-level variable on IPR protection quality. Lastly, in alternate regression specifications, I substitute variables on property rights protection, judicial independence, and political transparency for \(IPR_{tc}\), similarly to what I do in equation (13).
Intuitively, the condition implies that the examiner leniency instrument $AVGGRANTRATE_{it}$ must significantly impact the value of the treatment variable, $PATENTS_{it}$. As Lemley and Sampat (2010) and Sampat and Williams (2019) both note, patent examiner leniency positively impacts the probability of a patent application’s success. Therefore, it remains intuitively plausible that the average examiner leniency faced across all US patents held by a firm positively impacts that firm’s total US patent holdings.

Figure 6: *The Relationship between Firm-Level Patents and Average Examiner Grant Rates in Firm-Level and Subsidiary-Level Data*

NOTE: Figure 6a on the left shows the relationship between firm-level patent counts and average examiner leniency in my firm-level data (see Appendix Table D1). Figure 6b on the right displays the graphical relationship between parent company patents and average examiner leniency in my subsidiary-level data (see Appendix Table D2). Also, to account for potential nonlinearities in the relationship between patent counts and examiner leniency, Appendix C figures 3a-3b present analogous versions of these figures, except with a log-transformed version of firm-level patents on the y-axis.

Following the conventional econometric standards outlined by Angrist and Pischke (2009), I more formally test the relevance assumption’s validity by running first stage regressions and observing the first stage F-statistic. Figures 6a-6b above graphically display the relationship between average examiner leniency and firm-level patent counts, while Table 2 documents the first-stage regression results.\footnote{First-stage F-statistics are found by running regressions over the entire firm-level and subsidiary-level data sets described in Appendix D tables D1 and D2.} To ac-
count for patent application approval times and volume as a potential confounding factors in this IV framework (see subsequent discussion on conditional independence + exclusivity for more context), I directly control for average patent approval time and annual application count in all columns of Table 2. In addition, to account for potential non-random assignment of patent examiners to patents across industry and over time, I also include a full set of industry-year fixed effects across all columns.

**Table 2: First Stage Regression Results with Firm and Subsidiary-Level Data**

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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
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<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
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<td></td>
<td>Stratified</td>
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<td>Average Examiner Grant Rate (%)</td>
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<td>362.293</td>
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</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1

NOTE: Columns (1) and (2) display first stage regression results for regressions run over the firm-level data described in Appendix Table D1. These regression results correspond with the specification provided in equation (15). Columns (3) and (4) display first stage regression results for regressions run over the subsidiary-level data described in Appendix Table D2. These regression results correspond with the specification provided in equation (16). Columns (1) and (3) employ firm-level patent count as the first stage dependent variable, while columns (2) and (4) employ a log-transformed version of this patent count as the dependent variable. Observable controls include average patent approval time and annual patent applications across all 4 regression specifications. Additional observable controls on a parent company’s subsidiary count and average subsidiary ownership share, as well as firm fixed effects, are included in the subsidiary-level regressions of columns (3) and (4).

To interpret the regression results in Table 2, column (1) suggests that a one percentage point (pp) increase in average examiner grant rate increases a firm’s patent count in a given year by 11.46 patents on average. Alternatively, column (2) suggests that a one pp increase in average examiner leniency increases a firm’s patent count in a given year by approximately 5.17% on average. Likewise, columns (3) and (4) apply
the first-stage regression specifications in a subsidiary-level context; both columns show that an increase in average examiner leniency raises a parent company’s patent count on average. Furthermore, all reported first-stage F-statistics in Table 2 remain above the critical value of 10 proposed by Angrist and Pischke (2009) as well as the critical value of 23.01 proposed by Montiel-Olea and Pflueger (2013). Lastly, since examiner leniency is so strongly correlated with a firm’s patent holdings, the interacted instrument presented in equation (18) \((AVGGRANTRATE_{it} \times IPR_{tc})\) should likewise be strongly correlated with the interaction term, thus validating the relevance condition in my 2SLS regression with two instruments. Thus, since examiner leniency appears to significantly increase a firm’s patent holdings, I can confirm that my USPTO examiner leniency instrument satisfies the relevance assumption.

**Conditional Independence:**

Next, to explain why I include the controls and fixed effects shown in Table D2, I discuss the conditional independence assumption (CIA), which, in this context, can be described mathematically as follows:

\[
E[\epsilon_{it} \times AVGGRANTRATE_{it}] = 0 \tag{20}
\]

Intuitively, the condition states that average examiner leniency must be as good as randomly assigned across firms, once a complete vector of controls \(Z_{it}\) is included. At first glance, USPTO assignment of patent examiners to individual patent applications does appear as good as randomly assigned. According to Lemley and Sampat (2010), the USPTO publicly declares that “all patents are created equal” in its examination process. Furthermore, prior studies which exploit exogenous variation in patent examiner leniency such as Sampat and Williams (2019) document that USPTO patent examiners are as good as randomly assigned to patent applications within broad technological fields. Thus, given such random assignment, firm-level selection in acquiring
more lenient patent examiners on average appears impossible within an industry. To corroborate these claims, Appendix Table D4 shows that the average examiner grant rate instrument does not appear significantly correlated with a variety of firm-level characteristics such as past levels of sales and sales growth. Although it remains impossible to definitively test whether or not the CIA is satisfied, such covariate balance tests provide suggestive evidence that the condition holds.

Nonetheless, as Righi and Simcoe (2017) note, due to limitations in examiners’ areas of scientific expertise, patent examiners and examiner leniency may not be as good as randomly assigned across broad technological sectors. For example, patent examiners who review pharmaceutical drug patents might be inherently stricter than examiners who review semiconductor patents. Alongside potential nonrandom assignment across technological classes, the retirement and hiring of patent examiners over time may also contribute to nonrandom assignment of examiners. To mitigate such sources of nonrandom examiner assignment, I include a full set of industry-year effects. I assume that firms within the same industry will seek patent protection in similar technological fields, since firms should theoretically be incentivized to patent within technological fields most useful to their operations. Lastly, since I aggregate patent examiner leniency into an average at the firm-year level, firms with more patent applications are more likely to have an average examiner leniency measure closer to the sample mean in the examiner-level PERD data. To mitigate this source of nonrandom assignment in examiner leniency, I directly control for the number of patent applications filed by a firm in a given year. Including these fixed effects and controls help to corroborate my claim that the CIA is satisfied.

*Exclusion Restriction:*

I proceed to show that exclusivity, or the exclusion restriction, also holds for my average grant rate IV. The exclusion restriction generally states that an instrument can only affect the outcome variable through its effect on the treatment variable.
In this paper’s context, this would imply that the average USPTO patent examiner leniency faced by a firm only affects a firm’s aggregate and subsidiary sales through its effect on the firm’s US patent holdings. While the effect of average examiner leniency on a firm’s US patent holdings is well-documented in Figures 5a-5b and Table 2, Righi and Simcoe (2017) note that examiner leniency also affects the length of a patent application’s review. Specifically, tougher examiners tend to prolong the patent application review process. Since, as Budish et al (2015) point out, a patent’s term length is determined by its application filing date, a longer patent application review may lower a patent’s value, thus affecting a firm’s global sales and operations. Thus, I control for the average approval time faced by a firm’s patents in a given year. Appendix B constructs this control variable in greater mathematical detail.

In addition, as Farre-Mensa (2018) and Gaule (2018) note, firms facing tougher examiners could be more incentivized to submit subsequent US patent applications, since it is more likely that their initial patent applications fail. To mitigate this exclusivity concern, I directly control for a firm’s patent application count in a given year. It nonetheless remains difficult to conduct a definitive empirical test on whether the exclusion restriction is satisfied. However, once controls for patent application count and average approval time are included, it appears plausible that USPTO patent examiner leniency could only affect firms’ global sales through their effect on a firm’s US patent holdings. Thus, the exclusivity condition plausibly holds.

**Monotonicity:**

Lastly, I consider the monotonicity assumption, which can be mathematically summarized as follows:

\[
\frac{\partial PATENTS_{it}}{\partial AVGGRANTRATE_{it}} \geq 0, \forall i
\]  

(21)

Intuitively, the condition states that an increase in average examiner leniency will
induce an increase in the number of patents held for all firms in my data. That is, there cannot exist a firm which would hold fewer patents if the average examiner grant rate that it faced were positively and exogenously shocked. This assumption is difficult to empirically test, since one cannot observe a firm’s counterfactual patent count had its average examiner leniency been lower/higher. Nonetheless, economic intuition and prior work such as Farre-Mensa et al (2018) and Gaule (2018) suggest that assigning more lenient patent examiners to a given firm would increase the firm’s patent holdings. Thus, the monotonicity condition should plausibly hold.

**Remaining Limitations:**

While the use of an examiner leniency instrument improves causal identification in this paper on the whole, certain caveats concerning such estimates’ internal and external validity remain. To begin, the paper’s IV analyses are only conducted over patent-holding firms, since firms that do not hold patents are not assigned patent examiners. Thus, the sample for my IV analyses are drawn as a subset of the sample used for my fixed effect analyses. More importantly, by only observing firms that choose to patent, my IV analyses already restricts itself to a subsample of firms whose business models and sales are likely more dependent on successful patenting. This data restriction may render my IV estimates higher than my fixed effect estimates, although they do not imply bias in the IV estimates’ internal validity.

In addition, my IV estimates represent local average treatment effects of the treatment variable on the outcome variable, instead of the average treatment effect which a randomized control trial would produce. In this paper’s context, the treatment effects estimated by my IV regressions more heavily weight firms whose level of patent protection is most affected by the average leniency of their patent examiners. Intuitively, this could suggest that the IV coefficients mostly reflect the effect of patents on the sales of firms with many “marginal” patent applications, whose success depends more upon examiner leniency than their (presumably mediocre) intrinsic quality. If
these firms’ financial fortunes are more contingent upon the success of their patent applications, my IV estimates could again be biased upwards.

6 Empirical Results

In this section, I detail my complete empirical results. I find that US patents increase aggregate firm-level and subsidiary-level sales both within the US and globally on average. Furthermore, although US patents at the parent company level appear to increase the sales of a company’s US subsidiaries, the impact of US patents on the sales of a company’s foreign subsidiaries remains ambiguous and widely varied across countries. Nonetheless, further analyses suggest that the country-specific levels of IPR protection, property rights, judicial independence, and political transparency effectively explain the across-country heterogeneity in the relationship between US patents and foreign subsidiary sales fairly well. To illustrate, country-by-country and across-country analyses both suggest that additional US patent protection increases subsidiary sales in countries with strong IPR protection, whereas it decreases subsidiary sales in countries with weak IPR protection. Lastly, I provide additional evidence suggesting that my empirical results are primarily driven by within-firm responses to US patent protection, as opposed to across-firm sorting or entry into foreign markets, although I do note that firms with more extensive subsidiary operations and sales in countries with lower IPR protection quality are larger on average.

6.1 Aggregate Sales By Country

I first consider the impact of US patent protection on aggregate global, US, and foreign sales on a country-by-country (i.e. market-by-market) basis. To begin, I run the regressions described in equations (11) and (14) to determine the impact of US patent protection on firms’ global and US sales. That is, I restrict the subscript $c$ in
both equations first to global sales and then to US market segment sales. Table 3 displays the regression results for both global and US sales.

Table 3: The Impact of US Patents on Aggregate Global and US Sales

<table>
<thead>
<tr>
<th>Region:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Patents</td>
<td>0.00046***</td>
<td>3.2e-06</td>
<td>0.0026***</td>
<td>0.00041***</td>
<td>3.1e-06</td>
<td>0.0020***</td>
</tr>
<tr>
<td>(2.9e-05)</td>
<td>(4.8e-06)</td>
<td>(0.00032)</td>
<td>(2.1e-05)</td>
<td>(3.0e-06)</td>
<td>(0.00020)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>85,361</td>
<td>83,800</td>
<td>11,983</td>
<td>55,495</td>
<td>55,365</td>
<td>11,114</td>
</tr>
<tr>
<td>Observable Controls</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Industry-Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Firm FE</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>First-Stage F-stat</td>
<td>N/A</td>
<td>N/A</td>
<td>148.642</td>
<td>N/A</td>
<td>N/A</td>
<td>193.115</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

NOTES: Logged global sales are the dependent variable in columns (1)-(3), while logged US sales are the dependent variable in columns (4)-(6). Fixed effect (FE) regression specifications were conducted in columns (1), (2), (4), and (5), while IV/2SLS regression specifications were conducted in columns (3) and (6). Average patent approval time and patent application count were included as observable controls. In Appendix D Table 5, I run these regressions over a log-transformed version of the US patents treatment variable as a robustness check.

Interpreting these results, my preferred specifications (in columns (3) and (6)) suggest that an additional US patent increases a company’s global sales by $100 \times 0.0026 = 0.26\%$, while it increases a company’s US sales by 0.20\%. I prefer the 2SLS specifications used in columns (3) and (6) because they best minimize the internal validity threats of selection bias and reverse causality detailed in section 5. Nonetheless, my fixed effect regression specifications in the other columns also find that an increase in US patents lead to increases in firm-level aggregate sales both globally and in the US. Lastly, the 2SLS regression estimates appear significantly larger than the fixed effect regression estimates. I mostly attribute this to the fact
that the 2SLS estimates only consider patent-holding firms. These firms, as opposed to non-patenting firms, actively choose to patent, presumably because patenting is relatively more profitable for them. Thus, it is expected that the 2SLS estimates in columns (3) and (6) are larger than the fixed effect estimates in the other columns.\(^{58}\)

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>FE Estimate 1</th>
<th>FE Estimate 2</th>
<th>2SLS Estimate</th>
<th>First Stage F-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.000952***</td>
<td>-0.0000218</td>
<td>0.00107*</td>
<td>24.76</td>
</tr>
<tr>
<td>Europe</td>
<td>0.000240***</td>
<td>7.57e-07</td>
<td>0.000373***</td>
<td>60.00</td>
</tr>
<tr>
<td>China</td>
<td>0.000322***</td>
<td>9.23e-06**</td>
<td>0.000576***</td>
<td>32.67</td>
</tr>
<tr>
<td>UK</td>
<td>0.000622***</td>
<td>0.0000211</td>
<td>0.00141***</td>
<td>54.53</td>
</tr>
<tr>
<td>Japan</td>
<td>0.000272***</td>
<td>0.0000135***</td>
<td>0.0000986</td>
<td>32.14</td>
</tr>
<tr>
<td>Germany</td>
<td>0.000527***</td>
<td>0.0000265***</td>
<td>0.000515</td>
<td>44.02</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.000360***</td>
<td>0.000202**</td>
<td>N/A</td>
<td>3.08</td>
</tr>
<tr>
<td>France</td>
<td>0.000941***</td>
<td>-0.0000232</td>
<td>0.00231***</td>
<td>24.53</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.0000891</td>
<td>0.000224***</td>
<td>0.00645***</td>
<td>20.91</td>
</tr>
<tr>
<td>Australia</td>
<td>0.00160***</td>
<td>9.38e-06</td>
<td>0.00352*</td>
<td>12.89</td>
</tr>
<tr>
<td>Korea</td>
<td>0.000592***</td>
<td>-0.0000217</td>
<td>N/A</td>
<td>0.04</td>
</tr>
<tr>
<td>Taiwan</td>
<td>0.000422***</td>
<td>-1.62e-06</td>
<td>N/A</td>
<td>2.11</td>
</tr>
<tr>
<td>India</td>
<td>0.000376***</td>
<td>-6.78e-06</td>
<td>N/A</td>
<td>8.64</td>
</tr>
<tr>
<td>Controls</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

NOTES: The dependent variable in columns (1)-(3) is a logged aggregate sales measure for total firm sales in a given country/region, as specified in the leftmost column. The main treatment variable whose coefficients across geographic markets are displayed in columns (1)-(3) is a firm’s US patent count. Each row represents an iteration of the regressions specified in equations (11) and (14), applied to a specific geographic market. First-stage F-statistics in column (4) are generated for the 2SLS regressions in column (3). I omit 2SLS estimates when the first stage F-statistic is less than 10, the critical value suggested by Angrist and Pischke (2009).

In addition to investigating the impact of US patent protection on firms’ US and global sales, I also analyze the impact of US patent protection on firms’ ag-

\(^{58}\)Taking log transformations of sales allows me to measure the relative increase in sales across different markets. This allows me to compare the relative magnitude of the effect of US patents on sales across different markets.
aggregate foreign market sales on a country-by-country (i.e. market-by-market) basis. Specifically, I separately consider the impact of US patent protection on Canadian, European, Chinese, UK, Japanese, German, Mexican, Brazilian, French, Taiwanese, Australian, Korean, and Indian sales. Again, I implement regression specifications described in equations (11) and (14) to conduct my analysis, separately restricting $c$ to the countries listed above. Table 4 (on p. 58) details the relevant results.

The results in Table 4 appear to imply that US patent protection increases a company’s foreign sales across a wide variety of markets. For example, in my preferred 2SLS regression specifications, I predict that an additional US patent increases Brazilian sales by $100 \times 0.00645 = 0.645\%$, European sales by 0.037\%, and Chinese sales by 0.058\%. The fixed effect regression specifications also mostly return positive point estimates. Again, the 2SLS coefficients generally appear larger in magnitude than the fixed effect coefficients, which I again attribute to the 2SLS regressions’ focus on patenting firms. Furthermore, the magnitudes of the 2SLS coefficient estimates across all countries usually appear smaller than the coefficients for US sales in Table 3.\(^{59}\) Since my theoretical model would suggest that US patent protection increases sales in the US by relatively more than sales abroad, the lesser magnitudes of the 2SLS estimates in Table 4 are unsurprising. Lastly, Appendix figure 4 displays the spatial distribution in the relationship between US patents and foreign aggregate sales.

### 6.2 Subsidiary Sales By Country

Complementing my analysis of aggregate market sales, I also consider the impact of parent company US patent protection on subsidiary sales on a country-by-country basis. I first conduct an analysis on this relationship without restricting by a subsidiary’s country. Next, I consider the impact of US patents on US as well as non-US subsidiary sales. For these analyses, I implement the regression specifications pro-

\(^{59}\)France, Brazil, and India appear to be the only exceptions.
posed in equations (12) and (15) in section 5. Table 5 displays the corresponding fixed effect and 2SLS regression results.

<table>
<thead>
<tr>
<th>Subsidiary Region:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method:</td>
<td>FE</td>
<td>2SLS</td>
<td>FE</td>
<td>2SLS</td>
<td>FE</td>
<td>2SLS</td>
</tr>
<tr>
<td>US Patent Count</td>
<td>1.674**</td>
<td>1.278**</td>
<td>3.333**</td>
<td>1.096***</td>
<td>0.396***</td>
<td>-1.963</td>
</tr>
<tr>
<td></td>
<td>(0.694)</td>
<td>(0.600)</td>
<td>(1.597)</td>
<td>(0.145)</td>
<td>(0.134)</td>
<td>(4.080)</td>
</tr>
<tr>
<td>Observations</td>
<td>69,275</td>
<td>21,174</td>
<td>44,058</td>
<td>11,868</td>
<td>24,754</td>
<td>9,139</td>
</tr>
<tr>
<td>Observable Controls</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Industry-Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>First-Stage F-stat</td>
<td>N/A</td>
<td>135.875</td>
<td>N/A</td>
<td>63.819</td>
<td>N/A</td>
<td>26.44</td>
</tr>
</tbody>
</table>

NOTE: Global, US, and Foreign subsidiary sales (my dependent variables) are measured in millions of current USD. Fixed effect (FE) regression specifications were conducted in columns (1), (3), and (5), while IV/2SLS regression specifications were conducted in columns (2), (4), and (6). Average patent approval time, a patent application count, average subsidiary ownership share, and a total subsidiary count were included as observable controls. Standard errors are clustered at the parent-company level. Lastly, in Appendix D Table 6, I run these regressions over a log-transformed version of the US patents treatment variable as a robustness check.

Interpreting these results, I observe from my preferred 2SLS regressions that an additional firm-level US patent increases a subsidiary’s sales by $1.28 million on average, while it also increases a US subsidiary’s sales by $1.10 million on average. While statistically significant, these estimates may appear practically small at first. However, when one considers that a large parent company often holds many subsidiaries and many patents, the result appears more economically significant. In contrast, the impact of firm-level US patents on a foreign subsidiary’s sales appears ambiguous, as the estimates shown in Table 5 column (6) are negative and statistically insignificant.

To understand the ambiguity in the impact of US patent protection on foreign subsidiary sales, I first consider the relationship on a country-by-country basis. Specif-
ically, I separately investigate the impact of US patents on the sales of subsidiaries located in the UK, Germany, France, China, Japan, the Netherlands, Belgium, Russia, Australia, Brazil, Korea, India, and Singapore.\textsuperscript{60} Table 6 displays the country-by-country subsidiary-level results, and Appendix C figure 5 displays the spatial distribution in the relationship between US patents and foreign subsidiary sales.

Table 6: The Impact of US Patents on Subsidiary Sales Abroad: Country-by-Country Analysis

<table>
<thead>
<tr>
<th>Country</th>
<th>FE Estimate (1)</th>
<th>2SLS Estimate (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>24.93***</td>
<td>194.6***</td>
</tr>
<tr>
<td>Netherlands</td>
<td>14.54***</td>
<td>14.44***</td>
</tr>
<tr>
<td>China</td>
<td>1.92</td>
<td>-35.94</td>
</tr>
<tr>
<td>UK</td>
<td>0.022</td>
<td>23.61***</td>
</tr>
<tr>
<td>Japan</td>
<td>76.62***</td>
<td>-7.15</td>
</tr>
<tr>
<td>Germany</td>
<td>37.97***</td>
<td>35.82***</td>
</tr>
<tr>
<td>Russia</td>
<td>-0.29***</td>
<td>-0.32***</td>
</tr>
<tr>
<td>France</td>
<td>44.73***</td>
<td>45.57***</td>
</tr>
<tr>
<td>Brazil</td>
<td>-35.36*</td>
<td>-11.14***</td>
</tr>
<tr>
<td>Australia</td>
<td>0.77***</td>
<td>-8.65***</td>
</tr>
<tr>
<td>Korea</td>
<td>241.8***</td>
<td>23.69***</td>
</tr>
<tr>
<td>Belgium</td>
<td>9.81***</td>
<td>6.621</td>
</tr>
<tr>
<td>India</td>
<td>-0.13</td>
<td>-0.32***</td>
</tr>
</tbody>
</table>

Observable Controls: Y Y
Industry-Year FE: Y Y
Firm FE: Y Y

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

NOTES: The dependent variable in columns (1)-(2) is sales for a subsidiary located in a country specified in the leftmost column. The dependent variable is measured in millions of current USD. The treatment variable is a parent company’s US patent count. Each row represents an iteration of the regressions specified in equations (12) and (15), applied to a specific geographic market. The countries included in Table 6 were selected to best match the sample in Table 4. However, data limitations prevented me from standardizing the countries selected across Tables 4 and 6.

At first glance, Table 6 might suggest on the whole that US patents increase subsidiary sales in developed economies with strong IPR protections, while they decrease subsidiary sales in less developed economies with weaker IPR protections. For ex-

\textsuperscript{60}I kept the countries as consistent as possible with the countries used in the aggregate sales analysis. However, data limitations prevented me from using the exact same countries for both analyses.
ample, an additional US patent at the parent company level appears to increase a German subsidiary’s sales by $35.82 million on average. However, an additional US patent appears to decrease a Chinese subsidiary’s sales by $35.94 million on average. Visualizing this observation, I plot the relationship between the country-specific 2SLS estimates from Table 6 on country-level measures of average IPR and property rights quality during the 2008-2018 period. Figures 7a and 7b show the relevant graphs.61

Figure 7: The Impact of US Patent Protection on Foreign Subsidiary Sales Across Different Country-Level IPR and Property Rights Regimes

NOTE: Figure 7a on the left shows how the impact of US patent protection on subsidiary sales in a specific foreign country changes as the average country-specific quality of IPR protection changes. Figure 7b on the right shows how the impact of US patent protection on subsidiary sales in a specific foreign country changes as the average country-specific quality of property rights protection changes. The y-axis on both graphs is measured in $ millions, and the specific country-level IV/2SLS point estimates from Table 6 represent the individual points in my graph.

6.3 Subsidiary Sales Across Country

Building off my analyses in section 6.2, I now consider how the relationship between US patent protection and foreign subsidiary sales varies across country-level quality of IPR, property rights, judicial independence, and political transparency. Figures 7a and 7b presented in section 6.2 suggest that the impact of US patent

61In Appendix C, figures 6a and 6b similarly show how the impact of US patents on foreign subsidiary sales changes alongside country-level measures of judicial independence and political transparency.
protection on foreign subsidiary sales could depend on IPR protection quality in the subsidiary’s country. To investigate this possibility with greater empirical rigor, I implement the fixed effect and 2SLS regression specifications proposed in equations (13) and (16). To disentangle the impact of country-level IPR protection quality from related variables such as economic development and market size, I include country fixed effects. In addition to considering country-level IPR quality, I also consider country-level measures of property rights quality, judicial independence, and political transparency in my analyses. Tables 7 and 8 display the fixed effect and 2SLS regression results respectively.

### Table 7: The Relation Between US Patents and Foreign Subsidiary Sales: Treatment Heterogeneity Across Country-Level Variables

<table>
<thead>
<tr>
<th>Country-Level Vars:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method:</td>
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<td>FE</td>
<td>FE</td>
<td>FE</td>
</tr>
<tr>
<td>US Patents</td>
<td>-0.0768</td>
<td>-0.0657</td>
<td>-0.0564</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>(0.250)</td>
<td>(0.248)</td>
<td>(0.210)</td>
<td>(0.203)</td>
</tr>
<tr>
<td>X</td>
<td>2,177***</td>
<td>-197.6</td>
<td>2,018***</td>
<td>975.2**</td>
</tr>
<tr>
<td></td>
<td>(638.6)</td>
<td>(714.2)</td>
<td>(538.3)</td>
<td>(473.3)</td>
</tr>
<tr>
<td>US Patents*X</td>
<td>0.104***</td>
<td>0.0986***</td>
<td>0.0945***</td>
<td>0.0954***</td>
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<tr>
<td></td>
<td>(0.0370)</td>
<td>(0.0349)</td>
<td>(0.0262)</td>
<td>(0.0329)</td>
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<td>23,409</td>
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<td>Observable Controls</td>
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<td>Y</td>
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<tr>
<td>Industry-Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Country FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

NOTES: Subsidiary sales, measured in millions of current USD, is the dependent variable across all 4 columns. Regarding the Country-Level Variables, IPR stands for the quality of IPR protection, PR stands for property rights protection, JI stands for judicial independence, and PT stands for political transparency/favoritism. The IPR, PR, JI, and PT variables are all country-level survey variables collected from the World Bank’s GovData360 database. Further description is found in section 4.4. I drop US subsidiary observations from my sample before running these regressions. Standard errors are clustered at the firm level. Lastly, in Appendix D Table 7, I run these same regressions over a log-transformed US patent count as a robustness check.
The results in Tables 7 and 8 on the whole suggest that the relationship between US patents and foreign subsidiary sales grows more positive as country-level quality of IPR protection, property rights protection, judicial independence, and political transparency increase. For example, to interpret my fixed effect specifications in column (1) of Table 7, US patent protection is predicted to lead to an increase of \(-0.0768 + 0.104 \times 6 = \$547,200\) (on average) in a subsidiary’s sales if the subsidiary is located in a country with a high IPR score of 6. However, US patent protection is predicted to lead to an increase of only \$27,200\) (on average) in a subsidiary’s sales if the subsidiary is located in a country with a low IPR score of 1.

Table 8: The Impact of US Patents on Foreign Subsidiary Sales: Treatment Heterogeneity Across Country-Level Variables

<table>
<thead>
<tr>
<th>Country-Level Vars:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X=IPR</td>
<td>-2.549</td>
<td>-3.262</td>
<td>-2.418</td>
<td>-0.945</td>
</tr>
<tr>
<td>X=PR</td>
<td>(3.157)</td>
<td>(2.426)</td>
<td>(1.955)</td>
<td>(1.409)</td>
</tr>
<tr>
<td>X=JI</td>
<td>0.725</td>
<td>0.832*</td>
<td>0.760**</td>
<td>0.659**</td>
</tr>
<tr>
<td>X=PT</td>
<td>(0.565)</td>
<td>(0.428)</td>
<td>(0.347)</td>
<td>(0.325)</td>
</tr>
<tr>
<td>X</td>
<td>208.8</td>
<td>-2,387**</td>
<td>480.2</td>
<td>189.3</td>
</tr>
<tr>
<td></td>
<td>(746.6)</td>
<td>(1,087)</td>
<td>(744.6)</td>
<td>(1,005)</td>
</tr>
<tr>
<td>Observations</td>
<td>20,730</td>
<td>20,801</td>
<td>20,801</td>
<td>20,801</td>
</tr>
<tr>
<td>Observable Controls</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Industry-Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Country FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

NOTES: The regressions run in columns (1)-(4) of the table above are analogous to the regressions run in columns (1)-(4) of Table 7, except that the estimates presented in Table 8 above are derived from the 2SLS regressions outlined in equation (18). In Appendix D Table 8, I run these same IV/2SLS regressions over a log-transformed US patent count as a robustness check.

I am reasonably confident that the estimates are driven by improvements in IPR protection as opposed to other across-country traits such as economic development or market size, since I include country fixed effects. In addition, building on my fixed
effect regressions in Table 7, Table 8 provides further evidence that the impact of US patent protection on foreign subsidiary sales grows more positive as the country-level quality of IPR protection, property rights protection, judicial independence, and political transparency increase.\(^{62}\) Specifically, it displays the 2SLS estimates that I derive by running the double-IV regression specification outlined in equation (18) in section 5. To interpret the coefficients in column (3) of table 8 as an example, I find that in a country with a high judicial independence score of 6, an additional US patent increases subsidiary sales by \(-2.418 + 0.760 \times 6 = \$2.142\) million on average. However, in a country with a low judicial independence score of 1, an additional US patent decreases subsidiary sales by \$1.658\) million. Lastly, the magnitude of the coefficients on the interaction term in table 8 appear considerably larger than those in table 7. I again attribute this to my IV/2SLS regression specifications’ focus on patent-holding parent companies.

6.4 Firm-Level Sorting

To conclude this section, I evaluate the extent to which firm-level sorting might influence my across-country subsidiary-level results. From Table 1 in section 4.1, I have shown suggestive evidence that firms with reported foreign sales tend to have higher global sales on average than firms which report US sales. This fact appears to corroborate Melitz (2003)’s conjecture that more productive firms are more likely to enter foreign markets. Similarly, to consider how firm-level characteristics vary over different countries in my subsidiary-level data, I split observations in my subsidiary-level data into “high-IPR” and “low-IPR” observations. High-IPR observations come from subsidiaries located in countries with an World Bank-assigned IPR quality score over 5, while low-IPR observations come from subsidiaries located in countries with IPR quality scores under 5. I chose the cutoff of 5 after observing the bimodal

\(^{62}\)I note that the interaction term coefficient estimates in Table 8 are generally less statistically significant than the ones in Table 7, although they are generally larger than in Table 7.
distribution of IPR score in my data, as shown in figure 8a. In addition, figure 8b shows which countries are classified as high-IPR vs. low-IPR in 2018.

Figure 8: The Distribution of IPR Quality In the Subsidiary-Level Data

NOTE: All observations which fall to the right of the red line in figure 8a (on left) are classified as “high-IPR”, whereas all observations which fall to the left of the red line are classified as “low-IPR”. In figure 8b (on right), countries which classify as “high-IPR” in 2018 are shaded in dark blue, while countries classified as “low-IPR” in 2018 are shaded in lighter blue. Countries without a recorded IPR score in 2018 are left unshaded.

After constructing the high vs. low-IPR threshold, I consider the summary statistics of firms that operate in high-IPR and low-IPR markets respectively. Table 9 details various characteristics of firms that operate in high and low-IPR countries, including consolidated company revenue, total global subsidiary revenue, and US patent count.\textsuperscript{63} I find suggestive evidence that firms which maintain subsidiary operations in low-IPR markets appear to have higher sales and more US patents than firms which operate in high-IPR markets on average. Furthermore, since the summary statistics show that most firms operating in low-IPR markets also operate in high-IPR markets, they may also suggest that larger and more innovative firms tend to maintain subsidiaries in both high and low-IPR markets, whereas relatively smaller and less innovative firms are more likely to maintain subsidiaries only in high-IPR markets.

\textsuperscript{63}I only consider how firm-level characteristics vary across firms operating in high vs. low IPR countries. Due to data limitations, I cannot compare firms that maintain overseas subsidiary operations with firms that do not.
### Table 9: Firm-Level Characteristics of Entrants and Non-Entrants in High and Low-IPR markets: Subsample Means

<table>
<thead>
<tr>
<th>Market Type: High-IPR:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent Company Sales</td>
<td>6,613</td>
<td>9,605</td>
<td>7,627</td>
<td>11,369</td>
</tr>
<tr>
<td>US Patent Count</td>
<td>108.3</td>
<td>222.8</td>
<td>155.0</td>
<td>281.4</td>
</tr>
<tr>
<td>Total Subsidiary Sales</td>
<td>260.2</td>
<td>6,500</td>
<td>320.2</td>
<td>12,733</td>
</tr>
<tr>
<td>Entry (Other)</td>
<td>1</td>
<td>0.391</td>
<td>1</td>
<td>0.786</td>
</tr>
</tbody>
</table>

NOTES: Columns (1)-(4) report subsample means of parent company sales, US patents, and total global subsidiary sales for four different types of firms. Column (1) considers firms without subsidiaries in high-IPR markets, while column (2) considers firms with subsidiaries in high-IPR markets. Likewise, column (3) considers firms without subsidiaries in low-IPR markets, while column (4) considers firms with subsidiaries in low-IPR markets. Parent company and subsidiary sales are measured in $ millions. Finally, the “Entry” variable represents the fraction of companies within a subsample that are considered entrants in the other type of IPR market. For example, column (2) tells us that about 39.1% of firms with subsidiaries in high-IPR countries in the overall sample also maintain subsidiaries in low-IPR countries. Lastly, since I include all partially-owned subsidiaries in my calculations for total subsidiary sales, total subsidiary sales are often higher than the sales at the parent company level.

Lastly, I confirm the suggestive evidence from table 9’s summary statistics by running fixed effect regressions of the following form:

\[
P_{ith} = \beta_0 + \beta_1 PATENTS_{it} + \delta Z_{it} + \gamma_{jt} + \epsilon_{it} \quad (22)
\]

\[
P_{idt} = \beta_0 + \beta_1 PATENTS_{it} + \delta Z_{it} + \gamma_{jt} + \epsilon_{it} \quad (23)
\]

All right hand side variables in both equations above are defined in the same manner as in equation (11) from section 5. On the left hand side, \( P_{ith} \) represents the probability that firm \( i \) maintains subsidiary operations in any high-IPR country in year \( t \). Likewise, \( P_{idt} \) represents the probability that firm \( i \) maintains subsidiary operations in any low-IPR country in year \( t \). Table 10 details the regression results.
probability of operating a subsidiary in any high-IPR country. In addition, firms with
an additional US patent on average see a 0.00163 percentage point increase in their
probability of operating a subsidiary in any low-IPR country. However, the statistical
significance of these results is not robust to including firm fixed effects, nor is it ro-
bust in a 2SLS framework. Thus, while the results support Melitz (2003)’s claim that
more productive and efficient are more likely to operate abroad with these results, I
am unable to conclude that additional US patent protection induces firm-level entry
into foreign markets. Thus, it is likely that the positive impact of US patents on sales
found in section 6.1-6.3 are driven primarily by within-firm adjustments to US patent
protection, as opposed to firm-level sorting into foreign markets.

<table>
<thead>
<tr>
<th>IPR Quality:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method:</td>
<td>FE</td>
<td>FE</td>
<td>FE</td>
<td>FE</td>
<td>2SLS</td>
<td>2SLS</td>
</tr>
<tr>
<td>US Patents</td>
<td>6.52e-06**</td>
<td>1.63e-05**</td>
<td>3.84e-06</td>
<td>-3.47e-06</td>
<td>7.86e-05</td>
<td>9.79e-05</td>
</tr>
</tbody>
</table>
| Robust standard errors in parentheses
| *** p<0.01, ** p<0.05, * p<0.1 |

NOTES: Columns (1) and (2) represent coefficient estimates derived from equations
(22) and (23) above. Columns (3) and (4) add firm fixed effects to the specifications in
columns (1) and (2) respectively, while columns (5) and (6) present 2SLS versions of
the estimates in columns (1) and (2) using patent examiner leniency as an instrument.

7 Discussion

The previous section’s empirical results find that US patent protection increases
a firm’s aggregate sales in US, foreign, and overall global markets. Furthermore, the
results show that firm-level US patent protection increases a US subsidiary’s sales. However, the impact of US patent protection on a foreign subsidiary’s sales appears to depend on the quality of IPR protection and related variables which vary across a subsidiary’s country-level location. This section proposes potential theoretical mechanisms which might justify these rather nuanced empirical results. I first reconcile the empirical results with the theoretical model presented in section 3. After assuming that subsidiary sales serve as a decent proxy for the value of a firm’s local production within countries, I find the theoretical model to be mostly consistent with the paper’s empirical results. In contrast, alternative theoretical mechanisms that I consider, including foreign patent protection and economies of scale, only back up certain portions of my empirical results.

7.1 From Theory to Empirics

I first consider the extent to which this paper’s theoretical model might justify its empirical results. To begin, this paper’s empirical findings corroborate the model’s conjectures that domestic patent protection increases a firm’s domestic and foreign aggregate sales. As the regression results in section 6.1 suggest, an increase in US patents raises firm-level aggregate sales within both the United States and various foreign countries. Furthermore, the empirical findings largely support the theoretical conjecture that domestic patent protection will raise domestic sales by a relatively larger magnitude than foreign sales. For the most part, in the 2SLS specifications of section 6.1, the impact of US patent protection on US sales appears relatively larger than the impact of US patent protection on sales in various foreign countries. Nonetheless, I cannot determine the exact extent to which a decrease in competitor entry or imitation likelihood might be responsible for the paper’s empirical results. Specifically, since I am unable to observe all global competitors for the firms in my sample, I cannot empirically determine the extent to which a firm’s US patents de-
increases its competitors’ presence in foreign markets. Furthermore, since the composition of firms’ R&D operations remains largely classified, it is difficult to ascertain whether domestic patents decrease the likelihood of competitor imitation globally. Accordingly, in section 7.2, I discuss alternative theoretical mechanisms which could also potentially explain the paper’s empirical results concerning aggregate sales.

The paper’s empirical results also corroborate the model’s conjectures on the relationship between domestic patents and a firm’s location of production. To begin, I empirically find that additional firm-level US patents increase US subsidiary sales, while their impact on foreign subsidiary sales is ambiguous on the whole. If one views subsidiary sales as a proxy for sales derived from local production, these empirical findings are consistent with my theoretical claims. Specifically, the model in section 3 predicts that US patent protection will increase domestic production by (i) raising aggregate global sales and (ii) increasing the relative profitability of domestic production. Through a combination of the results presented in sections 6.1 and 6.2, my findings suggest that US patent protection increases sales from US production via the first mechanism, an increase in aggregate US sales.\footnote{To reiterate, I define aggregate US sales as the total sales values of goods sold in the US. I define sales derived from US production as the total sales values of goods produced in the US.}

In addition, to address the second mechanism, my findings also suggest that US patent protection incites a reallocation of production away from foreign countries into the US. In fact, the results presented in section 6.3 suggest that such reallocation might be a primary factor which explains the across-country heterogeneity in the impact of US patents on foreign subsidiary sales. Specifically, in sections 6.1 and 6.2, I find that aggregate sales in foreign markets increase in response to US patent protection, while sales of foreign subsidiaries only increase in certain countries with strong IPR protections. These findings may suggest that firms not only increase their aggregate foreign sales upon US patent protection, but also do so via a combination of increases in foreign production and domestically-produced exports. This is consistent
with my theoretical predictions that increased foreign profits from US patent protection works to boost foreign production, while the reallocation of foreign sales towards domestically-produced exports simultaneously works to reduce foreign production.

Thus, in my theoretical model, I posit that the impact of domestic patents on foreign production will depend on two factors: (i) the extent to which a domestic patent induces an increase in global sales/production and (ii) the extent to which a domestic patent incentivizes a reallocation of production into the domestic market. If the threat of imitation from foreign production is sufficiently high, it is more likely that the second effect will dominate, leading to a negative relationship between domestic patents and foreign production. In contrast, if the threat of imitation from foreign production is low, the first effect will likely dominate, resulting in a positive relationship between domestic patents and foreign production. Fitting my model’s conjectures, my empirical results in sections 6.2 and 6.3 find that the relationship between US patents and foreign subsidiary sales is more likely to be negative in countries with weak IPR protection. If one considers the quality of IPR protection, property rights, judicial independence, and political transparency to be reliable proxies for the probability of competitor imitation within a foreign country, these empirical results appear to corroborate my theoretical conjectures that a firm’s incentives to substitute domestically-produced exports for subsidiary-driven foreign production increase as the probability of imitation from foreign production increases. Thus, on the whole, the model presented in section 3 appears to provide plausible explanations for this paper’s empirical results.

7.2 Alternative Mechanisms

Although the theoretical model presented in section 3 appears to explain the paper’s empirical results decently well, I concede that other theoretical mechanisms could also play a role in explaining the paper’s empirical results. Thus, I discuss
the extent to which two other theoretical mechanisms could justify the empirical results. Overall, I find that these alternative explanations explain certain portions of my empirical results well, yet they do not appear as successful as my theoretical model in explaining all aspects of the results.

**Foreign Patent Protection**

One mechanism which could justify my empirical results lies in a firm’s acquisition of foreign patents. Specifically, if, upon receiving more US patents, firms are more likely to acquire additional patents in high-IPR foreign countries than in low-IPR countries, it could be that variation in foreign patent holdings might explain the across-country heterogeneity in the impact of US patents on foreign subsidiary sales. Specifically, by restricting imitation from sales and production in foreign markets, foreign patent protection increases a firm’s foreign sales through the same mechanisms by which a domestic patent increases domestic sales. Thus, domestic and foreign sales would both increase. Furthermore, since a foreign patent bars imitation from production in a foreign market, firms would be more likely to produce in high-IPR locations where they possess patent protection than in low-IPR locations. This in turn would explain the across-country heterogeneity in the relationship between US patents and foreign subsidiary sales.

Nevertheless, foreign patent protection cannot entirely explain why the impact of US patent protection on foreign subsidiary sales increases when country-level variables such as property rights quality, judicial independence, and political transparency increase. I admit that measures of IPR quality may be tightly correlated with these country-level variables. However, the impact of increases in these variables on the relationship between US patents and foreign subsidiary sales appears to largely persist even upon inclusion of country fixed effects. This may suggest that upon domestic patent protection, firms increase subsidiary/local production in markets with strong

65 These alternative theoretical mechanisms by no means represent an exhaustive list. I welcome any additional suggestions of theoretical mechanisms which could explain my results.
institutions, regardless of whether they acquire a foreign patent. Furthermore, although I cannot empirically test the extent to which my examiner leniency instrument correlates with the size of a firm’s foreign patent collection, prior literature including Farre-Mensa et al (2018) and Gaule (2018) find that a patent’s probability of success in a foreign office is uncorrelated with its examiner’s leniency in the United States. While the implications of this fact are not definite, it could suggest that a firm’s foreign patent holdings and the average examiner leniency for its US patents are uncorrelated. If this claim holds true, foreign patent acquisition fails to explain why my 2SLS regressions also find that US patents positively impact foreign subsidiary sales in certain countries, as well as a firm’s aggregate foreign sales in general.

**Decreasing Marginal Costs and Economies of Scale**

Another mechanism posits that US patent protection might increase foreign aggregate sales through economies of scale and decreasing marginal costs that are inseparable across different countries. That is, once a domestic patent increases a firm’s domestic profits and sales from a specific good via the enforcement of monopoly power, it likely induces an increase in the firm-level quantity sold of that good. Furthermore, assuming that the firm faces global economies of scale and globally decreasing marginal costs, domestic patent protection lowers the average variable cost and marginal cost to produce an additional unit of that good. With a lower marginal cost of production, the profits gained from selling an additional unit of the good abroad would likely increase. Thus, the patent would stimulate higher profits within the foreign market as well as the domestic market, and under certain demand assumptions it would likely increase domestic and foreign sales as well.

At first glance, economies of scale and decreasing marginal costs appear pretty consistent with the paper’s empirical findings. Indeed, economies of scale and decreas-

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66 This is due to a lack of data on foreign patents. Future work could empirically test this proposition by downloading global patent data from the European Patent Office’s PATSTAT database.

67 This could be justified via a learning-by-doing argument where marginal costs were inseparable across the domestic and foreign markets.
ing marginal costs could explain why US patent protection increases aggregate sales both within the US and across various foreign markets. However, economies of scale and decreasing marginal costs explain the paper’s empirical results on subsidiary-level sales less well. Specifically, while economies of scale and decreasing marginal costs would predict that US patent protection increases US subsidiary sales, they explain the heterogeneity in the impact of US patent protection on foreign subsidiary sales less well. If globally inseparable and decreasing marginal costs did in fact drive the rise in a firm’s global aggregate sales in response to US patent protection, one might realistically expect production to be increased mostly within the US market. However, this paper’s empirical analyses suggest that an increase in US patent protection not only increases US subsidiaries’ sales but also the sales of subsidiaries located in foreign countries with high IPR protection quality. Likewise, inseparable and decreasing marginal costs also offer no explanation for why US patent protection appears to decrease the sales of subsidiaries located in countries with low IPR protection quality.

8 Conclusion

This paper examines the theoretical and empirical relationship between US patent protection and firm’s international operations. First, in a theoretical model, the paper describes how domestic patent protection may raise both domestic and foreign profits and sales. According to the model, in the domestic market, a domestic patent increases sales by erecting legal barriers to entry for potential competitors. These legal barriers in turn allow a firm with the domestic patent to acquire monopoly market power within the domestic market, thus boosting its profits and sales. In contrast, while legal restrictions to market entry may not apply a foreign market, a domestic patent increases foreign market sales by decreasing the probability of competitor imitation and entry. Specifically, by restricting both imitative activity and entry in the
domestic market, domestic patent protection makes competitor entry into the foreign market less likely. This increases a firm’s foreign sales and profits.

In contrast, the model predicts a more nuanced relationship between domestic patents and the scale and spatial distribution of firm production. On the one hand, by increasing both foreign and domestic sales, a domestic patent increases the overall sales value of global production for a firm. On the other hand, by ensuring no competitor imitation or entry only within the domestic market, domestic patent protection increases a firm’s incentive to produce all of its goods sold both at home and abroad within the domestic market. In result, the model predicts that domestic patent protection will increase domestic production through both a profit expansion and reallocation effect. However, its net effect on foreign production is ambiguous, as the profit expansion effect and reallocation effect work in opposite directions abroad. Lastly, the relative magnitude of these two effects appears to be determined by two main factors: export costs and the probability of imitation from foreign production. When export costs are high and the probability of imitation from foreign production is low, the profit expansion effect dominates the reallocation effect. This would imply that domestic patent protection would increase sales derived from foreign production. In contrast, if imitation from foreign production is high, the reallocation effect dominates the profit expansion effect. In this scenario, domestic patent protection would decrease a firm’s sales derived from foreign production.

To assess the model’s theoretical conjectures, this paper empirically investigates the relationship between US patent protection and firms’ global, US, and foreign operations. Exploiting USPTO patent examiner leniency in an instrumental variables approach, I find that US patents increase a firm’s US, foreign, and global aggregate sales, as the model would predict. In addition, using subsidiary-level sales to proxy for the sales value of production from within a country, I find that US patents at the parent-company level increase the sales of US subsidiaries. However, the impact
of US patents on the sales of a company’s foreign subsidiaries proves ambiguous on the whole. Whereas US patents appear to increase foreign subsidiary sales in countries with strong IPR protection, the opposite appears true in countries where IPR protection is weak. Although the discrepancy in the empirical results on aggregate sales and subsidiary sales may at first appear nuanced, the paper’s theoretical model appears to explain both the aggregate sales and subsidiary sales results fairly well.

Future research can build off this paper’s work in various ways. First, to more directly link this paper with Hall and Helmers (2019), future work could examine the effect of local patent protection on firms’ international operations using patents from another non-USPTO patent office. Since the USPTO currently serves the world’s largest consumer market, analysis of the impact of patent protection in small markets on firms’ within-country and cross border sales would add to the external validity of this paper’s causal estimates on the international spillovers of local patenting. Although information on examiners in foreign patent offices may not be available if one wishes to employ a similar 2SLS identification strategy, abundant data on global patents enforced by non-US offices is readily available through the European Patent Office’s PATSTAT database. This at least makes fixed effect analyses feasible.

Second, this paper’s subsidiary-level analyses only consider first-level subsidiaries of parent companies. Nonetheless, given Bureau Van Dijk’s data on firm ownership linkages, one could plausibly extend this paper’s analyses “down” the ownership chain to examine the impact of parent company patent protection on lower-level subsidiary operations and performance. Third, one could examine the impact of competitor patent protection on a firm’s global sales and performance. Variables identifying a given company’s “peer group” in Bureau Van Dijk and Compustat could make such an analysis feasible. Lastly, and perhaps most ambitiously, one can attempt to understand additional global welfare implications of local patent protection. For example, one could investigate how local patent protection might affect both the global scope
and regional distribution of firm-level innovation. These extensions represent only a few of the many directions in which my work can be extended. Further extensions of this paper’s work are left to future research.

Understanding how multinationals globally respond to the ever-changing heterogeneous landscape of IPR protection across countries has long been a critical question for both economists and policymakers alike. Furthermore, as tensions over the role of firm-driven international technology transfer lie at the center of various current trade disputes, addressing such a question has only increased in importance. Currently, multinationals serve as critical agents of both innovation and international trade, two phenomena that are perhaps most responsible for the substantial rise in global economic development and welfare in the past 75 years. Despite the benefits that firm-driven trade and innovation bring, recent protectionist headwinds threaten the continued vitality of both phenomena.

However, alongside the rather counterproductive calls for protectionism, new proposals for increased domestic policy harmonization on the regional and global levels could help to improve the system governing multinational activity in international trade and innovation. By analyzing how across-country heterogeneity in patent protection and other domestic policies might alter the scale and distribution of firms’ international operations, economists might be able to better determine the channels through which domestic policy harmonization might enhance global welfare. With more harmonized policies to govern trade, investment, and technology transfer, firms’ foreign operations may no longer fall victim to “the greatest intellectual property theft in human history”. Instead, they may continue to ensure that the global diffusion of trade and technology continues to occur.
9 Appendix

9.1 Appendix A: Additional Theory

In this subsection, I mathematically formalize the major theoretical claims and assumptions made in section 3. I proceed to provide a brief proofs of each proposition that I make. I begin with the theoretical claims made in section 3.1.

ASSUMPTIONS AND PROPOSITIONS IN THE ONE MARKET CASE

ASSUMPTION 1: Product $g$ does not act as a substitute or complement to any other product sold by firm $i$. Given price $p_h$ for any good $h \in G$, where $G$ is the set of firm $i$’s goods, this statement can be mathematically expressed as follows:

$$\frac{\partial p_h}{\partial p_g} = 0, \forall h \in G, h \neq g$$

This assumption allows us to effectively restrict firm $i$’s total profit maximization problem into a profit maximization problem exclusively on its new product $g$. Nonetheless, I admit that it is a rather large assumption.

PROPOSITION 1: Conditional upon successful imitation, the probability of firm $j$’s market entry from firm $i$’s perspective is given by

$$\lambda = \Pr(F_j < \frac{1}{2}\pi_d^M).$$

Proof. Conditional upon its successful imitation of product $g$ from firm $i$ (which occurs with probability $\psi$), firm $j$ will receive the following total expected profits if it enters the market for good $g$:

$$E[\Pi_j | ENTRY_j] = \frac{1}{2}\pi_d^M - F_j = \frac{1}{2}(p_d^* - c_d)D_d(p_d^*) - F_j$$

Assuming that it is risk neutral, firm $j$ enters if and only if its total expected profits upon entry are greater than 0. Mathematically, the condition states the following:

$$E[\Pi_j | ENTRY_j] = \frac{1}{2}\pi_d^M - F_j > 0 \implies F_j < \frac{1}{2}\pi_d^M$$

Lastly, firm $i$ regards $F_j$ as a random variable, and it knows that firm $j$ will enter the market if and only if the condition above is met. Thus, I can define $\lambda$, the probability that firm $j$ enters the market conditional upon successful imitation from firm $i$’s perspective, as follows:

$$\lambda = Pr(F_j < \frac{1}{2}\pi_d^M)$$
PROPOSITION 2: Assume that \( F_p = 0 \). Then, borrowing the terms from equations (2) and (3) in section 3, it follows that \( E[\Pi_i|\text{PATENT}] \geq E[\Pi_i|\text{NOPATENT}] \).

Proof. Referring to the expressions in equations (2) or (3) from section 3 and plugging in 0 for \( F_p \), I know firm \( i \)'s expected profits with and without patent protection:

\[
E[\Pi_i|\text{PATENT}] = \pi_d^M - F_i - F_p = \pi_d^M - F_i
\]

\[
E[\Pi_i|\text{NOPATENT}] = (1 - \lambda \psi)\pi_d^M + \lambda \psi \left( \frac{1}{2} \pi_d^M \right) - F_i = (1 - \frac{1}{2} \lambda \psi)\pi_d^M - F_i
\]

Since \( \lambda, \psi \in [0, 1] \) by definition, it follows that \( 1 - \frac{1}{2} \lambda \psi \leq 1 \). The proposition that \( E[\Pi_i|\text{PATENT}] \geq E[\Pi_i|\text{NOPATENT}] \) directly follows. \( \square \)

PROPOSITION 3: Assuming that firm \( j \) can split monopoly profits in the market for good \( g \) with firm \( i \) upon entry, patent protection in market \( d \) will raise firm \( i \)'s expected firm-level sales of product \( g \).

Proof. Without loss of generality, I assume that firm \( i \) finds it profitable to enter the market for good \( g \) even without patent protection.\( ^{68} \) For firm \( i \) to choose to patent good \( g \), the condition that \( E[\Pi_i|\text{PATENT}] \geq E[\Pi_i|\text{NOPATENT}] \) must be true. Writing out the full mathematical expressions for \( E[\Pi_i|\text{PATENT}] \) and \( E[\Pi_i|\text{NOPATENT}] \), it follows that the following inequality must hold:

\[
\pi_d^M - F_i - F_p = (p_d^* - c_d)D_d(p_d^*) - F_i - F_p \geq (1 - \frac{1}{2} \lambda \psi)\pi_d^M - F_i = (1 - \frac{1}{2} \lambda \psi)\pi_d^M - F_i
\]

Since firm \( j \) splits monopoly profits with firm \( i \) conditional upon its entry, it follows that the market price and market quantity demanded remain at the optimal monopoly level when both firms enter into the market for good \( g \). Thus, I proceed to rearrange the equation above as follows:

\[
p_d^*D_d(p_d^*) - c_dD_d(p_d^*) - F_i - F_p \geq (1 - \frac{1}{2} \lambda \psi)p_d^*D_d(p_d^*) - (1 - \frac{1}{2} \lambda \psi)c_dD_d(p_d^*) - F_i
\]

\[
p_d^*D_d(p_d^*) \geq (1 - \frac{1}{2} \lambda \psi)p_d^*D_d(p_d^*) + \frac{1}{2} \lambda \psi c_dD_d(p_d^*) + F_p
\]

Lastly, I note that \( p_d^*D_d(p_d^*) \) represents firm \( i \)'s expected sales of product \( g \) with patent protection (i.e. when it has a legally-enforced monopoly on product \( g \)), while \( (1 - \frac{1}{2} \lambda \psi)p_d^*D_d(p_d^*) \) represents firm \( i \)'s expected sales of product \( g \) without patent protection. Marginal cost \( c_d \), fixed patenting cost \( F_p \), \( \lambda \), \( \psi \), and optimal monopoly quantity demanded \( D_d(p_d^*) \) are all by definition positive, so it follows that \( \frac{1}{2} \lambda \psi c_dD_d(p_d^*) + F_p \) is positive. The proposition directly follows. \( \square \)

\(^{68}\)If this were not the case, patent protection would increase firm \( i \)'s sales from 0 to some weakly positive figure.
ASSUMPTIONS AND PROPOSITIONS IN THE TWO MARKET CASE

PROPOSITION 4: Assume $F_p = 0$. Then domestic patent protection will raise firm $i$’s profits from both domestic and foreign sales of product $g$. Furthermore, the relative increase in domestic profits that results from patent protection will be larger than the relative increase in foreign profits.

**Proof.** Equations (5) and (7) in section 3.2 provide expressions for firm $i$’s expected global profits with and without domestic patent protection. I begin by showing that $\rho \geq \psi_f$, where $\rho = 1 - (1 - \psi_d)(1 - \psi_f)$ (as defined in equation (7) in section 3.2).

Rearranging, I find the following inequality:

$$\rho = 1 - (1 - \psi_d)(1 - \psi_f) = 1 - (1 - \psi_f - \psi_d \psi_f) = \psi_f + \psi_d - \psi_d \psi_f \geq \psi_f$$

I know that the rightmost inequality holds since $\psi_f, \psi_d \in [0, 1]$ implies that $\psi_d - \psi_d \psi_f \geq 0$. Thus, $\rho \geq \psi_f$.

Next, I consider how acquisition of a domestic patent by firm $i$ alters firm $j$’s expected profits and market entry decision upon successful imitation of product $g$. I consider firm $j$’s expected profits (i) when firm $i$ acquires domestic patent protection and (ii) when firm $i$ does not below:

$$E[\Pi_j|ENTRY_j, PATENT_i] = \frac{1}{2} \pi_d^M - F_j$$

$$E[\Pi_j|ENTRY_j, NOPATENT_i] = \frac{1}{2} \pi_d^M + \frac{1}{2} \pi_f^M - F_j$$

The $\pi_d^M$ term does not enter expected profits when firm $i$ acquires domestic patent protection because the patent bars firm $j$ from selling its imitated good into the domestic market. Firm $j$ will only choose to enter the global market for product $g$ if its expected profits are positive. Thus, for any given random variable $F_j$ whose value is known to firm $j$ but not firm $i$, from firm $i$’s perspective the following must be true:

$$Pr(F_j < \frac{1}{2} \pi_f^M) \leq Pr(F_j < \frac{1}{2} \pi_d^M + \frac{1}{2} \pi_f^M)$$

In section 3.2, I define $\lambda'$ to equal the right hand side expression, while I define $\lambda$ to equal the left hand side expression. Thus, $\lambda' > \lambda$.

I proceed to rearrange the expressions for expected profits in equations (5) and (7) so that each contains a “domestic” profit and “foreign” profit component:

$$E[\Pi_i|PATENT] = \pi_d^M + (1 - \frac{1}{2} \lambda \psi_f) \pi_f^M - F_i$$

$$E[\Pi_i|NOPATENT] = (1 - \frac{1}{2} \lambda' \rho) \pi_d^M + (1 - \frac{1}{2} \lambda' \rho) \pi_f^M - F_i$$

First, since $\lambda', \rho < 1$, I immediately note that profits from domestic sales will increase from $(1 - \frac{1}{2} \lambda' \rho) \pi_d^M$ to $\pi_d^M > (1 - \frac{1}{2} \lambda' \rho) \pi_d^M$ upon acquisition of domestic patent pro-
tection. Furthermore, since \( \lambda' > \lambda \) and \( \rho > \psi_f \), I also note that profits from foreign sales will increase from \((1 - \frac{1}{2}\lambda'\rho)\pi^M_f\) to \((1 - \frac{1}{2}\lambda\psi_f)\pi^M_f > (1 - \frac{1}{2}\lambda'\rho)\pi^M_f\) upon domestic patent acquisition. The first claim in proposition 4 directly follows.

Lastly, I consider the magnitudes of the relative change in firm \( i \)'s domestic vs. foreign profits upon domestic patent acquisition. The relative change in firm \( i \)'s domestic profits can be summarized as \( \frac{1 - \frac{1}{2}\lambda\psi_f}{1 - \frac{1}{2}\lambda'\rho} \). Likewise, the relative change in firm \( i \)'s foreign profits can be summarized as \( \frac{1 - \frac{1}{2}\lambda\psi_f}{1 - \frac{1}{2}\lambda'\rho} \). Since \( \lambda, \psi_f \leq 1 \), I deduce that the following inequality holds:

\[
\frac{1}{1 - \frac{1}{2}\lambda'\rho} \geq \frac{1 - \frac{1}{2}\lambda\psi_f}{1 - \frac{1}{2}\lambda'\rho}
\]

The second conjecture of proposition 4 directly follows.

**PROPOSITION 5:** If firm \( j \) could split monopoly profits for product \( g \) with firm \( i \) in both markets upon entry, domestic patent acquisition would raise both domestic and foreign sales.

**Proof.** The structure of the argument follows a similar logic from our proof of proposition 3, except that terms containing \( \pi^M_i \) are also included. For firm \( i \) to choose to patent good \( g \), it follows that \( E[\Pi_i|\text{PATENT}] \geq E[\Pi_i|\text{NOPATENT}] \) must be true. Writing out the full mathematical expressions for \( E[\Pi_i|\text{PATENT}] \) and \( E[\Pi_i|\text{NOPATENT}] \), the following inequality must hold:

\[
\pi^M_d + (1 - \frac{1}{2}\lambda\psi_f)\pi^M_f - F_i - F_p \geq (1 - \frac{1}{2}\lambda'\rho)\pi^M_d + (1 - \frac{1}{2}\lambda'\rho)\pi^M_f - F_i
\]

Writing out the full expressions for \( \pi^M_d \) and \( \pi^M_f \) and rearranging terms, the above equation becomes the following equation below:

\[
p^*_d D_d(p^*_d) - c^*_d D_d(p^*_d) + (1 - \frac{1}{2}\lambda\psi_f)p^*_f D_f(p^*_f) - (1 - \frac{1}{2}\lambda\psi_f)c_d D_f(p^*_f) \geq (1 - \frac{1}{2}\lambda'\rho)p^*_d D_d(p^*_d) - (1 - \frac{1}{2}\lambda'\rho)c_d D_d(p^*_d) \\
+ (1 - \frac{1}{2}\lambda'\rho)p^*_f D_f(p^*_f) - (1 - \frac{1}{2}\lambda'\rho)c_d D_f(p^*_f) + F_p
\]

\[
\Rightarrow p^*_d D_d(p^*_d) + (1 - \frac{1}{2}\lambda\psi_f)p^*_f D_f(p^*_f) \geq (1 - \frac{1}{2}\lambda'\rho)p^*_d D_d(p^*_d) + (1 - \frac{1}{2}\lambda'\rho)p^*_f D_f(p^*_f) \\
+ (1 - \frac{1}{2}\lambda'\rho)c_d D_d(p^*_d) + (1 - \frac{1}{2}\lambda\psi_f)c_d D_f(p^*_f) + F_p
\]

\[\text{As in section 3.2, I assume that production occurs in the domestic market at constant marginal cost } c_d.\]
I note that \( p_i^e D_d(p_i^e) + (1 - \frac{1}{2}\lambda\psi_f)p_i^f D_f(p_i^f) \) represents firm \( i \)'s expected global sales with domestic patent protection while \((1 - \frac{1}{2}\lambda')p_d^e D_d(p_d^e) + (1 - \frac{1}{2}\lambda')p_f^e D_f(p_f^e)\) represents firm \( i \)'s expected global sales without domestic patent protection. Since \((\frac{1}{2}\lambda')c_d D_d(p_d^e)\) and \((1 - \frac{1}{2}\lambda')c_d D_d(p_d^e)\) are both by definition positive, it follows that domestic patent protection increases firm \( i \)'s expected global sales in the two-market case.

Lastly, in proposition 4 I proved that domestic patent protection increases expected domestic and foreign market profits. That is, I proved that \( \pi^M_i \geq (1 - \frac{1}{2}\lambda'\rho)\pi^M_i \) and \( (1 - \frac{1}{2}\lambda'\rho)\pi^M_i \geq (1 - \frac{1}{2}\lambda'\rho)\pi^M_i \). Writing out the full mathematical expressions for \( \pi^M_i \) and \( \pi^M_i \) and rearranging terms gives us the following inequalities:

\[
p_i^e D_d(p_i^e) \geq (1 - \frac{1}{2}\lambda'\rho)p_i^e D_d(p_i^e) + (1 - \frac{1}{2}\lambda'\rho)c_d D_d(p_d^e)
\]
\[
(1 - \frac{1}{2}\lambda')p_f^e D_f(p_f^e) \geq (1 - \frac{1}{2}\lambda'\rho)p_f^e D_f(p_f^e) + (1 - \frac{1}{2}\lambda'\rho)c_d D_f(p_f^e)
\]

The left hand side terms in the inequalities above represent firm \( i \)'s expected domestic and foreign sales with domestic patent protection respectively, while the first terms on the right hand side in the inequalities above represent firm \( i \)'s expected sales without domestic patent protection. Again, since \( (\frac{1}{2}\lambda'\rho)c_d D_d(p_d^e)\) and \( (1 - \frac{1}{2}\lambda'\rho)c_d D_f(p_f^e)\) are both by definition positive, it follows that domestic patent protection increases both domestic and foreign sales for firm \( i \). The proposition follows.

\[\square\]

**PROPOSITION 6**: Assume that \( \phi_d = \phi_f \). Then domestic patent protection will increase firm \( i \)'s profits from product \( g \) regardless of where firm \( i \) chooses to locate production of \( g \). However, domestic patent protection may also incentivize firm \( i \) to reallocate production of good \( g \) into the domestic market.

**Proof.** Without loss of generality, I cover the case where firm \( i \) sells \( g \) in both markets. I begin by defining the following terms not directly mentioned in section 3.3:

\[
\pi^M_{dd} = (p_{dd}^* - c_d)D_d(p_{dd}^*);
\pi^M_{df} = (p_{df}^* - c_f)D_d(p_{df}^*);
\pi^M_{fd} = (p_{fd}^* - c_d)D_f(p_{fd}^*);
\pi^M_{ff} = (p_{ff}^* - c_f)D_f(p_{ff}^*)
\]

To define one of these terms as an example, \( \pi_{df} \) represents the optimal monopoly profits that can be earned on units of good \( g \) sold in the domestic market \( d \), if one produces these units in the foreign market \( f \). The other terms can be defined analogously.

I proceed to consider a firm’s expected profits without a domestic product under three different scenarios (described in section 3.3): (i) exclusive domestic production, (ii) ex-

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70 This is because \( \rho > \psi_f \) and \( \lambda' > \lambda \), as proven in proposition 4.
71 These two parameters are defined in section 3.3 as the probabilities of competitor imitation from domestic and foreign production respectively.
exclusive foreign production, and (iii) local production.\textsuperscript{72} I define $E[\Pi_i^d|\text{NOPATENT}]$ as firm $i$’s expected profits without patent protection under scenario (i), $E[\Pi_i^f|\text{NOPATENT}]$ as firm $i$’s expected profits without patent protection under scenario (ii), and $E[\Pi_i^l|\text{NOPATENT}]$ as firm $i$’s expected profits without patent protection under scenario (iii). Expressions for these three terms are given below:

$$E[\Pi_i^d|\text{NOPATENT}] = (1 - \frac{1}{2}\lambda^*\rho_d)\pi_{dd}^M + (1 - \frac{1}{2}\lambda^*\rho_d)\pi_{fd}^M - E$$

$$E[\Pi_i^f|\text{NOPATENT}] = (1 - \frac{1}{2}\lambda^*\rho_f)\pi_{ff}^M + (1 - \frac{1}{2}\lambda^*\rho_f)\pi_{df}^M - E$$

$$E[\Pi_i^l|\text{NOPATENT}] = (1 - \frac{1}{2}\lambda^*\rho_l)\pi_{dd}^M + (1 - \frac{1}{2}\lambda^*\rho_l)\pi_{lf}^M$$

I now define the terms that are newly introduced above. $E$ is the fixed export cost associated with selling good $g$ not in the market where it was produced. $\rho_d = 1 - (1 - \psi_d)(1 - \psi_f)(1 - \phi_d)$ intuitively represents the probability that the competitor $j$ successfully imitates firm $i$ if firm $i$ produces good $g$ exclusively in the domestic market without domestic patent protection. Likewise, $\rho_f = 1 - (1 - \psi_d)(1 - \psi_f)(1 - \phi_f)$ intuitively represents the probability that the competitor $j$ successfully imitates firm $i$ if firm $i$ produces good $g$ exclusively in the foreign market without domestic patent protection.\textsuperscript{73} In addition, $\rho_l = 1 - (1 - \psi_d)(1 - \psi_f)(1 - \phi_d)(1 - \phi_f)$ intuitively represents the probability that the competitor $j$ successfully imitates firm $i$ if firm $i$ produces good $g$ in the local market in which $g$ is sold without patent protection.\textsuperscript{74} Lastly, $\lambda^* = Pr(F_j \leq \max[\frac{1}{2}(\pi_{dd}^M + \pi_{fd}^M) - E, \frac{1}{2}(\pi_{ff}^M + \pi_{df}^M) - E, \frac{1}{2}(\pi_{dd}^M + \pi_{lf}^M)])$ intuitively represents the probability of competitor $j$’s entry into the global market for good $g$, conditional on its successful imitation of firm $i$.

I proceed to consider how domestic patent protection alters a firm’s expected profits in each of the three scenarios described above. Specifically, I express a firm’s expected profits under (i) domestic production, (ii) foreign production, and (iii) local production with domestic patent protection in the equations below:

$$E[\Pi_i^d|\text{PATENT}] = \pi_{dd}^M + (1 - \frac{1}{2}\lambda^{**}\rho_d')\pi_{fd}^M - E$$

$$E[\Pi_i^f|\text{PATENT}] = (1 - \frac{1}{2}\lambda^{**}\rho_f')\pi_{ff}^M + \pi_{df}^M - E$$

$$E[\Pi_i^l|\text{PATENT}] = \pi_{dd}^M + (1 - \frac{1}{2}\lambda^{**}\rho_l')\pi_{df}^M$$

In the equations above, $\lambda^{**} = Pr(F_j \leq \max[\frac{1}{2}\pi_{ff}^M, \frac{1}{2}\pi_{df}^M - E])$ intuitively represents the probability that competitor $j$ will enter the global market for good $g$ upon successful imitation of firm $i$. $\rho_d' = 1 - (1 - \psi_f) = \psi_f$ represents the probability that competitor

\textsuperscript{72}The fourth option of exclusively foreign production is not viable, as at least one of the three options listed will provide firm $i$ with more profits without patent protection.

\textsuperscript{73}\psi_d, \psi_f, \phi_f, and \phi_d are all defined in section 3.3.

\textsuperscript{74}I assume that the probabilities of imitation from foreign and domestic production are independent.
j imitates firm $i$ when firm $i$ chooses to produce good $g$ domestically. $\rho_f = 1 - (1 - \psi_f)(1 - \phi_f)$ represents the probability that competitor $j$ imitates firm $i$ when firm $i$ chooses to produce good $g$ abroad. Lastly, $\rho'_i = 1 - (1 - \psi'_f)(1 - \phi'_f) = \rho_f'$ represents the probability that competitor $j$ imitates firm $i$ when firm $i$ produces good $g$ locally.

I now note that the following inequalities are true: $\lambda^{**} \leq \lambda^*$, $\rho'_d \leq \rho_d$, $\rho'_f \leq \rho_f$, and $\rho'_i \leq \rho_i$. From these inequalities, it follows that the domestic patent protection increases firm $i$’s expected profits regardless of where it chooses to locate production of good $g$. That is,

$$E[\Pi_d^M|\text{PATENT}] \geq E[\Pi_d^M|\text{NOPATENT}]$$

$$E[\Pi_f^M|\text{PATENT}] \geq E[\Pi_f^M|\text{NOPATENT}]$$

$$E[\Pi_i^M|\text{PATENT}] \geq E[\Pi_i^M|\text{NOPATENT}]$$

The fact that firm $i$’s expected profits increase in response to domestic patent protection irrespective of whether firm $i$ produces domestically, abroad, or locally is what I term the profit expansion effect of domestic patent protection. That is, by increasing aggregate global profits, domestic patent protection increases the profitability of global production regardless of where it is located. Thus, this effect works to increase profits from both domestic and foreign production. The first part of the proposition accordingly follows.

Next, I employ the assumption that $\phi_d = \phi_f$. With this assumption, I show that the following inequalities hold:

$$\rho'_i - \rho'_d \geq \rho_i - \rho_d \implies \rho_d - \rho'_d \geq \rho_i - \rho'_i$$

$$\rho'_f - \rho'_d \geq \rho_f - \rho_d \implies \rho_d - \rho'_d \geq \rho_f - \rho'_f$$

$$\rho'_f - \rho'_i \geq \rho_f - \rho_i \implies \rho_i - \rho'_i \geq \rho_f - \rho'_f$$

In the upper equation, assuming that $\phi_d = \phi_f = \phi$, I note that $\rho'_i - \rho'_d = 1 - (1 - \psi_f)(1 - \phi) - 11 + (1 - \psi_f) = \phi(1 - \psi_f) \geq \phi(1 - \psi_d)(1 - \phi) = 1 - (1 - \psi_d)(1 - \phi) = \rho_i - \rho_d$. Likewise, in the second equation I note that $\rho'_f - \rho'_d = 1 - (1 - \psi_f)(1 - \phi) - 11 + (1 - \psi_f) = \phi(1 - \psi_f) \geq 0 = \rho_f - \rho_d$.\footnote{\(\rho_f - \rho_d = 0\) if one uses the assumption that $\phi_d = \phi_f$.}

The bottom equation can be solved using similar methods.

Intuitively, the first inequality above states that the difference in the probabilities of imitation in the domestic vs. local production scenarios increases upon domestic patent protection. That is, domestic patent protection causes a larger decrease in the probability of competitor imitation when firm $i$ locates its production domestically as opposed to locally. The second inequality likewise implies that domestic patent protection causes a larger decrease in the probability of competitor imitation when firm $i$ locates its production domestically as opposed to abroad. Lastly, the third inequality implies that domestic patent protection causes a larger decrease in the probability of
competitor imitation when firm $i$ locates its production locally as opposed to abroad.

Since domestic patent protection decreases the probability of competitor imitation faced by firm $i$ the most when firm $i$ locates its production in the domestic market. Intuitively, this may incentivize firm $i$ to shift the production of its foreign-produced goods into the domestic market upon domestic patent protection. I term this phenomenon the *production reallocation* effect. Mathematically, the production reallocation effect can be summarized by the following inequalities:

$$Pr((1 - \frac{1}{2} \lambda^* \rho_d) \pi_{fd}^M - E \leq (1 - \frac{1}{2} \lambda^* \rho_f) \pi_{ff}^M) \geq Pr((1 - \frac{1}{2} \lambda^* \rho_d') \pi_{fd}^M - E \leq (1 - \frac{1}{2} \lambda^* \rho_f') \pi_{ff}^M)$$

$$Pr((1 - \frac{1}{2} \lambda^* \rho_d) \pi_{fd}^M - E \leq (1 - \frac{1}{2} \lambda^* \rho_d') \pi_{fd}^M - E \leq (1 - \frac{1}{2} \lambda^* \rho_f') \pi_{ff}^M)$$

Intuitively, these equations show that the probability that producing goods sold in foreign market within the foreign market is more profitable than producing such goods in the domestic market decreases with a domestic patent. Mechanically, this is because $\rho_d - \rho_d' \geq \rho_f - \rho_f'$ and $\rho_d - \rho_d' \geq \rho_f - \rho_f'$. This in turn implies that the coefficients on the $\pi_{fd}^M$ terms increase by more than the coefficients on the $\pi_{ff}^M$ terms when $\rho_d'$ replaces $\rho_d$, $\rho_f'$ replaces $\rho_f$, and $\rho_l'$ replaces $\rho_l$. Thus, the inequalities above hold.

Lastly, I reiterate that the inequalities above show that the profitability of producing goods sold in the foreign market within the foreign market increases by relatively more than the profitability of producing such goods within the foreign market. Thus, firm $i$ will become relatively more incentivized to substitute foreign production with domestically-produced exports upon acquisition of domestic patent protection. The second part of the proposition accordingly follows.

\[\square\]

\[76\] A more complete mathematical derivation of the inequalities is left to the reader.
9.2 Appendix B: Constructing the Leniency Instrument

In this section, I mathematically formalize (i) the construction of a patent-level “leave-one-out” examiner grant rate and (ii) the aggregation of this “leave-one-out” grant rate into this paper’s examiner leniency instrument. I also provide brief intuition on why these values can plausibly be considered as good as randomly assigned. Lastly, I provide a mathematical definition of the paper’s average patent approval time control variable.

PART I: Leave-One-Out Grant Rates At the Patent Level

I first consider an arbitrary USPTO patent examiner “e” who examines a finite number of patent applications, denoted by $P$. Accordingly, let $\{P\}$ represent the set of patent applications that examiner $e$ reviews. For any patent application $p \in \{P\}$, I calculate the corresponding “leave-one-out” grant rate as follows:

$$GRANTRATE_p = \frac{1}{P-1} \times \sum_{q \in \{P\}, q \neq p} I(q)$$

This definition borrows from previous work by Farre-Mensa et al (2018) and Sampat and Williams (2019). To analyze the equation above in more detail, $q \in \{P\}$ represents some patent application reviewed by examiner $e$ that is not patent application $p$. $I(q)$ is an indicator function that equals 1 when patent application $q$ is successful (i.e. results in a patent grant) and 0 when $q$ is not successful.

To obtain the total number of successful patent applications reviewed by examiner $e$, I sum $I(q)$ over all $q \in \{P\}$ where $q \neq p$, the patent application currently under review. Lastly, I divide this sum by $P - 1$, the total number of patent applications reviewed by examiner $e$ excluding patent application $p$. This defines patent application $p$’s corresponding examiner grant rate. Since the success of patent application $p$ does not factor into this leniency measure, one can be confident that this measure of examiner leniency is not biased by patent application $p$’s quality.
PART II: Aggregation to the Firm-Year Level: Average Leave-One-Out Grant Rates

To construct this paper’s instrumental variable, I first consider all patents held by an arbitrary firm $i$ in an arbitrary year $t$. Let $\{P_{it}\}$ denote such a set of patents, and let $P'_{it}$ represent the total number of elements (i.e. patents) in $\{P_{it}\}$. Each $p' \in \{P'_{it}\}$ has a corresponding examiner leave-one-out grant rate. Aggregating these leave-one-out grant rates into an average at the firm-year level provides this paper’s instrumental variable. It is defined as follows:

$$AVGGRANTRATE_{it} = \frac{1}{P'_{it}} \times \sum_{p' \in \{P'_{it}\}} GRANTRATE_{p'}$$

$GRANTRATE_{p'}$ is defined exactly as in part I of Appendix B. Thus, I obtain an unweighted average of patent examiner leniency across all patents held by firm $i$ in year $t$, $AVGGRANTRATE_{it}$. I use this variable as my main instrument in my empirical analyses.

PART III: Average Patent Approval Time

I now consider the average patent approval time control variable in my fixed effect and instrumental variable regressions. Any patent $p'$ held by firm $i$ in year $t$ possess (i) an application filing date $A_{p'}$ and patent grant date $G_{p'}$. I define the approval time of patent $p'$ as $G_{p'} - A_{p'}$. Accordingly, using $\{P_{it}\}$ and $P'_{it}$ defined in Appendix B part II, I define the average patent approval time control variable as follows:

$$AVGAPPROVALTIME_{it} = \frac{1}{P'_{it}} \times \sum_{p' \in \{P'_{it}\}} (G_{p'} - A_{p'})$$
9.3 Appendix C: Additional Figures

Figures 1a-1d: *Country-Level Distribution of Average IPR Quality, Property Rights Quality, Judicial Independence, and Political Favoritism during 2008-2018 Period*

![Figures 1a-1d](image)

NOTE: All metrics of average IPR quality, Property Rights quality, Judicial Independence, and Political Favoritism/Transparency are measured on a 1-7 scale using survey data from the World Bank’s GovData360 database.

Figures 2a-2d: *Average IPR Quality, Property Rights Quality, Judicial Independence, and Political Favoritism By Country from 2008 to 2018*

![Figures 2a-2d](image)
NOTE: All metrics of IPR Quality, Property Rights Quality, Judicial Independence, and Political Favoritism are measured on a 1-7 scale using data from the World Bank’s GovData360 database. Countries with higher quality IPR protection, higher quality property rights protection, more independent judiciaries, and less political favoritism over the 2008-2018 period are colored in darker shades of blue in all figures above.

Figures 3a-3b: The Relationship between Log(1+Patents) and Average Examiner Leniency in the Firm and Subsidiary-Level Data

NOTE: Figures 3a and 3b above mirror figures 6a and 6b in the paper, except that firm/parent-company level patent counts have been log-transformed. I add 1 before performing the log transformation so that firms with no patents are not dropped from the data in my fixed effect specifications.

Figure 4: The Impact of US Patents on Aggregate Sales in Various Foreign Countries

NOTE: This map is a spatial representation of the estimates presented in column (3) of Table 4 in section 6.1. Countries where the impact of US patent protection on aggregate sales is more positive/stronger are presented in darker shades of blue, while countries where the impact of US patent protection is weaker are presented in lighter shades of blue. I leave out the European and Taiwanese estimates from the map due to the supra/intra-national nature of both regions.
Figures 5: The Impact of US Patents on Subsidiary Sales in Various Foreign Countries

NOTE: This map is a spatial representation of the estimates presented in column (2) of Table 6 in section 6.2. Countries where the impact of parent company US patent protection on subsidiary sales is more positive/stronger are presented in darker shades of blue, while countries where the impact of US patent protection is weaker or more negative are presented in lighter shades of blue.

Figures 6a-6b: The Impact of US Patent Protection on Foreign Subsidiary Sales Across Different Country-Specific Levels of Judicial Independence and Political Transparency

NOTES: Figure 6a on the left shows how the impact of US patent protection on subsidiary sales in a specific foreign country changes as the average country-specific level of judicial independence changes. Figure 6b on the right shows how the impact of US patent protection on subsidiary sales in a foreign country changes as the average country-specific level of political transparency changes. The y-axis on both graphs is measured in $ millions, and the country-specific 2SLS point estimates from Table 6 represent the individual points. Summary statistics for the x-axis variables on judicial independence and political transparency can be found in Appendix D Table 2.
## 9.4 Appendix D: Additional Tables

### Table D1: Average Values of Aggregate Firm-Level Variables Across Time

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2007-10</td>
</tr>
<tr>
<td>Number of Firms</td>
<td>13,157</td>
</tr>
<tr>
<td>Sales ($ Millions)</td>
<td>2,992</td>
</tr>
<tr>
<td>US Patents Held</td>
<td>55.88</td>
</tr>
<tr>
<td>US Patent Applications</td>
<td>0.0898</td>
</tr>
<tr>
<td>USPTO Examiner Grant Rate (%)</td>
<td>77.96</td>
</tr>
<tr>
<td>US Patent Approval Time (Days)</td>
<td>197.6</td>
</tr>
</tbody>
</table>

NOTES: All variables included in this table are annually measured, except for number of firms. To illustrate, 2,992 represents the average in annual sales reported by firms in Compustat North America during the 2007-2010 period, while 55.88 represents the average number of US patents held by such firms during a single year. In contrast, the number of firms variable measures the total number of unique firms represented in Compustat North America over the entire period specified in the column heading. Lastly, the USPTO Examiner Grant Rate and US Patent Approval Time are averaged across all patents held by a firm in a specific year. See Appendix B for more details on examiner grant rates and approval times.

### Table D2: Average Values of Subsidiary-Level Variables Across Time

<table>
<thead>
<tr>
<th>Variables</th>
<th>Period:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008-2013:</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>46,240</td>
</tr>
<tr>
<td>Firm Sales ($ Millions)</td>
<td>20,278</td>
</tr>
<tr>
<td>Subsidiary Sales ($ Millions)</td>
<td>199.1</td>
</tr>
<tr>
<td>Subsidiary Ownership Share</td>
<td>54.06</td>
</tr>
<tr>
<td>Number of Patents</td>
<td>255.7</td>
</tr>
<tr>
<td>Number of Patent Applications</td>
<td>0.474</td>
</tr>
<tr>
<td>Average Examiner Grant Rate (%)</td>
<td>74.92</td>
</tr>
<tr>
<td>Average Patent Approval Time (Days)</td>
<td>354.1</td>
</tr>
<tr>
<td>IPR Quality Score</td>
<td>5.087</td>
</tr>
<tr>
<td>Property Rights Quality Score</td>
<td>5.169</td>
</tr>
<tr>
<td>Judicial Independence Score</td>
<td>5.039</td>
</tr>
<tr>
<td>Political Favoritism Score</td>
<td>3.369</td>
</tr>
</tbody>
</table>

NOTES: All variables included in this table are annually measured, except for the number of observations. To illustrate, 4,275 represents the average annual sales (in $ millions) reported by a subsidiary in a given year during the 2014-2018 period, while 362,652 represents the number of observations recorded during the 2014-2018 period. In addition, 5.087 represents the average IPR quality score reported in the subsidiary-level data over the 2008-2013 period. The other variables take on relatively similar interpretations to their counterparts in Table D1.
Table D3: An Overview of Compustat Segment Data Name Matching

<table>
<thead>
<tr>
<th>Standard Name</th>
<th>Firm-Reported Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>United States; 6010United States; America; Americas ? U.S; The United States; U.S; U.S.A.; US; USA; Americas - U.S; United States and Territories; United State of America; United Stated of America; United States and Puerto Rico; U.S. Markets United States (U.S.); United States America; United States Of America; United States of America; United States/Puerto Rico; United Strates; United states;</td>
</tr>
<tr>
<td>China</td>
<td>Mainland China and Taiwan; China and Hong Kong; China (Incl. Hong Kong); China (including Hong Kong); China Taiwan and Hong Kong; China, Hong Kong and Taiwan; China, Macau and Taiwan; China/Hong Kong; Great China; Greater China; Greater China Region; Hong Kong and China; Hong Kong and Mainland China; Hong Kong/China; Mainland China; PRC; The PRC; Mainland China and Hong Kong; China; China (PRC); Mainland of China; PRC Mainland; China-Main Land; People’s Republic of China; People’s Republic of China; People’s Republic of China (PRC); People's Republic of China; Peoples Republic of China; Peoples Republic of China (PRC); Peoples’ Republic of China; The People's Republic of China</td>
</tr>
<tr>
<td>Canada</td>
<td>Canada; Canadian</td>
</tr>
<tr>
<td>Europe</td>
<td>Europe; Europe and United Kingdom; Europe (Including UK); European Countries; European Region; UK and Europe;</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>U.K. and Europe; United Kingdom and Europe; United Kindon/Europe; European United Kingdom; British; Britain; U.K.; U.K.; UK; United Kindom; Great Britain</td>
</tr>
<tr>
<td>France</td>
<td>France; Metropolitan France; Europe - France</td>
</tr>
<tr>
<td>Korea</td>
<td>Korea; Republic of Korea; Republic of Korea (ROK); South Korea; South korea</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Taiwan; Taiwan, R.O.C; Taiwan, R.O.C.; Taiwan, ROC; Republic of China; Republic of China (ROC); Republic of China (Taiwan)</td>
</tr>
</tbody>
</table>

NOTES: Standard names are names used to identify distinct geographic markets in this paper’s empirical analyses on aggregate US and foreign sales. Firm-reported names are specific geographic segment names listed by the firms that do report geographic segment sales in a given region. See section 4.1 for more specifics. Standard names and firm-reported names are exactly the same for market-specific sales reported in Japan, Germany, Mexico, Brazil, Australia, and India. Thus, these countries are not included in this table, although they are included in my empirical analyses.
Table D4: Covariate Balance Tests For Average Examiner Leniency Instrument

<table>
<thead>
<tr>
<th>Covariates</th>
<th>Number of Observations</th>
<th>Coefficient Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales ($ Millions), t-3</td>
<td>10,195</td>
<td>18.275</td>
<td>21.630</td>
</tr>
<tr>
<td>Sales ($ Millions), t-4</td>
<td>8,688</td>
<td>15.326</td>
<td>24.105</td>
</tr>
<tr>
<td>Sales ($ Millions), t-5</td>
<td>7,188</td>
<td>9.631</td>
<td>27.922</td>
</tr>
<tr>
<td>PPE ($ Thousands), t-3</td>
<td>54.06</td>
<td>39.137*</td>
<td>21.720</td>
</tr>
<tr>
<td>PPE ($ Thousands), t-4</td>
<td>8,602</td>
<td>45.851***</td>
<td>20.348</td>
</tr>
<tr>
<td>PPE ($ Thousands), t-5</td>
<td>7,127</td>
<td>39.083</td>
<td>23.818</td>
</tr>
<tr>
<td>Sales Growth ($ Millions), t-3</td>
<td>9,902</td>
<td>-6.1542</td>
<td>5.218</td>
</tr>
<tr>
<td>Sales Growth ($ Millions), t-4</td>
<td>8,490</td>
<td>-2.482</td>
<td>7.614</td>
</tr>
<tr>
<td>Sales Growth ($ Millions), t-5</td>
<td>7,064</td>
<td>0.459</td>
<td>6.273</td>
</tr>
<tr>
<td>PPE Growth ($ Thousands), t-3</td>
<td>9,771</td>
<td>-2.600</td>
<td>2.056</td>
</tr>
<tr>
<td>PPE Growth ($ Thousands), t-4</td>
<td>8,393</td>
<td>-1.513</td>
<td>1.861</td>
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<tr>
<td>PPE Growth ($ Thousands), t-5</td>
<td>6,996</td>
<td>-3.358</td>
<td>2.442</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1

NOTES: All Coefficient Estimates presented above come from univariate regressions of the selected covariates (displayed in the leftmost column) on the average examiner leniency instrumental variable \(AVGGRANTRATE_t\). In all rows, \(t-i\) represents how many years before the instrument the covariate was measured. For example, “SALES, t-3” represents firm-level sales 3 years before it was assigned \(AVGGRANTRATE_t\) in year \(t\). Heteroskedasticity-Robust Standard Errors are reported. PPE represents the property, plant, and equipment value reported in firm financial statements.

Table D5: The Impact of Logged US Patents on Aggregate Global and US Sales

<table>
<thead>
<tr>
<th>Region</th>
<th>Method</th>
<th>Log(1+ US Patents)</th>
<th>N</th>
<th>Observable</th>
<th>Controls</th>
<th>Industry-Year FE</th>
<th>Firm FE</th>
<th>First-Stage</th>
<th>F-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>FE</td>
<td>0.602***</td>
<td>85,361</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N/A</td>
<td>585.399</td>
<td>N/A</td>
</tr>
<tr>
<td>Global</td>
<td>FE</td>
<td>0.0180***</td>
<td>83,800</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N/A</td>
<td>55,495</td>
<td>N/A</td>
</tr>
<tr>
<td>Global</td>
<td>2SLS</td>
<td>0.629***</td>
<td>11,983</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N/A</td>
<td>55,365</td>
<td>N/A</td>
</tr>
<tr>
<td>US</td>
<td>FE</td>
<td>0.455***</td>
<td>55,495</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N/A</td>
<td>629.591</td>
<td>N/A</td>
</tr>
<tr>
<td>US</td>
<td>FE</td>
<td>0.00639*</td>
<td>55,365</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>US</td>
<td>2SLS</td>
<td>0.557***</td>
<td>11,114</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

NOTES: These specifications are exactly the same as the ones displayed in Table 3 in section 6.1, except that the treatment variable, US Patents, has been log-transformed
into \( \log(1 + PATENTS) \). To interpret the coefficients in columns (3) and (6) as an example, a 1\% increase in a firm’s US patent count appears to increase a firm’s global aggregate sales by 0.629\%, while increasing the firm’s US sales by 0.557\%.

### Table D6: The Impact of Logged US Patents on Global, US, and Foreign Subsidiary Sales

<table>
<thead>
<tr>
<th>Region</th>
<th>(1) Global</th>
<th>(2) Global</th>
<th>(3) US</th>
<th>(4) US</th>
<th>(5) Foreign</th>
<th>(6) Foreign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method:</td>
<td>FE</td>
<td>2SLS</td>
<td>FE</td>
<td>2SLS</td>
<td>FE</td>
<td>2SLS</td>
</tr>
<tr>
<td>Log(1+Patents)</td>
<td>-54.23</td>
<td>642.2**</td>
<td>149.5</td>
<td>387.0***</td>
<td>217.7</td>
<td>-1,380</td>
</tr>
<tr>
<td></td>
<td>(272.3)</td>
<td>(300.0)</td>
<td>(441.5)</td>
<td>(49.39)</td>
<td>(199.1)</td>
<td>(3,857)</td>
</tr>
<tr>
<td>N</td>
<td>69,275</td>
<td>21,174</td>
<td>44,058</td>
<td>11,868</td>
<td>24,754</td>
<td>9,139</td>
</tr>
<tr>
<td>Controls</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Industry-Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Firm FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>First-Stage F-stat</td>
<td>N/A</td>
<td>362.423</td>
<td>N/A</td>
<td>270.534</td>
<td>N/A</td>
<td>43.503</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

NOTES: These specifications are exactly the same as the ones displayed in Table 5 in section 6.2, except that the treatment variable, US Patents, has been log-transformed. To interpret the coefficients in columns (2) and (4) as an example, a 1\% increase in a firm’s US patent count increases a subsidiary’s sales by 0.01 \times 642.2 = $6.422 million on average, while it increases one of its US subsidiaries’ sales by $3.87 million.

### Table D7: The Relationship Between US Patents and Foreign Subsidiary Sales: Treatment Heterogeneity Across Country-Level Variables

<table>
<thead>
<tr>
<th>Country-Level Vars:</th>
<th>(1) X=IPR</th>
<th>(2) X=PR</th>
<th>(3) X=JI</th>
<th>(4) X=PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method:</td>
<td>FE</td>
<td>FE</td>
<td>FE</td>
<td>FE</td>
</tr>
<tr>
<td>Log(1+Patents)</td>
<td>-13.48</td>
<td>53.32</td>
<td>38.75</td>
<td>156.5</td>
</tr>
<tr>
<td></td>
<td>(263.4)</td>
<td>(261.9)</td>
<td>(246.7)</td>
<td>(206.0)</td>
</tr>
<tr>
<td>X</td>
<td>2,071***</td>
<td>-250.8</td>
<td>1,934***</td>
<td>955.6**</td>
</tr>
<tr>
<td></td>
<td>(628.7)</td>
<td>(716.2)</td>
<td>(535.3)</td>
<td>(486.5)</td>
</tr>
<tr>
<td>Log(1+Patents)*X</td>
<td>59.46*</td>
<td>45.61</td>
<td>48.51*</td>
<td>37.30*</td>
</tr>
<tr>
<td></td>
<td>(34.58)</td>
<td>(33.44)</td>
<td>(28.50)</td>
<td>(19.79)</td>
</tr>
<tr>
<td>Observations</td>
<td>23,310</td>
<td>23,409</td>
<td>23,409</td>
<td>23,409</td>
</tr>
<tr>
<td>Observable Controls</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Industry-Year FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Country FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
NOTES: The regressions run in columns (1)-(4) of the table above are analogous to the regressions run in columns (1)-(4) of Table 7 in section 6.3, except that the US patent count variable from Table 7 has been log transformed into log(1 + \( \text{Patents} \)). To interpret the new results, a 1% increase in a firm’s US patent count will lead to an increase in one of its subsidiaries’ sales by 0.01 \times (-13.48 + 59.46 \times 6) = $3.43 million on average if the subsidiary is located in a country with high IPR protection (i.e. an IPR score of 6). However, a 1% increase in a firm’s US patent count will lead to an increase in one of its subsidiaries’ sales by only $459,800 on average if the subsidiary is located in a country with low IPR protection (i.e. an IPR score of 1).

<table>
<thead>
<tr>
<th>Table D8: The Impact of Logged US Patents on Foreign Subsidiary Sales: Treatment Heterogeneity Across Country-Level Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Country-Level Vars:</strong></td>
</tr>
<tr>
<td><strong>Method:</strong></td>
</tr>
<tr>
<td>Log(1+Patents)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Log(1+Patents)*X</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>X</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Observations</td>
</tr>
</tbody>
</table>
| Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
NOTES: The regressions run in columns (1)-(4) of the table above are analogous to the regressions run in columns (1)-(4) of Table 8 in section 6.3, except that the US patent count variable from Table 8 has been log transformed into log(1 + \( \text{Patents} \)). To interpret the new results, a 1% increase in a firm’s US patent count will increase one of its subsidiaries’ sales by 0.01 \times (-1429 + 372.2 \times 6) = $8.04 million on average if the subsidiary is located in a country with high IPR protection (i.e. an IPR score of 6). However, a 1% increase in a firm’s US patent count will decrease one of its subsidiaries’ sales by $10.57 million on average if the subsidiary is located in a country with low IPR protection (i.e. an IPR score of 1). The magnitudes of the coefficient estimates on the interaction terms are again much larger here than in the fixed effect regressions of Table D7. I again attribute this to the 2SLS specifications’ focus on US patent-holding firms.
10 References


