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ABSTRACT

A central debate in economics concerns the relationship between competition and innovation, with some stressing that competition discourages innovation by reducing post-innovation rents and others emphasizing that more contestable markets spur currently dominant and other firms to invest more in innovation. We examine the impact of competition laws on innovation. We create a unique firm-level dataset on patenting activities that includes over 1.4 million firm-year observations, across 68 countries, from 1991 through 2015. Using a new, comprehensive dataset on competition laws, we find that more stringent competition laws are associated with increases in firms' number of self-generated patents and the citation-impact and explorative nature of those patents. We also conduct the first examination of the relationship between competition laws and firms' acquisition of patents from other firms. We find that competition increases patent acquisitions but lowers the ratio of acquired to self-generated patents. The results hold when using country-industry data on 186 countries over the 1888-2015 period.

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1. Introduction

A central debate in economics concerns the relationship between competition and innovation. Schumpeter (1942) stressed that more intense competition can discourage innovation by reducing post-innovation rents (e.g., Romer 1990; Aghion and Howitt 1992). In contrast, Arrow (1962) emphasized that more intense competition can encourage innovation by making markets more contestable, spurring both currently dominant and other firms to invest in innovation. Aghion et al. (2005) and Shapiro (2012) stress that these countervailing effects of competition on innovation are not mutually exclusive: the overall effect depends on how an intensification of competition shapes the contestability of markets and the ability of firms to appropriate returns from successful innovations. To evaluate empirically the impact of competition on innovation, an enormous literature uses data on firm size, market concentration, and price-cost margins to measure market structure and data on R&D expenditures and patents to measure innovation. As summarized by Cohen (2010), the results depend on the different measures of market structure and innovation and the different empirical methods employed by researchers (e.g., Nickell 1996; Blundell, Griffith, and Van Reenen 1999; Gilbert 2006; Jansen, Van Den Bosch, and Volberda 2006; Sutton 2007; Aghion et al. 2005, 2009; Hashmi 2013).

In this paper, we examine the connection between competition laws and innovation. Rather than analyzing measures of market structure, we examine the statutory laws that regulate competition among firms, such as the laws concerning mergers and acquisitions, anticompetitive agreements, the ability of firms to exploit their dominant position in markets, and the authority for addressing and remedying violations of those statutes. That is, we examine statutory policy levers that countries use to shape competition among firms. Using a unique panel dataset on competition laws, firm patents, and firm acquisition of patents, we study the relation between the stringency of competition laws and innovation.

We make three contributions to research on competition and innovation. First, we create a unique firm-level panel dataset with information on each firm's patents and financial accounts for public and private firms, across 68 countries, over the period from 1991 through 2015. To accomplish this, we combine the two global databases on patents (Worldwide Patent Statistical Database, PATSTAT and OrbisIP) and link this patenting information with firm-level data on

income and balance sheets. This matching is extraordinarily labor intensive, as firm identifiers differ across datasets and change over time. Using this new dataset with over 1.4 million firm-year observations, we construct measures of the number of patents, the impact of those patents as gauged by citations, and the extent to which the innovation is more explorative—involving inventions that fall outside of the firm's historic base of innovative knowledge as reflected in its patent applications—or exploitative—involving patents within the firm's historical technology classes. In addition to this firm-level dataset, we construct a country-industry dataset covering the period from 1888 through 2015 and use it to evaluate the connection between competition laws and innovation over 128 years. While recent studies explore several determinants of innovation (e.g., Chang et al. 2015; 2019; Brown and Martinsson, 2019; Moshirian et al. 2020), we believe that we are the first to examine the impact of competition laws on innovation for a large, international panel of private and public firms.

Second, we conduct the first examination of the relation between competition laws and the acquisition of patents by firms. Firms obtain patents from other firms by buying them directly or through mergers and acquisitions. We assemble data on patent transactions worldwide and study the connection between competition laws and innovation acquisition. Thus, we offer an initial study of how competition laws shape the in-house development of patents, the acquisition of patents, and the relative importance of self-developed and acquired innovation.

Third, we are the first to use a new, comprehensive dataset on competition laws across 123 countries from 1888 through 2010 to examine the relation between competition laws and innovation. Bradford and Chilton (2018) and Bradford et al. (2019) compiled and codified data on the multiplicity of competition laws that regulate mergers and acquisitions, the abuse of dominant positions, the use of anticompetitive agreements, and who has the authority and tools to raise and address potential violations of those laws. These data are much more extensive with respect to the measurement of different competition laws and the coverage of countries and years than any other dataset on competition laws. Based on Bradford et al (2019), we examine both their overall index of competition laws (*Competition Law Index*) and the subcomponents that focus on laws governing mergers and acquisitions, the abuse of dominant

positions, anticompetitive agreements, and authority, i.e., who has legal standing to raise concerns about the violation of competition laws and what are the remedies available for enforcing competition laws. These data offer a unique opportunity to evaluate the connection between the different competition laws that regulate competition among firms and innovation.

We begin our firm-level analyses by assessing the connections between innovation and the *Competition Law Index*, which is an aggregation of the following four subcomponents. *Merger Control* is an index of the laws regulating mergers and acquisitions and includes information on the laws governing pre-merger notification and approval, the degree to which the law grants authorities power to restrict mergers for economic and public interest reasons, and the scope and purview of merger and acquisition laws with respect to industries, enterprises, etc. *Anticompetitive Agreements* is an index designed to measure the degree to which a country's competition laws prohibit firms from colluding to set prices, divide markets, limit supply, rig bids, and engage in other anticompetitive activities. *Abuse of Dominance* is an index of laws designed to limit the ability of dominant firms to exploit their market positions in uncompetitive ways. *Authority* is an index that aggregates information on the degree to which both private and public entities have the legal authority to bring suits against firms for anticompetitive behaviours, the remedies available to authorities, and the scope of the law, i.e., the degree to which all industries and enterprises fall under the purview of a country's competition laws. The *Competition Law Index* and its subcomponents are based on statutory law, not on the implementation of those laws, and coded so that higher values signify laws that more stringently regulate "anticompetitive behaviours" by firms. Furthermore, the coding of *Merger Control*, *Anticompetitive Agreements*, and *Abuse of Dominance* indexes accounts for the possible defenses that firms might employ against accusations. In particular, Bradford and Chilton (2018) reduce the values of each of these subcomponents (and hence the *Competition Law Index*) when firms have legal recourse to the defenses that the economic efficiency benefits of their actions or the public interest benefits of their actions outweigh the anticompetitive costs.

Using a control function approach, we find a strong positive connection between the stringency of competition laws and innovation. In our initial analyses, we regress patent-based

measures of innovation on the *Competition Law Index* while controlling for firm fixed effects, industry-year fixed effects, lagged time-varying firm characteristics (e.g., size, leverage, profitability, and age), and time-varying country traits (e.g., Gross Domestic Product (GDP) per capita, the ratio of Credit to GDP, and the ratio of stock market capitalization to GDP). Furthermore, the results hold when controlling for an assortment of time-varying national policies, including laws and regulations associated with national patent systems, contract enforcement, property rights protection, and the regulation of financial intermediaries, markets, and international capital flows. Given these extensive controls and our finding that changes in national innovation rates do not predict changes in competition laws, we interpret these firm-level analyses as providing suggestive evidence on the impact of competition laws on innovation. Below, we employ additional strategies to enhance our ability to draw causal inferences about national competition laws and firm innovation. It is also worth emphasizing that the results are robust to including or excluding U.S. firms and to examining all firms, or limiting the sample to manufacturing firms.

Our coefficient estimates suggest an economically large effect of competition laws on firm innovation, as measured by the number of patents, forward citations to patents, citations per patent, the number of very highly cited patents (top-quartile of the citation distribution among patents in a year and technology class), and the number of explorative patents, i.e., patents that fall beyond a firm's historic base of innovative activities. For example, the coefficient estimates indicate that if a country's *Competition Law Index* increased by one standard deviation, then the total number of citations to patents received by firms in the country would increase by 11%.

We then examine the connection between competition laws and the acquisition of patents. In particular, we examine the relation between competition laws and (1) firms acquisition of innovation—as measured by both the number of patents and the citation impact of those patents, (2) the ratio of patents acquired from other firms to self-developed patents, where we compute this ratio based both on the number of patents and the citation impact of those patents, and (3) the extent to which firms acquire more explorative patents and patents from different industries. Since we are the first to examine the connection between competition

law and patent acquisition, we use these results as establishing a set of stylized facts rather than assessing competing theories about the impact of competition laws on patent acquisition.

There are three clear patterns regarding competition laws and the acquisition of innovation. First, greater values of the *Competition Law Index* are associated with significant increases in the total number of patents acquired and the impact of those patents, as measured by citations. These findings suggest that more stringent competition laws are associated with firms acquiring more and higher-impact patents. Second, more stringent competition laws are associated with a reduction in the ratio of acquired to self-generated innovation. While *Competition Law Index* boosts both acquired and self-developed innovation as measured by either the number or impact of patents, more stringent competition laws disproportionately boost the rate of self-developed patents. Third, when competition laws become more stringent, firms acquire more explorative patents (relative to exploitative patents) and they acquire a higher proportion of patents from firms in industries different from their own.

We next address a potential concern with these firm-level analyses: there might be an omitted time-varying country trait that both drives innovation and is correlated with changes in competition laws. To address this concern, we now differentiate among firms in countries, so that we can include country-year fixed effects. Specifically, we conjecture that if more stringent competition laws spur innovation, the effects should be stronger among firms in more "innovative-intensive" industries, i.e., more stringent competition laws should have a bigger effect on innovation among firms that are more likely to innovate. To categorize industries as "innovative-intensive," we use the Eurostat definition of high-technology industries, e.g., pharmaceuticals, computer, electronics, and optical products. We then evaluate whether more stringent competition laws spur innovation more among firms in innovative-intensive industries. This approach is similar to the identification strategy employed by Moshirian et al., (2020) and Levine, Lin, and Wei (2017), who assess the impact of stock market liberalization and insider trading laws on innovation respectively. Consistent with the results from using the simple control function approach discussed above, these cross-industry firm-level analyses suggest the following: among firms in innovative-intensive industries, more stringent

competition laws increase patenting, the patenting of higher-impact innovations, more explorative patents, and the ratio of self-developed to acquired patents.

Besides examining the overall *Competition Law Index*, we also analyze its individual components: *Authority*, *Merger Control*, *Abuse of Dominance* and *Anticompetitive Agreements*. The findings on *Competition Law Index* also hold for the individual sub-indexes of *Authority*, *Merger Control*, and *Anticompetitive Agreements*. Each of these sub-indexes enters positively and significantly when examining the number of patents, the impact of patents measured by citations, and the degree to which those patents are explorative. We also find that each of these sub-indexes of the overall index of competition law stringency is negatively associated with the ratio of acquired to self-developed patents. These results are consistent with the view that laws that grant greater authority to the antitrust regime, contain a broader range of provisions regulating mergers, and exert strong limits on horizontal and vertical agreements between companies that foster innovation and increase self-developed patents relative to the acquisition of patents from others.

The only exception regards the sub-index, *Abuse of Dominance*. Since *Abuse of Dominance* is unrelated to the different firm-level measures of innovation, we explore the components of *Abuse of Dominance*. Dividing *Abuse of Dominance* into its components suggests a potential reason for why the overall *Abuse of Dominance* sub-index is not strongly correlated with innovation. Exploiting the dominant position created by a patent might be one strategy through which firms obtain returns from innovation, so that limiting such "abuse" could reduce investment in innovation and hence future inventions. Therefore, a legal system that allows firms to exploit their dominant positions based on efficiency considerations could boost innovation.

Consistent with the view that allowing firms to exploit their positions of dominance for economic efficiency reasons boosts innovation, we find that the sub-component of *Abuse of Dominance* that measures whether firms can defend themselves against charges of abusing their dominant positions by using an efficiency defense enters positively and significantly when examining the impact on firm innovation. These findings suggest that the presence of an

efficiency defense for actions that would otherwise be classified as abusive facilitates corporate inventive activities.

Finally, we also confirm our findings using an industry-country level investigation that covers the period from 1888 through 2015 and includes a cross-section of 186 countries. Although we do not have firm-level data going back to the 19th century, we can differentiate innovation by industry, country, and year for a long panel of 128 years. All of the findings using these industry-country-year dataset are fully consistent with the firm-level analyses.

Besides the large body of research on competition and innovation, our research relates to several other lines of inquiry. A growing literature examines the financial and institutional determinants of innovation, as reviewed by He and Tian (2020). We examine a different but important determinant of innovation: competition laws. Furthermore, a well-established literature shows that laws shape the functioning of financial institutions, the contestability of markets, and economic outcomes (e.g., La Porta et al. 1998; La Porta, Lopez-De-Silanes, and Shleifer 2008; Ellul, Pagano, and Panunzi 2010; Brown, Martinsson, and Petersen 2013). We build on this work by showing that particular laws regulating firm competition have a material impact on innovation. A related line of research explores the regulation of entry. Djankov et al. (2002) show that countries that make it more costly for start-up firms to enter a market typically suffer from higher corruption levels, supporting a public choice view of entry regulation. We focus on the competition laws and their effects on innovation and our findings indicate that laws that limit anti-competition actions and activities are associated with faster rates of innovation. Researchers also show that competition shapes corporate valuations (e.g., Giroud and Mueller 2011). By showing the large impact of competition laws on firm innovation, our work offers an additional mechanism through which competition can influence firm valuations.

The remainder of the paper is organized as follows. Sections 2 and 3 respectively discuss the unique patenting and competition law data used in our study. Section 4 provides the firm-level regression analyses, and Section 5 presents the country-industry-year results. Section 6 concludes.

2. International Data on Patenting at the Firm and Country-Industry Levels

In this section, we first describe the construction of our firm-level dataset. These data include information on firms' patenting activity and financial accounts for a large panel of private and public firms across 68 countries for the period covering 1991 through 2015. We then describe the country-industry level dataset on patenting that covers the period from 1888 through 2015. We complete the section by providing summary statistics. To mitigate concerns that the United States might dominate the results, we exclude U.S. firms from the analyses. All of the findings reported below, however, hold when including U.S. data.

2.1 Firm-level patent and financial data

We compile a unique dataset that combines the two most comprehensive global databases on patents with detailed financial data on public and private firms. To the best of our knowledge, this is the first study to create and examine a firm-level dataset that contains panel information on each firm's financial accounts, patents, the nature and impact of those patents, and the firm's acquisition of patents for a broad range of firms, across many countries, and over an extensive time period.

The two global databases on patents are (1) the Worldwide Patent Statistical Database (PATSTAT), which is administered by the European Patent Office, and (2) OrbisIP, which is maintained by Moody's Bureau van Dijk (BvD). Each of these patent databases covers over 100 million patents filed with about 100 patent offices around the world, dating back to the 1800s. Each patent database provides detailed information on patents, such as application date, grant status, and technological class (e.g., International Patent Classification (IPC)). Our firm-level database covers the period starting in 1991 because we match these patenting data with firm balance sheet and income data that only starts in 1991 for a broad selection of firms. As discussed below, we also construct a country-industry-level dataset on patenting and use it to examine a longer time period.

The PATSTAT and OrbisIP datasets provide distinct and complementary information that we exploit to (1) measure patenting activity more accurately and (2) link these patenting datasets to firm-level datasets that contain income and balance sheet information. With respect

to measuring patenting activity, researchers face the following challenge: firms can, and do, apply for and receive patents in multiple patent offices. This means that there are sometimes multiple patents on the same underlying invention. Failure to account for this can lead to measurement problems. For example, researchers might incorrectly (a) record a single invention multiple times for a firm that obtains a patent from multiple patent offices; (b) record the wrong innovation date depending on which patent office filing the researchers use, and (c) measure patent citations by counting all of the citations from a single invention that received patents in multiple patent offices.[1]

To address this measurement challenge, we focus on the original invention. PATSTAT provides unique "patent family" identifiers, where a patent family includes all of the patents filed in different patent offices on the single underlying invention. This information, however, is not readily available from OrbisIP. Based on the PATSTAT patent family identifier, we ascertain the first time that an invention is granted a patent and we call this the "original patent." We date patents using the application year of the original patent (rather than the date when the patent is granted) because the application year is closer to the invention date (Griliches, Pakes, and Hall 1987) and various factors can influence the gap between the application and grant dates (Hall, Jaffe, and Trajtenberg 2001). We also use the International Patent Classification (IPC) of the original patent to define the technological section and subclass(es) of the invention.[2,3]

OrbisIP provides critical information—that is unavailable in PATSTAT—that allows us to (a) link the patenting data with other firm-level datasets and (b) obtain information on

[1] For example, if patent A is cited by patent B and patent C, and patents B and C are simply the same invention filed in two different patent offices, then failure to link patents B and C as a single invention will mean that patent A will be recorded as having two citations rather than the correct value of one.

[2] A typical IPC takes a form as follows: in the case of "A61K 36/815", the first character, "A", identifies the IPC "section". There are eight sections in total (from A to H). The first four characters, "A61K" provide the "subclass". With the next two characters ("36") and the last three characters ("815"), we can further identify the IPC at the "main group" and "sub-group" level. Since IPCs are not always available at the main group and sub-group level, we use the first four characters, i.e., the subclass level, as the most granular technological class in our analysis.

[3] As more than one IPC can be assigned to a patent, we follow the procedures in Levine et al. (2017). All patents have at least one inventive IPC. If the patent authority designates an inventive IPC as secondary ("L" in the ipc_position of the PATSTAT), we remove that IPC from further consideration. This leaves only inventive IPCs that the patent authority designates as primary ("F" in the ipc_position of the PATSTAT) or that the patent authority does not designate as either primary or secondary, but rather as an undesignated IPCs. In no case does a patent authority designate a patent as having two primary IPCs. In the few cases with multiple inventive IPCs where none are designated as primary, we keep the IPC with the highest alphabetical order.

firms' acquisitions of patents. In particular, OrbisIP provides unique identifiers (i.e., Bvd ID) for firms applying for patents that are the same as those in other Orbis databases that contain firm-level income and balance sheet data. Furthermore, OrbisIP records transactions of patents between firms, so that we can examine how competition influences patent transactions. By combining these datasets, we create a firm-level dataset on patenting and financial data for private and public firms around the world from 1991 through 2015.

Merging the firm-level patenting and financial datasets is challenging. While both patent databases use the patent application number from the original filing documents, PATSTAT and OrbisIP use different standardization methods for recording and presenting this "common" identifier. Moreover, the standardization rules changed over time and the different patent offices changed how they recorded the patent application number over time. Thus, we have reviewed the rules for each patent office and the standardization methods of the two patent databases and constructed our own unified identifiers to ensure a one-to-one matching between all patent records.[4]

Another challenge to compiling our firm-level dataset involves the retrieval of historical data from Orbis. For any particular version of Orbis, BvD only provides firm-level information for the most recent ten years. Thus, to cover the 1991-2015 period, we need to combine data from multiple versions of Orbis. However, the firm-level identifies (i.e., the BvD IDs) change over time, making it difficult to match firms over time across the different versions of Orbis. Thus, we had to check these records individually to resolve changes in a firm's BvD ID and eliminate duplicate records from overlapping years. By doing this, we construct what we believe is the broadest dataset containing a panel of firm-level data on patents, patent transactions, and financial information for private and public firms worldwide.

[4] Given the idiosyncrasies of patenting offices, we restrict our analyses to patent offices that granted at least 100,000 patents over their full history based on the records in PATSTAT. This accounts for more than 97% of the universe of eventually-granted patents in PATSTAT.

2.2 Firm-level patent measures

We construct six patent-based measures of innovation for each firm in each year, which have been used by an extensive literature (see, e.g., Chang et al., 2015, 2019; Balsmeier, Fleming, and Manso, 2017; Lin, Manso, and Liu, 2019).

2.2.1 Patent quantity

Patent Count equals the natural logarithm of one plus the total number of eventually-granted patents that firm *f* applied for in year *t*, i.e., the application date of the original patent in year *t*. Since patents granted after the last year covered by the database, i.e., 2018, will not be recorded as eventually-granted in the database, there can be truncation problems during the last few years of the database. Given that the average application-grant lag is about three years, we end our sample in 2015 to mitigate this truncation problem (e.g., Hall et al., 2001). We use the natural logarithm of one plus the total number of eventually-granted patents because the distribution of the number of patents is right-skewed. *Patent Count* measures the quantity of patents, but it does not measure the quality of patents.

2.2.2 Patent impact

Besides measuring the quantity of patents, we also use four measures of the "impact" of patents, where impact is measured using citations.

Citation equals the natural logarithm of one plus the total number of forward citations received by all eventually-granted patents that firm *f* applied for in year *t*. Since a patent may continue to receive citations beyond the observable coverage of the database, we adjust for truncation bias using the approach employed in Hall et al. (2001, 2005) and Levine et al. (2017). This measure gauges the degree to which an innovation influences other inventions.

Cit/Pat equals the natural logarithm of one plus the *average* number of forward citations received by all eventually-granted patents that firm *f* applied for in year *t*. This measure gauges the average impact, rather than the aggregate impact of patents by firm *f* in year *t*.

Cited Patent equals the natural logarithm of one plus the total number of eventually-granted patents that firm *f* applied for in year *t* that received at least one citation. We use *Cited*

Patent to assess whether competition influences the degree to which firms create new patents that are cited by at least one other invention.

Top Cited Patent equals the natural logarithm of one plus the total number of eventually-granted patents that firm *f* applied for in year *t* that have forward citation counts falling in the top 25% of the forward citation count distribution for patents within the same technology class and application year. This gauges whether a firm created a very high-impact patent. We use this to assess the relationship between changes in the competition laws facing firms and the likelihood that they create very impactful patents.

2.2.3 Explorative patents

Finally, in addition to measuring the quantity and impact of patents, we use an indicator of the extent to which a firm's patents are "explorative," meaning that the innovative activity reflected in the patent falls outside of the firm's typical line of research.

Explorative Patent equals the natural logarithm of one plus the total number of explorative patents that firm *f* applied for in year *t*. Following prior research (see, e.g., Manso, 2011; Balsmeier et al., 2017; Lin et al., 2019), a patent is defined as explorative if at least 60% of the citations to which it refers are neither to patents that the firm produced during the last five years nor to patents that were cited by the firm's others patents filed over the past five years. Thus, an explorative patent is an invention that falls outside of the firm's historic base of innovative knowledge as reflected in its patent applications. *Explorative Patent* gauges the degree to which a firm engages in more explorative inventions—inventions in areas different from the firm's past inventions and lines of research.[5]

[5] Furthermore, we constructed and examined an alternative measure using a more restrictive cutoff percentage of patents. Specifically, *Explorative Patent (Alternative)* equals one if at least 80% of the citations to which it refers are neither patents that the firm produced nor patents that were cited by the firm's others patents filed during the past five years. The results hold using the alternative measure.

2.3 Patent acquisition measures

One of the advantages of using the OrbisIP database is that it provides information on patent transactions worldwide. Using this information, we construct and examine six measures of firms' acquisition of patents. Firms acquire patents primarily by purchasing them directly or through mergers and acquisitions.

Patent Acquired equals the natural logarithm of one plus the total number of patents acquired by a firm in a given year. This measures the quantity of patents acquired by a firm.

Patent Acquired Ratio equals the natural logarithm of one plus the total number of patents acquired by a firm in a given year minus the natural logarithm of one plus the total number of patents that the same firm applied for in that same year (i.e., the number of self-developed patents). The *Patent Acquisition Ratio* is approximately equivalent to the ratio of the number of patents acquired to the number of patents self-developed by the firm, which gauges the relative intensity of acquiring innovation versus conducting in-house innovation. Thus, we use this measure to evaluate the impact of competition laws on the degree to which firms acquire patents from other firms or develop those innovations in-house.

Explorative Patent Acquired Ratio equals the natural logarithm of one plus the total number of explorative patents acquired by a firm in a given year minus the natural logarithm of one plus the total number of exploitive patents acquired by the same firm in that same year. An acquired patent is considered to be explorative if at least 60% of the citations contained within the patent are neither to patents that the acquiring firm produced during the last five years nor to patents that were cited by the acquiring firm's others patents filed over the past five years. Similarly, an acquired patent is considered to be exploitative if at least 60% of the citations to which it refers are patents that the acquiring firm produced or patents that were cited by the acquiring firm's other patents filed over the past five years. An acquired exploitative patent, therefore, is an invention that falls within the acquiring firm's historic base of innovative knowledge, while an acquired explorative patent represents an invention that falls outside of that base of innovation. The *Explorative Patent Acquired Ratio* is approximately equivalent to the ratio of the number of explorative patents acquired to the number of exploitive

patents acquired by the firm. Thus, we use *Explorative Patent Acquired Ratio* to assess whether more stringent competition laws induce firms to acquire more explorative patents.

Intra-industry Patent Acquired Ratio equals the natural logarithm of one plus the total number of patents acquired from firms in the same industry (four-digit NACE level) as the acquiring firm in a given year minus the natural logarithm of one plus the total number of patents acquired from firms in different industries. We use *Intra-industry Patent Acquired Ratio* to assess whether competition influences the degree to which firms acquire patents from firms in the same industry relative to the acquisition of inventions patented by firms in other industries. For example competition might spur firms to seek out and acquire inventions in other industries to establish a competitive advantage in their own industries.

2.4 Other firm-level characteristics and country traits

For the firm-level sample, we start the sample in 1991 because the availability of firm-level income and balance sheet data increases in 1990 and we constructed the firm-level control variables with a one-year lag. We follow the literature (see, e.g., Hsu, Tian, and Xu, 2014) and include the following control variables in our analysis: *Firm Size*, *Leverage*, *Profitability* and *Age*. *Firm Size* is the natural logarithm of total assets of a firm in a year. *Leverage* is the ratio between non-current liability and total assets of a firm in a year. *Profitability* is the net income scaled the total assets of a firm in a year. *Age* is the natural logarithm of the number of years since the establishment of a firm.

We also include an assortment of country-level characteristics. *GDP per capita* is the natural logarithm of Gross Domestic Product (GDP in real U.S. dollar in 2010) of a country in a year, scaled by its total population. *Credit/GDP* is the ratio of total credit provided by the financial sector over GDP in a country-year. *Stock/GDP* is the ratio of total market capitalization of domestic firms over GDP in a country-year. The detailed definitions and sources of the variables introduced in this section are presented in Appendix A.

By requiring non-missing values for these firm-level characteristics and the firm's industry classification and country traits, the final firm-level sample consists of about 200,000 firms from 68 countries over the period from 1991 through 2015.

2.5 Country-industry-level innovation measures

We complement the firm-level analyses with country-industry data. In moving to the country-industry-level, we extend the sample period to cover 128 years: 1888 through 2015. Thus, while we lose the granularity of firm-level data and the transactions-level information, we gain the ability to examine the relationships between competition and patent-based measures of innovation for 186 countries over more than a century.

In constructing the country-industry-level patent-based innovation measures, we continue to (a) consider all eventually-granted patents, (b) use the PATSTAT "patent family" identifier to identify the original patent, (c) date patents using the application year of the original patent, and (d) use the IPC of the original patent to define the technological section and subclass(es) of each invention. To assign patents to industries, we convert the patent's IPC subclass level to the two-digit Standard Industry Classification (SIC) level using the latest mapping scheme from the World Intellectual Property Office (WIPO) and the United Nations Statistical Division.[6] To assign patents to countries, we use information from the original patent on the country of residence of the patent's primary assignee.

We construct four patent-based measures of innovation for each industry *j*, in country *c*, in year *t* from PATSTAT: *Patent Count-Ind*, *Citation-Ind*, *Top Cited Patent-Ind*, and *Explorative Patent-Ind*. *Patent Count-Ind*$_{c,j,t}$ equals the natural logarithm of one plus the total number of eventually-granted patents in industry *j*, in country *c*, in year *t*. *Citation-Ind* and *Top Cited Patent-Ind* are defined analogously, building on the firm-level variables defined above. For *Explorative Patent-Ind*, we need to identify the degree to which a patent involves innovation beyond the firm's past inventive activity. Thus, we first restrict to those patents where OrbisIP has the applicants' BvD ID to identify the firm it belongs to and evaluate whether it is considered as explorative for the firm. This restriction is not needed for the other three measures. Then, we count the number of explorative patents belonging to a certain IPC

[6] We first map IPC subclasses to the International Standard Industrial Classifications (ISICs) using the mapping scheme at: https://are.ucdavis.edu/people/faculty/travis-lybbert/research/concordances-patents-and-trademarks/.Then, we convert the ISICs to SICs using the concordance scheme from the United Nations Statistical Division, which is available at: http://unstats.un.org/unsd/cr/registry/regdnld.asp?Lg=1.

subclass that are filed by firms in a country-year, convert it to the two-digit SIC level, and take the natural logarithm of one plus the count to obtain the final value for *Explorative Patent-Ind*. By construction, the number of industry-country-year observations with *Explorative Patent-Ind* available is smaller than that for the other patent-based innovation measures in the industry-country-level dataset. We require each industry-country to have at least one eventually-granted patent to be included in our analysis.

2.6 Summary information on patent-based measures of innovation

Table 1 provides summary statistics on patenting at (1) the firm-level for the period 1991-2015 on a maximum of 68 countries and (2) country-industry-level for the period 1888-2015 on a maximum of 186 countries. Focusing first on the firm-level sample, the average firm (a) develops 1.3 eventually-granted patents in a year and (b) receives 30.3 forward citations to the eventually-granted patents that it applies for in a year. Furthermore, about 0.23 of an average firm's 1.3 eventually-granted patents in a year generate forward citations that place the innovation in the top 25% of the forward citation distribution for all patents within the same technology class and application year. An average firm has 0.27 explorative patents (out of its 1.3 patents) in a year.[7] In terms of patent acquisitions, the average firm in our sample acquires 0.11 patents per year from other firms and these acquired patents receive on average four forward citations. We follow the common practice in the literature and treat the firm-year observations without any patent records as containing a value of zero for these measures. All these measures of innovation are highly right skewed as shown by the standard deviations and values at the 10th, median, and 90th percentiles. The median size firm in our sample has total assets of US$6 million, with a leverage ratio of 16.9% and profitability (net income/assets) of 3.7%.

The country-industry-level measures of innovation cover the period from 1888 to 2015. These measures are also based on the original patent and then linked to an industry based on the patent's IPC subclass and to a country based on residence of the patent's primary assignee.

[7] Our example excludes firms without any patents, so *Explorative Patent* does not measure firms that innovate for the first time.

Thus, *Citation-Ind*$_{c,j,t}$ equals the natural logarithm of one plus the total number of forward citations received by all eventually-granted patents in industry *j*, in country *c*, in year *t*.

3. Competition Laws

Bradford and Chilton (2018) and Bradford et al. (2019) recently compiled the most comprehensive dataset on competition laws around the world and over time. The data cover 123 countries that have had a competition law in place over the period from 1888 through 2010. Their data go well beyond other datasets with respect to the coverage of (a) competition laws, (b) countries, and (c) years. Researchers have only begun to exploit the wealth of information contained in their dataset on the statutory laws that shape competition among firms (see, e.g., Bradford and Chilton 2018; Bradford et al. 2019).[8] In this section, we summarize features of their data that are central to our examination of competition laws and innovation.

Bradford and Chilton (2018) and Bradford et al. (2019) constructed the data as follows. First, they collected all laws containing provisions regulating market competition for 123 countries dating back to each country's first competition law or 1888, whichever came later. For example, the first relevant U.S. federal law regulating market competition is the Sherman Act of 1890. They then coded the content of those laws with respect to provisions concerning mergers and acquisitions, the abuse of dominant positions, anticompetitive agreements, and the authority for addressing and remedying violations of those provisions. In this way, Bradford and Chilton (2018) and Bradford et al. (2019) codify the multifaceted provisions of competition laws for a large panel of countries.

Bradford and Chilton (2018) aggregate data on individual competition laws into four indexes. *Authority* captures provisions concerning who has standing to raise concerns about the violation of competition laws and the remedies available for enforcing those laws. The next three indexes measure the regulation of (1) mergers and acquisitions (*Merger Control*), (2) agreements among firms that limit competition (*Anticompetitive Agreements*), and (3)

[8] See: http://comparativecompetitionlaw.org//.

strategies used by dominant firms to abuse their positions (*Abuse of Dominance*). In the remainder of this section, we discuss the codification of these four indexes.

3.1 Authority

In constructing the *Authority* index, Bradford and Chilton (2018) include information on (1) who can bring suits against firms that are alleged to have engaged in anticompetitive behavior, (2) the remedies that the authorities can impose on firms that violate competition laws, and (3) the scope of the law, i.e., the degree to which all industries and enterprises fall under the purview of a country's competition laws.

Authority is the summation of eight components. *Private right of action* equals one if a country allows individuals and firms to bring suits against companies for violating competition rules. While governments typically enforce competition laws, some countries allow for an additional avenue for raising and then adjudicating claims of anti-competition actions: private actions by individuals and firms. Since allowing for these private actions expands the competition regime beyond government enforcement, Bradford and Chilton (2018) add one to the overall authority measure, *Authority*, when *Private right of action* equals one.

The next five components of *Authority* concern remedial powers and scope. *Fines* equals one if the authorities have the authority to levy monetary fines on firms that violate competition laws. *Imprisonment* equals one if a country can imprison those who violate competition laws. *Divestiture* equals one if a country's authorities have the right to stop, reverse, or modify the structure of a merger or acquisition. *Damages* equals one if the authorities can reward damages to private parties as compensation for another entity violating competition laws. *Extraterritoriality* equals one when a country's authorities can address conduct by those operating outside of the geographic boundaries of the country if those action violate the country's competition laws and affect the competitive environment in the domestic economy.

The next two components of *Authority* concern exemptions to the country's competition laws. As stressed by Bradford and Chilton (2018), the extent to which countries limit the purview of their competition laws by limiting their authority over market competition. Thus, *Industry Exemptions* equals -0.5 when a country's competition law provides any

exemptions for industries (e.g., agriculture) adhering to the nation's competition laws. Similarly *Enterprise Exemptions* equals -0.5 when there are any exemptions for enterprises (e.g., state-owned).

3.2 Merger Control

To gauge the extent to which competition laws regulate mergers and acquisitions, Bradford and Chilton (2018) include information on each country's laws in each year with respect to (1) regulating pre-merger notification and approval, (2) granting expansive powers to the authorities to restrict mergers for economic and public interest reasons, and (3) permitting an assortment of arguments by firms to defend mergers and acquisitions and limiting the scope of laws, i.e., the degree to which all industries and enterprises are within the purview of the competition laws.

Merger Control is the summation of seven components. The first two measure the degree to which competition laws require that firms get approval before undertaking a merger. *Pre-merger Notification* equals one if firms obtain approval before completing a merger voluntarily or mandatorily. *Mandatory Notification* equals one if firms must obtain approval before closing a merger. The next two components focus on the types of reasons that can be used to restrict mergers. *Economic Reason* equals one if the law grants the regulatory authority expansive powers to limit mergers on grounds that the merger would lessen competition or strengthen a firm's dominant position. *Public Interest* equals one if the country's competition laws permit merger restrictions on grounds that the merger would hurt the public interest. As stressed by Bradford and Chilton (2018), *Merger Control* is designed to capture the extent to which a country grants officials control over mergers and acquisitions.

The next three components of *Merger Control* concern the arguments that firms can use to defend themselves against accusations that a merger is anticompetitive. *Efficiency Defense* equals -0.5 if firms can argue that the merger will enhance economic efficiency enough to outweigh any anticompetitive effects. This enters negatively into the *Merger Control* index because such a defense reduces regulatory control over mergers. Similarly, *Failing Firm Defense* equals -0.5 if a country's competition law allows firms to justify anticompetitive

mergers when firms are failing and bankruptcy would eliminate the value of their assets. Finally, *Public Interest Defense* equals -0.5 if a country's competition laws allow firms to defend mergers based on the argument that the public interest benefits outweigh the anticompetitive costs.

3.3 Abuse of Dominance

Competition laws often limit the ability of a dominant firm to abuse its power and limit competition. In a few countries, the law gives the authorities broad, general powers to prohibit abusive conduct. In most countries, the law identifies specific behaviors that are considered anticompetitive abuses of a dominant position. Bradford and Chilton (2018) compute an overall index, *Abuse of Dominance*, that measures the extent to which competition laws limit the ability of dominant firms to abuse their market positions in uncompetitive ways.

Abuse of Dominance is the summation of eleven components. *General Prohibition* equals two if the country's competition law gives the authorities broad, general powers to prohibit abusive conduct. This type of blanket prohibition gives authorities discretion over what constitutes abusive conduct by a dominant company, which is why Bradford and Chilton (2018) give it a weight of two.[9] The next eight components of *Abuse of Dominance* involve laws prohibiting specific behaviors that are generally viewed as abusive when dominant firms perform them. *Market Access* equals 0.25 if the country's competition law prohibits a firm from limiting the supply of its goods or services to the market or restricting sales to downstream purchasers or consumers. *Tying* equals 0.25 if the law prohibits conditioning the sale of a product on the sale or acquisition of another product that is not directly connected. *Discounts* equals 0.25 if the law prohibits a dominant firm from offering discounts that incentivize the buyer to deal exclusively or predominantly with the dominant firm. *Discriminatory Pricing* equals 0.25 if the law prohibits setting different prices for the same products for different

[9] We made one adjustment in constructing *Abuse of Dominance*. We redefined *General Prohibition*. In the original version, *General Prohibition* equals two if the law prohibits the abuse of a dominant position, either generically or by specifying actions that would constitute an impermissible abuse of a dominant position. We redefined *General Prohibition* as equal to two if the law prohibits the abuse of a dominant position generically, and equal to zero if the law enumerates any types of abusive action. Our results remain robust if we use the original definition of *General Prohibition*.

customers. *Unfair Pricing* equals 0.25 if the law prohibits setting the product's price at a supra-competitive level. *Predatory Pricing* equals 0.25 if the law prohibits setting prices below the costs of production to eliminate competitors. *Retail Price Maintenance* equals 0.25 if the law prohibits setting a minimum resale price at which retailers will ultimately sell their product to consumers. *Other Abusive Acts* equals 0.25 if the law prohibits firms from engaging in acts—other than those specified above—that abuse a firm's dominant position.

The next two components of *Abuse of Dominance* incorporate information on the degree to which firms can defend actions that would otherwise be classified as abusive actions. *Efficiency Defense (Dom.)* equals -0.5 if firms can argue that the actions will enhance economic efficiency enough to outweigh adverse effects from those abuse actions. This enters negatively because such a defense reduces regulatory power over behaviors by a dominant firm. Similarly, *Public Interest Defense (Dom.)* equals -0.5 if a country's competition laws allow dominant firms to defend abusive behaviors based on the argument that the public interest benefits outweigh the costs of those actions.

3.4 Anticompetitive Agreements

Competition laws often limit the ability of firms to form cartels and collude in setting prices, dividing-up markets, limiting supply, rigging bids, and engaging in other activities designed to limit competition. The *Anticompetitive Agreements* index is designed to measure the degree to which a country's competition laws prohibit firms from colluding—both horizontally and vertically—to constrain competition.

In particular, *Anticompetitive Agreements* is the summation of ten components. The first four involve laws limiting horizontal agreements. *Price Fixing*, *Market Sharing*, *Output Limitations*, and *Bid Rigging* each equals 0.5 if a country's competition laws limit firms from colluding to (1) set market prices for a product, (2) divide the market along geographic, demographic, price, or other dimensions, (3) limit the overall supply of products, and (4) bid on products and contracts to obtain preferential prices, respectively. The next four components of the *Anticompetitive Agreements* index focus on limiting vertical agreements. *Exclusive Dealing*, *Resale Price Maintenance*, *Tying*, and *Eliminate Competitors* each equals 0.5 if a

country's laws prohibit firms from colluding to (1) not sell/buy their products to/from specific companies or groups of companies, (2) set the price at which retailers will ultimately sell the product to consumers, (3) condition contracts on buying additional products that are not directly connected to the product that is the subject of the contract, and (4) engage in coercive practices that eliminate competitors or make it very difficult for them to increase market share.

Finally, as above, the last two components of *Anticompetitive Agreements* involve defenses that firms can employ against accusations that they entered into anticompetitive agreements. *Efficiency Defense (Anti.)* equals -0.5 if firms can defend anticompetitive agreements by arguing that the economic efficiency gains outweigh the costs of those agreements. Similarly, *Public Interest Defense (Anti.)* equals -0.5 if a country's competition laws allow firms to defend anticompetitive actions by arguing that the public interest benefits of those actions outweigh the costs.

3.5 Competitive Law Index (CLI)

Following Bradford and Chilton (2018), we construct an overall *Competition Law Index* from these four sub-indexes. Bradford and Chilton (2018) assign a weight of 50% to *Authority* and a weight of 16.67% to each of the other three indexes: *Merger Control*, *Abuse of Dominance*, and *Anticompetitive Agreements*. Since the exact weighting is arbitrary, we (1) follow their weighting and (2) explore the relationship between innovation and each of the four sub-indexes of the *Competition Law Index*, which addresses concerns with this particular weighting.

3.6 Summary statistics on the *Competition Law Index* and Innovation

To illustrate the broad relationship between the stringency of competition laws and innovation, we plot the number of patents and citations against the *Competition Law Index* in Figure 1. Each observations represents one country. The number of patents is defined as average number of patents in a country over period 1990 – 2015, while the number of citations is the average number of citations in a country over the period 1990 – 2015. In particular, we first calculate the total number of patents (citations) in each country across all industries in a

year using data from PATSTAT. We then compute the average annual number of patents (citations) for each country over the 1990 – 2015 period. As shown, there is a positive correlation between the stringency of competition laws (as measured by the *Competition Law Index*) and innovation (as measured by the number of patents and the impact of those patents). Since many confounding factors could account for these patterns, we now provide firm-level and then industry-country level analyses of the relationship between the *Competition Law Index* and our patent-based innovation measures.

4. Firm-Level Results

4.1 Empirical Strategy

To evaluate the relationship between national competition laws and firm innovation, we begin with the following regression specification.

$$Innovation_{f,c,t} = \alpha_0 + \beta \times Competition\ Law\ Index_{c,t} + \gamma \boldsymbol{X}'_{f,c,t-1} + \delta_f + \delta_{ind,t} + \varepsilon_{f,c,t}, \quad (1)$$

where *f*, *c*, and *t* index firm, country, and year, respectively. The dependent variable, $Innovation_{f,c,t}$, represents one of the patent-based measures of innovation for firm *f* in country *c* in year *t* defined in Section 2. The key explanatory variable, $Competition\ Law\ Index_{c,t}$ denotes the *Competition Law Index* in country *c* in year *t*. In robustness tests reported below, we separately examine the sub-indexes of the *Competition Law Index* (*Authority*, *Merger Control*, *Abuse of Dominance*, and *Anticompetitive Agreements*). $X'_{f,c,t-1}$ denotes a set of one-year-lagged time-varying firm characteristics (*Firm size*, *Leverage*, *Profitability*, and *Age*) and country traits (*GDP per capita*, *Credit/GDP*, and *Stock/GDP*). We include firm (δ_f) and industry-by-year ($\delta_{ind,t}$) fixed effects. In this way, our analyses account for all unobservable time-invariant firm characteristics (and hence for time-invariant country effects) and time-varying industry influences. The firm-level analyses cover the period from 1991 through 2015 for over 1.4

million firm-year observations.[10] We estimate Equation (1) using ordinary least squares (OLS) and cluster the standard errors at the country level since competition laws are defined at the country level.

4.2 Validity Test

One potential challenge to drawing confident inferences about the influence of competition laws on innovation is reverse causality: changes in innovation among firms in an economy could trigger changes in its competition laws. As a first step toward addressing this concern, we examine whether innovation predicts changes in competition laws using the following regression equation.

$$Competition\ Law\ Index_{c,t} = \alpha_0 + \beta \times Innovation_{c,t-1} + \gamma \boldsymbol{X'_{c,t-1}} + \delta_c + \delta_t + \varepsilon_{c,t}, \quad (2)$$

where the *Competition Law Index* and **X'** are the same as in equation (1). $Innovation_{c,t-1}$ is the average value of one of the innovation measures across firms in country *c* in year *t-1*. We include country (δ_c) and year (δ_t) fixed effects to account for any unobservable time-invariant country characteristics and time effects. We estimate Equation (2) using ordinary least square (OLS), with standard errors clustered at the country level.

As shown in Table 2, we find no evidence that innovation predicts changes in competition laws. The lagged patent-based innovation measures enter the regressions with estimated coefficients that are insignificantly different from zero. These findings are consistent with the view that changes in firms' innovative activity do not drive changes in competition laws, reducing reverse causality concerns.

[10] The *Competition Law Index* is available until 2010. Given that the *Competition Law Index* is relatively stable within a country, we use the value of 2010 for the period of 2011 – 2015. Our findings hold when using a sample period from 1991 to 2010.

4.3 Firm Innovation

Table 3 presents our initial examination of the relationship between national competition laws and firm innovation. The dependent variable, *Patent Count*, is a simple measure of the number of eventually-granted patents filed by a firm in a given year. The main explanatory variable, *Competition Law Index*, gauges the overall stringency of a country's competition laws.

As shown, the *Competition Law Index* enters positively and significantly in all specifications. The results are robust to conditioning on firm and year fixed effects (column 1) or firm and industry-year fixed effects (column 2). The results also hold when limiting the sample to manufacturing firms (column 3), which Moshirian et al. (2019) find are the most innovative industries. The estimated coefficients are similar in magnitude across each specification.

The estimated coefficients on *Competition Law Index* suggest an economically meaningful relationship between competition laws and firm-level innovation as measured by *Patent Count*. For example, the estimates from column 2 indicate that a one standard deviation increase in the *Competition Law Index* would increase the number of patents by about 4% (=0.1638*0.242).

We next examine the connections between competition laws and firm-level measures of patent quality. That is, we move beyond simply measuring the quantity of patents (*Patent Count*) and measure the impact of a firm's patents using five citation-based indicators: (1) the total number of forward citations received by a firm's eventually granted patents (*Citation*), (2) the average number of citations per patent (*Cit/Pat*), (3) the total number of patents that have received at least one citation (*Cited Patent*), (4) the total number of patents whose citations fall in the top quartile of the citation distributions (*Top Cited Patent*), and (5) the number of explorative patents (*Explorative Patent*).

The estimation results reported in Table 4 suggest that with stricter competition laws, firms produce higher impact and more explorative patents. Firms operating in countries that have more intensive competition laws tend to produce patents with greater impact as measured by the total number of citations (*Citation*), the average number of citations per patent (*Cit/Pat*),

and the number of high impact patents (*Top Cited Patent*). For example, the coefficient estimates from columns 1, 2 and 4 indicate that if the *Competition Law Index* increases by one standard deviation, *Citation* would rise by 11% (=0.443*0.242), *Cit/Pat* would rise by 7% (=0.2735*0.242), and *Top Cited Patent* would rise by 2% (=0.087*0.242). Furthermore, the *Competition Law Index* is positively associated with the extent to which patents are ever cited. The coefficient estimate in column 3 indicates that a one-standard-deviation increase in a country's *Competition Law Index* will raise the number of patents that are ever cited (*Cited Patent*) by 4% (=0.1751*0.242). Also note positive connection between *Competition Law Index* and the extent to which firms engage in explorative innovation, as measured by *Explorative Patent*. In particular, the estimated coefficients in column 5 suggest that a one standard deviation increase in *Competition Law Index* will increase *Explorative Patent* by 3% (=0.1303*0.242).

4.4 Acquisition of Innovation

Firms can obtain patents both by creating them in-house and acquiring them from others. One unique feature of our database is that it contains information on patent transactions worldwide. We use these data to explore the relationship between the stringency of competition laws and (1) firms' acquisition of patents, (2) the relative degree to which firms obtain patents by acquiring them or developing them in-house, and (3) the types of innovations acquired from other firms. More specifically, we evaluate the effect of the *Competition Law Index* on (a) the acquisition of patents, (b) the ratio of acquired to self-developed patents, and (c) the extent to which firms acquire more explorative patents and patents from different industries.

We begin in Table 5 by examining the relationship between the stringency of competition laws and the acquisition of patents. As shown in column (1), greater values of *Competition Law Index* are associated with (a) a significant increase in both the total number of patents acquired (*Patent Acquired*). The results are consistent with the view that more stringent competition laws spur firms to acquire more patents.

We next focus on the ratio of acquired to self-developed patents. As shown in column (2) of Table 5, we discover that more stringent competition laws reduce the ratio of acquired

to self-generated innovation. While increases in the *Competition Law Index* boost (a) the acquisition of patents (columns 1) and (b) the in-house development of patents (Tables 3 and 4), more stringent competition laws disproportionately boost the rate of in-house innovation. As shown, *Competition Law Index* enters negatively and significantly when the dependent variable is *Patent Acquired Ratio*. This evidence suggests that, as competition intensifies, firms choose to do relatively more in-house technological development, reducing their comparative reliance on other firms for innovation. This shift could reflect increased difficulties in acquiring or leasing technologies from rival firms as competition intensifies.

Finally, we turn to the impact of competition laws on the types of innovations that firms acquire from other firms. In particular, we examine *Explorative Patent Acquired Ratio*, which gauges the ratio of acquired explorative patents to acquired exploitative patents, and *Intra-industry Patent Acquired Ratio* measures the extent to which firms make intra-industry versus inter-industry patent acquisitions. These two measures allow us to shed empirical light on whether the nature of patent acquisitions changes when competition laws change. Columns (3) and (4) of Table 4 show that a higher *Competition Law Index* is associated with a significant increase in *Explorative Patent Acquired Ratio* and a significant decrease in *Intra-industry Patent Acquired Ratio*: more stringent competition laws are associated with firms acquiring more explorative (relative to exploitative) patents and acquiring a higher ratio of patents from other industries relative to intra-industry acquisitions. Taken together, the evidence suggests that intensified competition creates an impediment to using technologies developed by industrial peers, encouraging more explorative patents and more inter-industry patent acquisitions.

4.5 Robustness

We were concerned that changes in a country's competition laws could happen simultaneously with changes in other laws, regulations, and policies. By omitting these other variables from the analyses, we might be misinterpreting the results above as reflecting the impact of competition laws on innovation when the results are driven by these omitted factors. We address this omitted variable concern in two key ways. We now discuss a control function

approach. Below, we differentiate across industries so that we can include country-year fixed effects.

For the control function approach, we condition on three policy indicators: *Financial Reform Index*, *PR & Legal Index*, and *Patent Law*. *Financial Reform Index* is an aggregate index of the degree to which a country's laws and regulations foster competition, the setting of market prices, private ownership, and liberalization more generally in the financial sector. This index, which was developed by Abiad, Detragiache, and Tressel (2010), includes information on credit controls, interest rate controls, capital controls, entry barriers, bank privatization, and the regulation of banks and securities markets and the extent of liberalization of the financial market. The *Financial Reform Index* ranges from 0 to 27, with higher values indicating fewer restrictions on a country's financial markets. *PR & Legal Index* is a measure of the overall strength of a country's system for protecting private property rights and fostering the rule of law and the effective enforcement of contracts. The *PR & Legal Index* was created by Gwartney, Lawson, and Hall (2015) for the Fraser Institute and includes information on (a) protecting private property rights and effectively enforcing contracts, (b) judicial independence, impartiality, and integrity, as well as the reliability of the police and military influence over the rule of law, (c) regulatory restrictions on the sale of real property, and (d) cost of crime to businesses. The index ranges from 0 (weakest) to 10 (strongest). *Patent Law* is an indicator that equals one in the years after a country enacts its first patent law, and zero otherwise. We obtain *Patent Law* from World Intellectual Property Organization (WIPO) Lex Database. Appendix A provides detailed definitions for these variables.

As shown in Table 6, the results are robust to conditioning on these additional policy reform indicators. *Competition Law Index* continues to enter positively and significantly in regressions where the dependent variable is (1) the quantity (*Patent Count*) or patents, (2) the quality of patents as measured by either *Citation* or *Top Cited Patent*, or (3) the explorative nature of patents as measured by *Explorative Patent*. In addition, the coefficient estimate on the *Competition Law Index* score is negative and statistically significant in the regression of *Patent Acquired Ratio*, suggesting that competition law stringency boosts the intensity of self-developed patents more than patent acquisition. The economic magnitudes of the coefficients

become slightly smaller than those from the baseline results but remain statistically and economically significant, and most of the coefficient estimates are within one standard deviation of those reported in Tables 3-5 and all are well within two standard deviations. These results mitigate concerns that the association between the competition law and innovative activities is driven by simultaneous changes of other policies.

4.6 The Sub-Components of the Competition Law Index

So far we have examined an overall index of competition laws, the *Competition Law Index*, which is composed of data on (1) authority, (2) laws limiting mergers, (3) laws prohibiting anticompetitive agreements among firms, and (4) laws limiting the ability of firms to abuse their dominant positions in a market to restrict competition. We now separately examine the association between firm innovation and each of the sub-indexes of *Competition Law Index*: *Authority*, *Merger Control*, *Abuse of Dominance* and *Anticompetitive Agreements*. Table 7 presents the results.

As shown in Panel A and B, the findings on the overall index of competition laws also hold for the individual sub-indexes *Authority*, *Merger Control*, and *Anticompetitive Agreements*. Each of these sub-indexes enters positively and significantly in the regressions where the dependent variable is *Patent Count*, *Citation*, *Top Cited Patent*, or *Explorative Patent*, and they enter negatively in the regression where the dependent variable is the *Patent Acquired Ratio*. These results are consistent with the view that competition laws that (a) grant greater authority to the antitrust regime, (b) contain a broader range of provisions regulating mergers, and (c) more stringently limit horizontal and vertical agreements between companies foster technological innovation and increase self-developed patents relative to the acquisition of patents from others.

Since the results in Panels A-B of Table 7 also demonstrate that the sub-index, *Abuse of Dominance*, enters insignificantly across all of the five regressions, we dig deeper into the components of *Abuse of Dominance* to explore the reasons underlying the findings on *Abuse of Dominance*. As constructed by Bradford and Chilton (2018), *Abuse of Dominance* is composed of (1) *Prohibition (Dom.)*, which accounts for the extent to which laws prohibit a

firm from abusing its dominant market position (i.e., it is the summation of *General Prohibition*, *Market Access*, *Tying*, *Discounts*, *Discriminatory Pricing*, *Unfair Pricing*, *Predatory Pricing*, *Retail Price Maintenance*, *Other Abusive Acts*), (2) *Efficiency Defense (Dom.)*, which measures whether firms can argue that the economic efficiency benefits from abusive actions dominate the anticompetitive costs of those actions, and (3) *Public Interest Defense (Dom.)*, which measures whether firms can argue that the public interest benefits of abusive actions outweigh the adverse anticompetitive effects.

Dividing *Abuse of Dominance* into its components highlights a potential explanation for why the overall *Abuse of Dominance* index is not strongly correlated with innovation: exploiting the dominant position created by a patent might be one mechanism that firms use to maximize the returns from innovation, so that limiting such "abuse" could reduce investment in innovation and hence future patenting. From the perspective of maximizing patent-based innovation, therefore, a legal system that allows firms to exploit their dominant positions based on efficiency considerations could boost innovation. Thus, in Panels C and D of Table 7, we examine the association between the sub-components of *Abuse of Dominance* (namely *Prohibition (Dom.)*, *Efficiency Defense (Dom.)*, and *Public Interest Defense (Dom.)*) and firm-level measures of innovation.

Consistent with the view that allowing firms to exploit their positions of dominance for economic efficiency reasons boosts innovation, we find that *Efficiency Defense (Dom.)* enters positively and significantly at the 1% level in the regressions of *Patent*, *Citation*, *Top Cited Patent* and *Explorative Patent*, and negatively and significantly in the regression of *Patent Acquired Ratio*. These findings suggest that the presence of an efficiency defense for actions that would otherwise be classified as abusive enhances corporate inventive activities.

4.7 Cross-Industry Heterogeneity

We next differentiate firms by whether they are in more or less "innovative-intensive" industries. As in Levine, Lin, and Wei (2017), and other cross-firm studies of innovation, we conjecture that if more stringent competition laws spur innovation, the effects should be stronger among firms in more innovative-intensive industries. To measure innovative-intensive,

we use the Eurostat definition of high-technology industries: (a) basic pharmaceutical products and pharmaceutical preparation and (b) computer, electronics, and optical products. [11] We then define *High-tech* as a dummy variable that equals one if a firm belongs to a high-technology industry and zero otherwise.

We evaluate whether more stringent competition laws spur innovation more among firms in innovative intensive industries by modifying equation (1) and including interaction between the *Competition Law Index* and *High-tech*. In particular, we use the following specification that allows us condition out time-varying country factors, including laws, policies, and regulations.

$$Innovation_{f,c,t} = \alpha_0 + \beta \times Competition\ Law\ Index_{c,t} \times High\ Tech_j + \gamma \boldsymbol{X'}_{f,c,t-1} + \delta_f + \delta_{j,t} + \delta_{c,t} + \varepsilon_{f,c,t}, \quad (3)$$

where *f*, *j*, *c*, and *t* index firm, industry, country, and year, respectively. *High Tech*$_j$ denotes the indicator of whether firm *f* in industry *j* belongs to a high-technology industry. Other variables have the same definition as in Equation (1) above. The coefficient of interest, β, captures the differential impact of the *Competition Law Index* on firms in innovative-intensive industries. In addition to firm (δ_f) and industry-by-year ($\delta_{ind,t}$) fixed effects, we include country-by-year fixed effects ($\delta_{c,t}$), which conditions out time-varying country characteristics. Note that these fixed effects subsume the linear terms, i.e., *Competition Law Index* and *High Tech*. We estimate Equation (3) using OLS regression and cluster the standard errors at the country level.

Consistent with the view that more stringent competition laws spur innovation more among firms in more innovative-intensive industries, we find that the interaction term, *Competition Law Index* * *High-Tech*, enters positively and significantly at the 1% level when the dependent variable is either *Patent Count*, *Citation*, or *Top Cited Patent*, or *Explorative Patent*, as reported in Table 8 (columns 1 – 3). We also find that the *Competition Law Index* has an especially large, positive effect on the degree to which firms engage in explorative

[11] The classification of high-tech and knowledge intensive industries is available at: https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

innovations (*Explorative Patent*) and an especially large, negative impact on the extent to which firms acquire rather than create patents in-house (*Patent Acquired Ratio*). These cross-firm analyses allow us to condition out time-varying country characteristics, confirm the results in Tables 3-6, and hence mitigate omitted variable concerns.

5. Country-Industry-Level Results

We complement these firm-level analyses with an industry-country level investigation. The industry-country level investigation covers a much longer period, 1888 (the first year that the *Competition Law Index* is available) through 2015 and includes a cross-section of 186 countries. In particular, we estimate the following regression:

$$Innovation_{j,c,t} = \alpha_0 + \beta \times Competition\ Law\ Index_{c,t} \times High\ Tech_j + \delta_{c,j} + \delta_{j,t} + \delta_{c,t} + \varepsilon_{j,c,t}, \quad (4)$$

where j, c, and t denote industry (2-digit SIC), country, and year, respectively. The dependent variable, $Innovation_{j,\,c,\,t}$, is one of the patent-based measures of innovation of industry j in country c in year t defined in Section 2. The key explanatory variable is the interaction between the $Competition\ Law\ Index_{c,t}$ and $High\ Tech_j$, where $High\ Tech_j$ represents the indicator of whether industry j is classified as a high-technology industry or not. For each industry at the two-digit SIC level, we define high-tech industries using the average growth rate of R&D expenditures of U.S. firms over the period from 1950 through 2010 (see, e.g., Hsu et al., 2014; Levine et al., 2017). *High-tech* equals one if the average growth rate is greater than the sample median value and zero otherwise.[12] We include the full array of possible fixed effects for this level of analysis: country-by-industry ($\delta_{c,j}$), industry-by-year ($\delta_{j,t}$), and country-by-year ($\delta_{c,t}$)

[12] We use a different definition of High-tech industries in the firm-level and country-industry level data for the following reason. The industry code in the Orbis firm-level data is NACE, and Eurostat defines industries as high-tech based on NACE. In contrast, the country-industry data are from PATSTAT, which defines industries using the SIC coding.

fixed effects. We estimate the model using the OLS regression and cluster the standard errors at the country level.

The estimation results at the country-industry-year level reported in Table 9 confirm our earlier findings based on firm-level measures of innovation. The coefficient estimates on the interaction term, *Competition Law Index * High-Tech*, are positive and statistically significant in all columns, suggesting that the positive relationship between stricter competition laws and innovation are particularly strong among innovation-intensive industries. The differential effects are economically meaningful. The estimated coefficients in column 1, for example, imply that a one-standard-deviation increase in a country's *Competition Law Index* would raise the number of patents among firms in the high-technology group by almost 4 percentage points more than that of the low-technology group (=0.1593*0.242).

6. Conclusion

We examined the impact of competition laws on innovation. To conduct this study, we (1) used a new, comprehensive dataset on competition laws, (2) created a large, international firm-level panel dataset with detailed information on patenting activity and financial accounts, and (3) assembled novel data on firms' acquisition of patents from other firms. These unique data allow us to evaluate the impact of different competition laws on a multiplicity of firm-level patenting activities, including the number of patents, the impact of those patents as measured by forward citations, the explorative nature of those patents, the acquisition of patents, and the relative importance of self-developed and acquired patents.

We discovered a tight connection between competition laws and firm innovation. First, more stringent competition laws are associated with sharp increases in firm innovation, as measured by the number of patents, forward citations to patents, citations per patent, the number of very highly cited patents, and the number of explorative patents. Second, more stringent competition is also tightly linked with the firms' acquisition of patents from other firms. Specifically, we find that competition law stringency is associated with significant increases in (a) the total number of patents acquired, the citation-impact of those patents, and the explorative nature of those acquired patents and (b) the ratio of self-generated to acquired

patents, competition law stringency disproportionately boosts the rate of self-developed patents. These results are robust to several robustness tests and extensions. For example, we confirm that these results hold when (a) differentiating by firms so that we can condition on country-year effects to mitigate omitted variable concerns, (b) examining the sub-component of the overall competition law stringency index, and (c) employing an industry-country panel that covers the period from 1888 through 2015 and includes 186 countries.

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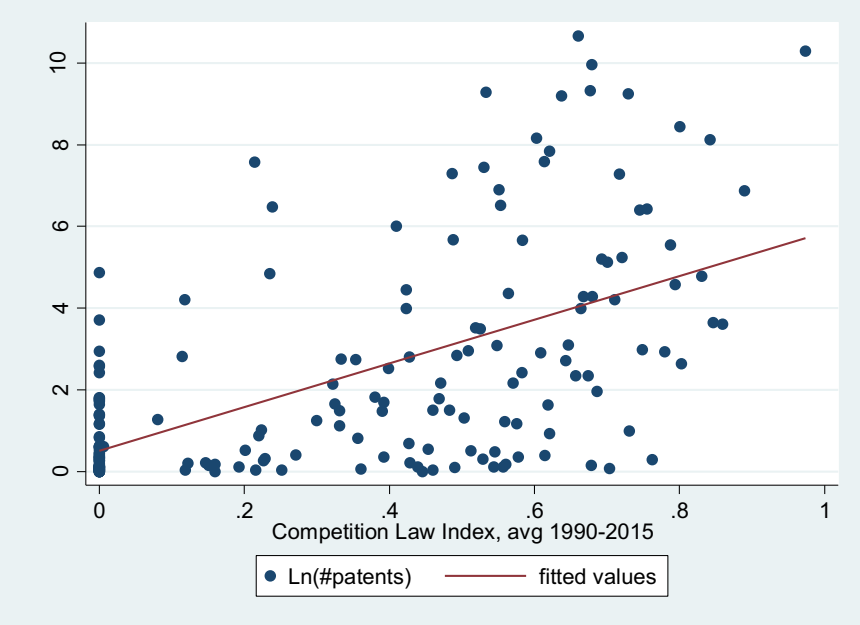
Figure 1. Cross-country innovation and CLI, 1990 – 2015

These figures plot (a) the average annual number of patents filed by entities from each country and (b) the average annual number of forward citations to patents filed by entities from each country against the average value of the *Competition Law Index*. The averaging is done over the years from 1990 through 2015. That is, we first calculate the total number of patents (citations) in each country in a year and then compute the average number of patents (citations) for each country over 1990 – 2015. Each dot represents one country.

(a1) # of Patents



(b1) # of Citations

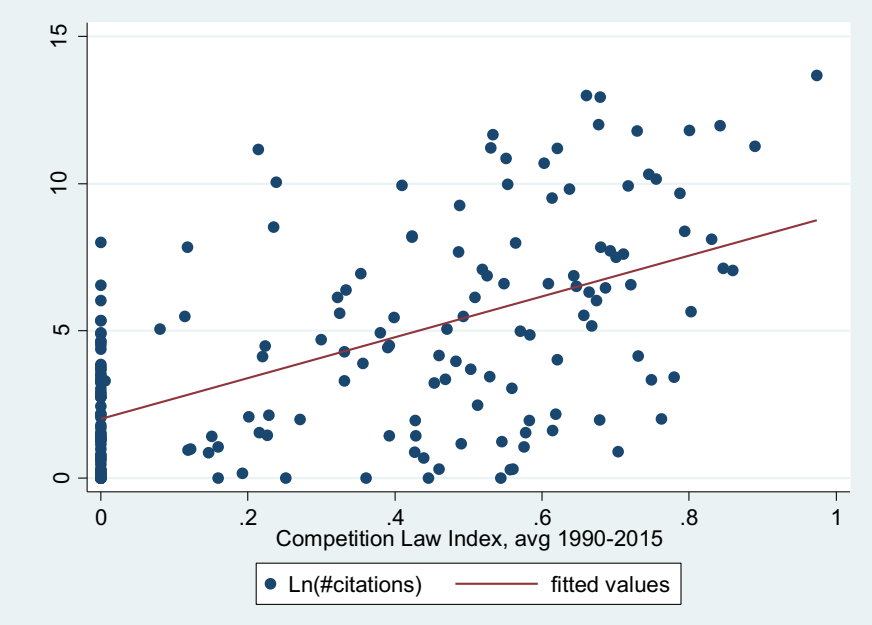


Table 1 Summary Statistics

This table presents the summary statistics of the variables used in our analysis. Statistics for firm-level variables are calculated based on the firm-level sample during 1991-2015; statistics for country-level and country-industry-level variables are based on the broadest country-industry level sample from 1888 to 2015.

Variable	N	Mean	Std. Dev.	P10	P50	P90
Innovation Measures						
Firm Level (log)						
Patent Count	1410369	0.2010	0.5598	0	0	0.6931
Citation	1410369	0.3405	1.1290	0	0	1.152
Cit/Pat	1410369	0.2487	0.8042	0	0	0.8513
Cited Patent	1410369	0.1160	0.4244	0	0	0.6931
Top Cited Patent	1410369	0.0490	0.2744	0	0	0
Explorative Patent	1410369	0.1148	0.3828	0	0	0
Patent Acquired	1410369	0.0180	0.1828	0	0	0
Patent Acquired Ratio	1410369	-0.1830	0.5345	-0.6931	0	0
Explorative Patent Acquired Ratio	1410369	0.0091	0.1334	0	0	0
Intra-industry Patent Acquired Ratio	1410369	-0.0097	0.1428	0	0	0
Firm Level (non-log)						
Patent Count	1410369	1.344	34.2	0	0	1
Citation	1410369	30.340	1296	0	0	2.165
Cit/Pat	1410369	2.217	25.280	0	0	1.343
Cited Patent	1410369	0.682	21.610	0	0	1
Top Cited Patent	1410369	0.229	7.628	0	0	0
Explorative Patent	1410369	0.267	1.055	0	0	0
Patent Acquired	1410369	0.109	5.284	0	0	0
Firm characteristics						
Firm Size	1410369	8.7550	2.3500	5.855	8.709	11.79
Leverage	1410369	0.1685	0.2343	0	0.0807	0.4565
Profitability	1410369	0.0367	0.2129	-0.08961	0.04196	0.2056
Age	1410369	2.6540	0.9828	1.386	2.708	3.892
Country-Industry Level (log)						
Patent-Ind	509727	0.3990	0.9200	0	0	1.5834
Citation-Ind	509727	0.6577	1.4651	0	0	2.8779
Top Cited Patent-Ind	509727	0.1489	0.4363	0	0	0.4266
Explorative Patent-Ind	423062	0.3281	0.7956	0	0	1.2368
Country-Industry Level (non-log)						
Patent-Ind	509727	2.4965	8.4534	0	0	3.8717
Citation-Ind	509727	15.9127	58.1251	0	0	16.7760
Top Cited Patent-Ind	509727	0.3568	1.2314	0	0	0.5320
Explorative Patent-Ind	423062	1.6425	5.7977	0	0	2.4447
CLI score and other country characteristics						
Competition Law Index	927	0.6151	0.242	0.2212	0.6538	0.875
Authority	927	0.6407	0.2528	0.2857	0.6429	0.9286
Merger Control	927	0.5736	0.2895	0.125	0.625	0.875
Abuse of Dominance	927	0.6492	0.2478	0.3636	0.7273	0.9091
Anticompetitive Agreements	927	0.578	0.2439	0.3	0.6	0.9

GDP per capita	927	9.659	1.138	8.011	9.978	10.82
Credit/GDP	927	105.2	63.84	38.9	96.1	179
Stock/GDP	927	66.06	56.71	14.4	48.4	143

Table 2 Competition Law and Preexisting Innovation

This table reports the connection between pre-existing measures of innovation and the competition law index. The dependent variable, *Competition Law Index*, measures the overall stringency of a country's competition laws. The key explanatory variables are one-year-lagged measures of innovation, *Patent Count*, *Citation*, *Top Cited Patent*, *Explorative Patent*, and *Patent Acquired Ratio*, averaged across each country. Country controls include GDP per capita, Credit/GDP and Stock/GDP. We include country and year fixed effects. Robust standard errors clustered at the country level are reported in parentheses. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Dependent Var.	Competition Law Index				
	(1)	(2)	(3)	(4)	(5)
Patent Count	0.0211				
	(0.038)				
Citation		0.0099			
		(0.011)			
Top Cited Patent			0.0467		
			(0.075)		
Explorative Patent				0.0271	
				(0.041)	
Patent Acquired Ratio					-0.0122
					(0.024)
GDP per capita	0.1128	0.1176	0.1150	0.1143	0.1172
	(0.106)	(0.109)	(0.110)	(0.107)	(0.110)
Credit/GDP	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Stock/GDP	0.0003	0.0003	0.0003	0.0003	0.0003
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Country FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Observations	1,042	1,042	1,042	1,042	1,042
Adjusted R-squared	0.854	0.855	0.855	0.855	0.854

Table 3 Competition Law and Innovation Intensity

This table presents the effect of competition law on innovation intensity measured at the firm level based on different fixed effects, classifications and time period. The dependent variable, Patent is the measure of innovation intensity using the natural logarithm of one plus the total number of (eventually granted) patents filed by a firm in a given year. Column 3 is based on firms from manufacture industry. The key explanatory variable, *Competition Law Index*, measures the overall stringency of a country's competition laws. Firm-level controls include *Firm Size*, *Leverage*, *Profitability* and *Age*. Country controls include *GDP per capita*, *Credit/GDP* and *Stock/GDP*. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parenthesis. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Dependent Var	Patent Count		
			Manufacturing industries
	(1)	(2)	(3)
Competition Law Index	0.1549***	0.1638***	0.1645***
	(0.038)	(0.035)	(0.039)
Firm Size	0.0337***	0.0337***	0.0454***
	(0.006)	(0.006)	(0.008)
Leverage	-0.0094	-0.0098	-0.0091
	(0.010)	(0.009)	(0.017)
Profitability	0.0093	0.0100	0.0251
	(0.011)	(0.011)	(0.016)
Age	-0.0040	-0.0058	-0.0037
	(0.012)	(0.011)	(0.019)
GDP per capita	0.4150***	0.4058***	0.3907***
	(0.073)	(0.062)	(0.063)
Credit/GDP	-0.0005	-0.0004	-0.0007
	(0.000)	(0.000)	(0.001)
Stock/GDP	-0.0002	-0.0003	-0.0003
	(0.000)	(0.000)	(0.000)
Firm FE	Y	Y	Y
Year FE	Y	N	N
Industry-Year FE	N	Y	Y
Observations	1,410,369	1,410,369	793,271
Adjusted R-squared	0.621	0.622	0.624

Table 4 Competition Law and Innovation Quality

This table presents the effect of competition law on innovation quality measured at the firm level. The dependent variables include Citation, Cit/Pat, Cited Patent, Top Cited Patent, and Explorative Patent. Citation is the natural logarithm of one plus the total number of truncation-adjusted forward citations made to patents filed by a firm in a given year. Cit/Pat is the natural logarithm of one plus the number of truncation-adjusted forward citations per patent filed by a firm in a given year. Cited Patent is the natural logarithm of one plus the total number of patents with at least one citation, which are filed by a firm in a given year. Top Cited Patent is the natural logarithm of one plus the total number of patents at firm-year level whose citations fall in the top 25% of citation distribution across all patents in the same technology class in the same year. Explorative Patent is the natural logarithm of one plus the total number of (eventually granted) explorative patents filed by a firm in a given year. A patent is defined as explorative if at least 60% of the citations it refers are not from its existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years. The key explanatory variable, *Competition Law Index*, measures the overall stringency of a country's competition laws. Firm-level controls include *Firm Size*, *Leverage*, *Profitability* and *Age*. Country controls include *GDP per capita*, *Credit/GDP* and *Stock/GDP*. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Dependent Var	Citation	Cit/Pat	Cited Patent	Top Cited Patent	Explorative Patent
	(1)	(2)	(3)	(4)	(5)
Competition Law Index	0.4430***	0.2735***	0.1751***	0.0870***	0.1303***
	(0.073)	(0.052)	(0.038)	(0.016)	(0.036)
Firm Size	0.0497***	0.0328***	0.0180***	0.0085***	0.0236***
	(0.007)	(0.004)	(0.003)	(0.001)	(0.005)
Leverage	-0.0201	-0.0144	-0.0061	-0.0029	-0.0052
	(0.013)	(0.010)	(0.004)	(0.003)	(0.008)
Profitability	0.0034	0.0015	0.0036	-0.0026	0.0002
	(0.022)	(0.016)	(0.009)	(0.003)	(0.004)
Age	-0.0116	-0.0113	0.0057	0.0000	0.0048
	(0.016)	(0.009)	(0.007)	(0.004)	(0.011)
Country Control	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y
Observations	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369
Adjusted R-squared	0.498	0.341	0.603	0.636	0.549

Table 5 Competition Law and Patent Acquisition

This table presents the connections between competition laws and firm-level measures of patent acquisition. We use eight patent acquisition measures, *Patent Acquired*, *Patent Acquired Ratio*, *Explorative Patent Acquired Ratio*, and *Intra-industry Patent Acquired Ratio*. The key explanatory variable, *Competition Law Index*, measures the overall stringency of a country's competition laws. Firm-level controls include *Firm Size*, *Leverage*, *Profitability* and *Age*. Country controls include *GDP per capita*, *Credit/GDP* and *Stock/GDP*. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Dependent Var	Patent Acquired	Patent Acquired Ratio	Explorative Patent Acquired Ratio	Intra-industry Patent Acquired Ratio
	(1)	(2)	(3)	(4)
Competition Law Index	0.0337***	-0.1301***	0.0126***	-0.0203***
	(0.006)	(0.032)	(0.004)	(0.005)
Firm Size	0.0054***	-0.0284***	0.0031***	-0.0024***
	(0.001)	(0.006)	(0.001)	(0.001)
Leverage	0.0017	0.0115	0.0011	-0.0026**
	(0.001)	(0.008)	(0.001)	(0.001)
Profitability	-0.0029*	-0.0129	-0.0017	0.0026**
	(0.002)	(0.010)	(0.001)	(0.001)
Age	-0.0092***	-0.0034	-0.0053***	0.0042**
	(0.003)	(0.014)	(0.002)	(0.002)
Country Control	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y
Observations	1,410,369	1,410,369	1,410,369	1,410,369
Adjusted R-squared	0.399	0.535	0.205	0.227

Table 6 Competition Law and Innovation: Robustness to Policy Reform

This table shows the effect of competition law on innovation conditional on a series of other policy reforms. We include Financial Reform Index, which measures the overall financial liberalization, PR & Legal Index, which measures the overall strength of legal system and property rights protection, and Patent Law, which equals to one in the years after a country enacts its first patent law, and equals zero otherwise. We focus on five firm-level measures of innovation, namely *Patent Count*, *Citation*, *Top Cited Patent*, *Explorative Patent* and *Patent Acquired Ratio*. The key explanatory variable, *Competition Law Index*, measures the overall stringency of a country's competition laws. Firm-level controls include *Firm Size*, *Leverage*, *Profitability* and *Age*. Country controls include *GDP per capita*, *Credit/GDP* and *Stock/GDP*. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Dependent Var	Patent Count	Citation	Top Cited Patent	Explorative Patent	Patent Acquired Ratio
	(1)	(2)	(3)	(4)	(5)
Competition Law Index	0.1379***	0.3779***	0.0767***	0.1100**	-0.1074***
	(0.035)	(0.062)	(0.014)	(0.043)	(0.034)
Firm Size	0.0337***	0.0494***	0.0085***	0.0236***	-0.0284***
	(0.006)	(0.007)	(0.001)	(0.005)	(0.006)
Leverage	-0.0100	-0.0208*	-0.0031	-0.0053	0.0119
	(0.008)	(0.012)	(0.002)	(0.007)	(0.008)
Profitability	0.0104	0.0044	-0.0025	0.0005	-0.0133
	(0.011)	(0.022)	(0.003)	(0.004)	(0.010)
Age	-0.0056	-0.0105	0.0001	0.0049	-0.0036
	(0.011)	(0.016)	(0.004)	(0.011)	(0.014)
Financial Reform Index	Y	Y	Y	Y	Y
PR & Legal Index	Y	Y	Y	Y	Y
Patent Law	Y	Y	Y	Y	Y
Country Control	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y
Observations	1,405,852	1,405,852	1,405,852	1,405,852	1,405,852
Adjusted R-squared	0.622	0.499	0.636	0.550	0.535

Table 7 Competition Law and Innovation: Sub-index

This table presents the association between sub-components of the CLI score and firm-level measures of innovation. Panel A and B show the relation between each sub-component (i.e., *Authority*, *Merger Control*, *Abuse of Dominance*, and *Anticompetitive Agreements*) and firm innovation. Panel C and D shows the relation between each sub-component of the *Abuse of Dominance* (i.e., *Prohibition (Dom.)*, *Efficiency Defense (Dom.)*, and *Public Interest Defense (Dom.)*) and firm innovation. We focus on five firm-level measures of innovation, namely *Patent Count*, *Citation*, *Top Cited Patent*, *Explorative Patent* and *Patent Acquired Ratio*. The key explanatory variable, *Competition Law Index*, measures the overall stringency of a country's competition laws. Firm-level controls include *Firm Size*, *Leverage*, *Profitability* and *Age*. Country controls include *GDP per capita*, *Credit/GDP* and *Stock/GDP*. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Panel A. Sub-Components of the CLI Score

Dependent Var.	Patent Count				Citation				Top Cited Patent			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Authority	0.1372***				0.3989***				0.0790***			
	(0.047)				(0.109)				(0.024)			
Merger Control		0.0991***				0.2451***				0.0469***		
		(0.017)				(0.052)				(0.011)		
Abuse of Dominance			-0.0012				-0.0039				0.0064	
			(0.045)				(0.088)				(0.014)	
Anticompetitive Agreements				0.1730***				0.3427**				0.0543***
				(0.062)				(0.132)				(0.020)
Firm Size	0.0338***	0.0335***	0.0338***	0.0335***	0.0499***	0.0492***	0.0498***	0.0492***	0.0086***	0.0084***	0.0086***	0.0085***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)	(0.001)	(0.001)	(0.001)	(0.001)
Leverage	-0.0098	-0.0093	-0.0100	-0.0109	-0.0202	-0.0188	-0.0206	-0.0225*	-0.0029	-0.0026	-0.0029	-0.0033
	(0.009)	(0.009)	(0.009)	(0.009)	(0.013)	(0.014)	(0.014)	(0.013)	(0.003)	(0.003)	(0.003)	(0.003)
Profitability	0.0099	0.0102	0.0101	0.0103	0.0032	0.0039	0.0038	0.0042	-0.0027	-0.0025	-0.0025	-0.0025
	(0.011)	(0.011)	(0.011)	(0.011)	(0.022)	(0.022)	(0.022)	(0.022)	(0.003)	(0.003)	(0.003)	(0.003)
Age	-0.0056	-0.0060	-0.0061	-0.0075	-0.0111	-0.0122	-0.0124	-0.0152	0.0001	-0.0001	-0.0002	-0.0006
	(0.011)	(0.011)	(0.012)	(0.011)	(0.016)	(0.016)	(0.017)	(0.016)	(0.004)	(0.004)	(0.004)	(0.004)
Country Control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369
Adjusted R-squared	0.622	0.622	0.621	0.622	0.498	0.498	0.498	0.498	0.635	0.635	0.635	0.635

Panel B. Sub-Components of the CLI Score

Dependent Var.	Explorative Patent				Patent Acquired Ratio			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Authority	0.1086***				-0.1053**			
	(0.031)				(0.042)			
Merger Control		0.0829***				-0.0825***		
		(0.013)				(0.015)		
Abuse of Dominance			0.0170				0.0064	
			(0.031)				(0.042)	
Anticompetitive Agreements				0.1021**				-0.1620***
				(0.046)				(0.058)
Firm Size	0.0237***	0.0235***	0.0237***	0.0235***	-0.0284***	-0.0282***	-0.0284***	-0.0281***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Leverage	-0.0052	-0.0047	-0.0052	-0.0059	0.0115	0.0110	0.0117	0.0125
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.008)
Profitability	0.0001	0.0003	0.0003	0.0004	-0.0128	-0.0130	-0.0130	-0.0132
	(0.004)	(0.004)	(0.004)	(0.004)	(0.010)	(0.010)	(0.010)	(0.010)
Age	0.0050	0.0047	0.0045	0.0038	-0.0035	-0.0032	-0.0032	-0.0019
	(0.011)	(0.011)	(0.011)	(0.011)	(0.014)	(0.014)	(0.014)	(0.013)
Country Control	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369
Adjusted R-squared	0.549	0.549	0.549	0.549	0.535	0.535	0.534	0.535

Panel C. Sub-Components of Abuse of Dominance

Dependent Var.	Patent Count			Citation			Top Cited Patent		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Prohibition (Dom.)	0.0296			0.0658			0.0193*		
	(0.032)			(0.060)			(0.010)		
Efficiency Defense (Dom.)		0.0459***			0.1016***			0.0163***	
		(0.012)			(0.023)			(0.005)	
Public Interest Defense (Dom.)			0.0006			0.0070			0.0046
			(0.012)			(0.023)			(0.003)
Firm Size	0.0338***	0.0333***	0.0338***	0.0498***	0.0487***	0.0498***	0.0085***	0.0084***	0.0085***
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.001)	(0.001)	(0.001)
Leverage	-0.0097	-0.0097	-0.0100	-0.0201	-0.0199	-0.0206	-0.0028	-0.0029	-0.0030
	(0.009)	(0.009)	(0.009)	(0.014)	(0.014)	(0.014)	(0.003)	(0.003)	(0.003)
Profitability	0.0102	0.0103	0.0101	0.0040	0.0042	0.0038	-0.0025	-0.0025	-0.0026
	(0.011)	(0.011)	(0.011)	(0.022)	(0.022)	(0.022)	(0.003)	(0.003)	(0.003)
Age	-0.0064	-0.0068	-0.0061	-0.0132	-0.0140	-0.0125	-0.0004	-0.0004	-0.0002
	(0.012)	(0.011)	(0.012)	(0.017)	(0.017)	(0.017)	(0.004)	(0.004)	(0.004)
Country Control	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369
Adjusted R-squared	0.621	0.621	0.621	0.498	0.498	0.498	0.635	0.635	0.635

Panel D. Sub-Components of Abuse of Dominance

Dependent Var.	Explorative Patent			Patent Acquired Ratio		
	(1)	(2)	(3)	(4)	(5)	(6)
Prohibition (Dom.)	0.0461*			-0.0180		
	(0.025)			(0.030)		
Efficiency Defense (Dom.)		0.0370***			-0.0399***	
		(0.014)			(0.012)	
Public Interest Defense (Dom.)			0.0034			0.0035
			(0.012)			(0.012)
Firm Size	0.0237***	0.0233***	0.0237***	-0.0284***	-0.0280***	-0.0284***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)
Leverage	-0.0050	-0.0051	-0.0053	0.0115	0.0114	0.0116
	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.009)
Profitability	0.0004	0.0005	0.0003	-0.0130	-0.0131	-0.0130
	(0.004)	(0.004)	(0.004)	(0.010)	(0.010)	(0.010)
Age	0.0041	0.0040	0.0045	-0.0030	-0.0025	-0.0032
	(0.011)	(0.011)	(0.011)	(0.014)	(0.014)	(0.014)
Country Control	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y	Y
Observations	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369
Adjusted R-squared	0.647	0.647	0.647	0.534	0.535	0.534

Table 8 Competition Law and Corporate Innovation: Cross-Industry Heterogeneity

This table presents the differential effect of competition law on corporate innovation in high-tech and other industries. High-tech is an indicator variable equal to one if a firm belongs to industries classified as high-tech and knowledge intensive according to the Eurostat guidance, and zero otherwise. We focus on five firm-level measures of innovation, namely *Patent Count*, *Citation*, *Top Cited Patent*, *Explorative Patent* and *Patent Acquired Ratio*. The key explanatory variable, *Competition Law Index*, measures the overall stringency of a country's competition laws, and High-tech is a dummy variable equal to one if a firm belongs to a high-tech industry based on the Eurostat guidance. Firm-level controls include *Firm Size*, *Leverage*, *Profitability* and *Age*. We include firm, industry-by-year, and country-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Dependent Var	Patent	Citation	Top Cited Patent	Explorative Patent	Patent Acquired Ratio
	(1)	(2)	(3)	(4)	(5)
Competition Law Index *High-tech	0.0843***	0.1102***	0.0234***	0.0845***	-0.0615***
	(0.015)	(0.040)	(0.006)	(0.014)	(0.012)
Firm Size	0.0324***	0.0495***	0.0084***	0.0228***	-0.0269***
	(0.006)	(0.007)	(0.001)	(0.005)	(0.006)
Leverage	-0.0205***	-0.0372***	-0.0063**	-0.0127***	0.0203***
	(0.005)	(0.009)	(0.002)	(0.004)	(0.005)
Profitability	0.0131	0.0074	-0.0018	0.0028	-0.0161
	(0.012)	(0.022)	(0.003)	(0.005)	(0.011)
Age	-0.0243***	-0.0351***	-0.0045*	-0.0083	0.0144
	(0.007)	(0.005)	(0.003)	(0.007)	(0.009)
Firm FE	Y	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y	Y
Country-Year FE	Y	Y	Y	Y	Y
Observations	1,410,369	1,410,369	1,410,369	1,410,369	1,410,369
Adjusted R-squared	0.625	0.502	0.638	0.555	0.538

Table 9 Competition Law and Corporate Innovation: Evidence from a Century's Observation, Country-industry-year Sample

This table shows the association between the CLI score and innovation at the country-industry(two-digit SIC)-year panel data, while differentiating industries by the degree of technological intensity. The dependent variables are *Patent Count-Ind*, *Citation-Ind*, *Top Cited Patent-Ind* and *Explorative Patent-Ind* in columns 1, 2, 3, and 4, respectively. High-tech is an indicator variable equal to one if it is a high-technology industry and equals zero otherwise. We define high-technology industry at the country-industry-year level sample as 2-digit SICs with an average industry R&D growth (benchmarked to the U.S.) above the sample median. We include a full set of country-by-industry, industry-by-year, and country-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses. ***, **, * denote significance levels at 1%, 5% and 10% respectively.

Dependent Var.	Patent Count-Ind	Citation-Ind	Top Cited Patent-Ind	Explorative Patent-Ind
	(1)	(2)	(3)	(4)
Competition Law Index *High-tech	0.1593***	0.2768***	0.0887***	0.1436***
	(0.041)	(0.065)	(0.024)	(0.045)
Time Period	1888-2015			
Country-Industry FE	Y	Y	Y	Y
Industry-Year FE	Y	Y	Y	Y
Country-Year EF	Y	Y	Y	Y
Observations	509,727	509,727	509,727	423,062
Adjusted R-squared	0.929	0.896	0.872	0.903

Appendix A. Variable Definition

Variable	Definition	Source
Firm Level		
Patent Count	Log one plus the total number of patents filed by a firm in a given year.	PATSTAT and ORBIS Database
Citation	Log one plus the total number of truncation-adjusted forward citations made to patents filed by a firm in a given year; truncation-adjusted citation count is obtained by weight factors using the average life-time citation distribution of patents estimated within each technology class and application year.	
Cit/Pat	Log one plus the number of truncation-adjusted forward citations per patent filed by a firm in a given year.	
Cited Patent	Log one plus the total number of patents with at least one citation that are filed by a firm in a given year.	
Top Cited Patent	Log one plus the total number of patents at firm-year level whose citations fall in the top 25% of citation distribution across all patents in the same technology class in the same year.	
Explorative Patent	Log one plus the total number of explorative patents filed by a firm in a given year. A patent is defined as an explorative patent if at least 60% of the citations to which it refers are neither to patents that the firm produced during the last five years nor to patents that were cited by the firm's patents filed over the past five years.	
Patent Acquired	Log one plus the total number of patents bought by a firm in a given year.	
Patent Acquired Ratio	Log one plus the total number of patents bought by a firm in a given year minus Log one plus the total number of patents filed by the same firm in the same year.	
Explorative Patent Acquired Ratio	Log one plus the total number of explorative patents acquired by a firm in a given year minus log one plus the total number of exploitive patents acquired by the same firm in that same year. A patent is considered to be exploitative if at least 60% of the citations to which it refers are patents that the firm produced or patents that were cited by the firm's other patents filed over the past five years. An exploitative patent, therefore, is an invention that falls within the firm's historic base of innovative knowledge, while an explorative patent represent an invention that falls outside of that base of innovation.	
Intra-industry Patent Acquired Ratio	Log one plus the total number of patents acquired from firms in the same industry (four-digit NACE level) as the acquiring firm in a given year minus Log one plus the total number of patents acquired from firms in different industries.	

Firm Size	Log the book value of total assets (in thousand USD)	
Leverage	The ratio between non-current liabilities and total assets	
Profitability	The ratio between net income and total assets	
Age	Log of firm's age	
Country-Industry Level		
Patent-Ind	Log one plus the total number of patents at country-industry-year level.	PATSTAT and ORBIS Database
Citation-Ind	Log one plus the total number of truncation-adjusted forward citations made to patents at country-industry-year level; truncation-adjusted citation count is obtained by weight factors using the average life-time citation distribution of patents estimated within each technology class and application year.	
Top Cited Patent-Ind	Log one plus the total number of patents at country-industry-year level whose citations fall in the top 25% of citation distribution across all patents in the same technology class in the same year.	
Explorative Patent-Ind	Log one plus the total number of explorative patents filed by a firm at country-industry-year level. A patent is defined as an explorative patent if at least 60% of the citations it refers are not from existing knowledge, which includes all the patents that the firm produced and all the patents that were cited by the firm's patents filed over the past five years.	
Country Level		
Competition Law Index	The overall competition law index, consisting of Authority, Merger Control, Abuse of Dominance and Anticompetitive Agreements.	Bradford and Chilton (2018)
Authority	An index that captures (1) who can bring suits against firms that are alleged to have engaged in anticompetitive behavior, (2) the remedies that the authorities can impose on firms that violate competition laws, and (3) the scope of the law, i.e., the degree to which all industries and enterprises fall under the purview of a country's competition laws.	
Merger Control	Index of each country's laws in each year with respect to (1) regulating pre-merger notification and approval, (2) granting expansive powers to the authorities to restrict mergers for economic and public interest reasons, and (3) permitting an assortment of arguments by firms to defend mergers and acquisitions and limiting the scope of laws, i.e., the degree to which all industries and enterprises are within the purview of the competition laws.	

Abuse of Dominance	Index of the extent to which competition laws limit dominant firms from abusing their market positions in uncompetitive ways. Abusive behaviors include price and nonprice related conduct, including discriminatory pricing, resale price maintenance, unfair (or excessive) pricing, predatory pricing, and anticompetitive discounts (price-related abuses), as well as tying and refusal to deal (nonprice abuses). The index includes data on firms' abilities to defend actions that would otherwise be classified as abusive on efficiency or public interest grounds.	
Anticompetitive Agreements	An index designed to measure the degree to which a country's competition laws prohibit firms from colluding—both horizontally and vertically—to constrain competition.	
GDP per capita	Log real GDP per capita measured in 2010 U.S. dollar.	World Bank WDI
Credit/GDP	Credit provided by the financial sector as a share of GDP.	
Stock/GDP	Stock-market capitalization as a share of GDP.	
Financial Reform Index	The summation of Credit Control, Interest-Rate Control, Entry Barriers, Bank Supervision, Bank Privatization, Capital Control, and Securities Market. Credit Control measures the restrictiveness of reserve requirements, existence of mandatory credit-allocation requirements, and credit ceilings; Interest-Rate Control measures liberalization of interest rates; Entry Barriers measures the ease of foreign bank entry and the extent of competition in the domestic banking sector; Bank Supervision measures the degree of supervision over the banking sector; Bank Privatization measures the importance of state-owned banks; Capital Control measures restrictions on international capital flows; Securities Market measures the level of development of securities markets and restrictions on foreign equity ownership. The index ranges from 0 to 27, with higher values indicating less restrictive and more liberalized financial markets.	International Monetary Fund (IMF); Abiad, Detragiache, and Tressel (2008)
PR & Legal Index	An index that measures the overall strength of the legal system and property-rights protection. It is the average value of nine components: judicial independence, impartial courts, protection of property rights, military interference in rule of law and politics, integrity of the legal system, legal enforcement of contracts, regulatory restrictions on the sale of real property, reliability of police, and business costs of crime. The index ranges from 0 (weakest) to 10 (strongest).	Fraser Institute; Gwartney, Lawson, and Hall (2015)

Patent Law	Indicator that equals one after a country enacts its first patent law, and zero otherwise.	World Intellectual Property Organization (WIPO) Lex Database