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INTELLECTUAL PROPERTY RIGHTS, ECONOMIC DEVELOPMENT AND APPLIED INNOVATION: A CROSS-COUNTRY EMPIRICAL INVESTIGATION

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Resumen

El objetivo de esta tesis es estimar el efecto de los Derechos de Propiedad Intelectual (DPI) sobre la innovación. Tratamos de identificar, en primer lugar, si este efecto es lineal, esto es, si mientras más estrictos sean los DPI en el país, mayor será la innovación. En segundo lugar, queremos comprobar si el efecto de los DPI es igual para países con diferente nivel de desarrollo, es decir, para países pobres o para países ricos.

Los DPI se refieren a los sistemas de patentes y derechos de autor que rigen en un país. De acuerdo con la teoría económica, los DPI son necesarios para incentivar la innovación puesto que, si no existieran, los inventores no tendrían incentivos para invertir en Investigación y Desarrollo (I+D), ya que los inventos podrían ser inmediatamente apropiados por terceros, privando a los inventores de la posibilidad de obtener beneficios extraordinarios. Por otro lado, DPI excesivos limitan la competencia económica e imposibilitan que haya imitación, lo que puede terminar disminuyendo la innovación

De esta cuestión surgen las siguientes preguntas: ¿hay algún nivel óptimo de DPI? ¿Nos beneficiamos del mismo modo los países en desarrollo que los países ricos? Para responderlas, utilizamos una muestra de 62 países para el periodo que va de 1970 a 1974. Para medir los DPI, utilizamos el Índice de Ginarte y Park (GPI, por sus siglas en inglés). Mientras más estricto sea el sistema de patentes en un país, el índice asignará un número mayor.

Por otro lado, para medir la innovación utilizamos el Índice de Complejidad Económica (ECI, por sus siglas en inglés). Este índice nos dice qué tan sofisticada es la estructura económica de un país, pues mide, en primer lugar, la diversidad de mercancías que exporta y, en segundo lugar, la ubicuidad de esa producción, es decir, cuántos otros países producen esas mercancías. En ese sentido, valores altos del índice se refieren a países que producen diversas mercancías que además no producen muchos otros países. Esto es, tienen una estructura económica sofisticada. Agregamos variables de infraestructura, educación, abertura e inversión extranjera directa (IED) para controlar por otros factores. El desarrollo económico lo medimos con el Producto Interno Bruto.

El aspecto más relevante de este trabajo es el uso de la moderna técnica econométrica “modelo de Regresión Panel con Transición Suave”. Este método nos permite responder a las dos preguntas planteadas al inicio de una manera consistente, puesto que no necesitamos imponer ninguna forma funcional a la relación entre DPI e innovación, ni tampoco hacer una división previa entre países desarrollados y subdesarrollados, como hacen otros trabajos en el tema. Esto le otorga gran flexibilidad a nuestros resultados.

Estimamos dos modelos distintos. En uno, el efecto de los DPI sobre la innovación depende del nivel inicial de DPI (esto sirve para ver si el efecto es lineal). En el segundo, el efecto de los DPI sobre la innovación depende del nivel de desarrollo de cada país. Encontramos los siguientes resultados. En primer lugar, aumentar los DPI cuando se empieza de niveles muy bajos tiene efectos positivos y altos sobre la innovación. Sin embargo, a partir de cierto nivel (1.8 del GPI), aumentar los DPI tiene un efecto prácticamente nulo sobre la innovación. Pero lo que es más relevante es que, para 2010, todos los países de la muestra tenían un nivel de DPI superior a 1.8. Esto quiere decir que prácticamente todos los beneficios de los DPI en términos de innovación han sido explotados.

En segundo lugar, encontramos que países con un PIB per Cápita menor a 5000 dólares constantes del 2010 no tienen incentivos para aumentar los DPI, mientras que países más ricos sí. Esto quiere decir que los beneficios de sistemas de patentes más estrictos dependen del nivel de desarrollo del país en cuestión. En síntesis, los resultados de esta investigación confirman de una manera novedosa que sistemas de DPI más rigurosos no son necesariamente óptimos, y que países pobres no tienen incentivos para fortificar sus sistemas de patentes.

La implicación de política económica es que el sistema que surgió del acuerdo “Aspectos de los Derechos de Propiedad Intelectual relacionados con el Comercio” (ADPIC) en 1994 no es óptimo, pues exige a todos los países miembros de la OMC el mismo nivel de protección, sin importar su estructura económica ni su nivel de desarrollo económico.

Abstract

We expand the literature about the relationship between Intellectual Property Rights (IPR) and innovation by estimating a Panel Smooth Transition Regression (PSTR) model to capture the effect of different patent systems on economic sophistication, which is a measure of applied innovation. We find two main results. The first one is that stronger IPR do not necessarily increase innovation or may even reduce it. The second one is that the benefits from strict patent systems are unevenly distributed between countries, depending on their level of economic development. The policy implication of these results is that a worldwide uniform and strict Intellectual Property regime, as the current one, is not optimal for all countries.

Índice General

Section 1
Introduction

It is a widely recognized theoretical fact that the rate of technological progress is one of the main forces driving economic growth (Arrow, 1962). Empirically, it has been proved that innovation is an essential element explaining growth rates (Ulku, 2007). A potential determinant of the rate of innovation that has received special attention in recent years is the Intellectual Property regime, better known as Intellectual Property Rights (IPR).

IPR is the term used to refer to the patent and copyright systems. Researches on the topic have focused mainly on the following two issues: (i) How do IPR intensity affects innovation? In other words, is the impact of IPR on innovation linear? And (ii) how does the level of economic development influence the effect of IPR on innovation (Hudson and Minea, 2013)? The objective of this research is to address these two questions in a novel manner, trying to overcome some of the limitations of former empirical researches.

The historical events that explain the rising interest in IPR are strongly related to the liberalization of the world economy and the rise of bilateral trade agreements, which took place in the 1980s of the past century and went deeper during the nineties. Although IPR existed long time ago, it was not until that time when they acquired the economic relevance they have today, by constituting a worldwide and almost uniform system.

According to Rodrik (2018), the free trade agreements that emerged during those years included several Intellectual Property regulations. As a culmination of this tendency, during the Uruguay round of bilateral negotiations the members of the World Trade Organization (WTO) signed the Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement. This agreement stipulated a minimum set of parameters regarding Intellectual Property that all members of the organization should satisfy.

Rodrkik (2018) says that this agenda was driven by developed countries, but specifically by big firms that were heavily dependent on copyrights and patents, such as pharmaceuticals and electronics. The TRIPS agreement was signed despite the opposition of developing countries. Since then, IPR regulations have increased as trade agreements have become a key element of each country's trade policy.

Currently, 61 per cent of preferential trade agreements include at least one aspect related to IPR (Limão, 2016). All these elements immediately generated the question of whether this was equally beneficial in terms of enhancing innovation and promoting general welfare for all countries. The present research is an attempt to help in our understanding of this question.

We estimate a Panel Smooth Transition Regression (PSTR) model to account for the influence of both IPR intensity and the level of economic development on the effect of IPR on innovation. The sample consists of 62 countries for the period 1970-2014. Additionally, we used the Economic Complexity Index (ECI), which measures exports sophistication, as our proxy for innovation.

We find that IPR exert a positive effect on innovation for almost all levels of patent protection. However there is a range in which stronger IPR reduce economic complexity. Furthermore, from a relatively low level of protection onwards, the positive effect of IPR on innovation is very close to zero. In 2010, all countries were in this range, which suggests that almost all benefits from tightening IPR systems have already been exploited.

Additionally, our results point out that strengthening IPR harms many developing countries. Specifically, we found a threshold of $4964.20 for GDP per Capita (in 2010 constant dollars), which means that, in the short run, countries with a GDP per Capita below this level do not have incentives to strengthen their patent systems, while richer countries do. Hence, IPR have positive and negative effects on economic complexity, depending on initial IPR protection and the level of economic development.

The main contribution of this research is that it combines the use of the ECI to measure innovation with a PSTR model, which allows for an almost unconstrained estimation of the complex effects of IPR on applied innovation. Former empirical works had to impose either an ex-ante division between developing and developed countries or an ex-ante polynomial form to the relationship between IPR and economic development (see e.g. Schneider, 2005; Allred and Park, 2007; Sweet and Eterovic Maggio, 2015;

Ginarte and Park, 1997; Park and Ginarte, 1997), whereas this model determines the optimal functional form endogenously (Hudson and Minea, 2013).

Moreover, the ECI presents some advantages over the other commonly used variables to measure innovation, i.e. the number of patents and investment in Research and Development (R&D). On the one hand, the number of patents can be a biased measure of innovation either because firms sometimes decide to strategically "over patent" in order to deter entry or extract rents from competitors; because many innovations are tacit and thus not patented, or because some countries lack of patenting culture.

On the other hand, it is not possible to know whether R&D investment is resulting in effective innovation. Additionally, data on this variable has been found to be biased towards large firms and inconsistent in developing countries (Sweet and Eterovic Maggio, 2015). The ECI lacks these problems as it captures all the inventions that are being applied in the production of goods for international trade.

This work is organized as follows: in the next section we review the literature, summarizing both theoretical and empirical evidence regarding IPR, innovation and economic development. In section 3 we expound our two main variables: the Economic Complexity Index, which measures innovation, and the Ginarte and Park Index, which measures IPR. In section 4 we describe the data and present some descriptive statistics. In section 5 we explain how to specify and estimate a PSTR model. Afterwards we present the results and their interpretation and discuss the limitations of our research. Finally, in section 7, we conclude and provide some policy implications.

Section 2

Main Empirical and Theoretical Arguments: A Literature Review

"A patent is the legal right of an inventor to exclude others from making or using a particular invention" (Hall, 2007). The patent is the main element of the current Intellectual Property system. The economic justification for its existence can be summarized as follows: knowledge and ideas are public goods, which means that it is extremely expensive to exclude individuals from using them. Thus, firms may not find profitable to invest in Research and Development (R&D) to increase their productivity or to create new and better products if other firms can enjoy these inventions without having done any effort to produce them (Stiglitz, 2008). In one word, knowledge is not appropriable in itself.

Furthermore, Arrow (1962) argues that the production function of inventions is characterized by uncertainty, since it is not possible to know *a priori* if the inventor will arrive to the desired outcome. These two properties of knowledge production -impossibility of appropriation and uncertainty- imply that perfect competition does not ensures a Pareto optimal assignation of resources, and hence a system of property rights is necessary to overcome these failures.

However, it has been acknowledged that there is a fundamental trade-off regarding patents: an innovation incentive benefit against an entry deterrence and reduced competition cost (Hudson and Minea, 2013). On the one hand, patents may increase firms' returns from R&D investment by allowing them to get extraordinary profits for a certain period of time, and in exchange, firms must make their invention public. On the other hand, this creates static inefficiencies by impeding entry and charging monopoly prices to consumers (Hall, 2007).

According to this scheme, policymakers should take into consideration these two opposite effects of IPR on welfare when deciding its optimal level. However, there are other effects which can offset them. The first one is that IPR do not necessarily increase innovation as patents may hinder sequential innovation. Innovation is sequential when an invention is based on and interacts with many other existing technologies (Woo, Jang and

Kim, 2015). More specifically, when "each successive invention builds on the preceding one, in the way that the Lotus 1-2-3 spreadsheet built on VisiCalc, and Microsoft's Excel built on Lotus" (Bessen and Maskin, 2009). It can also be argued that IPR have heterogeneous effects on innovation depending on the level of development of each country.

Additionally, IPR can have positive effects on competition as they permit the creation of markets for technology. These elements complicate the analysis because the positive and negative aspects of IPR act together. In this work, we will focus on the issues related to IPR and innovation with a special focus on economic development.

2.1 Intellectual Property Rights and Innovation

Why would tighter IPR hinder innovation? There are basically two reasons:

(i) Tighter IPR increase firms' incentives to practice what is known as "strategic patenting": firms determine a patent strategy with the main objective of deterring entry, not getting profits from their inventions (Woo et al., 2015). This may create what in the literature is known as a "patent thicket", which is a cluster of overlapping patents that are not justifiable from an innovation point of view but complicate entry and imitation (Zienonis, 2004).

(ii) If innovation is largely based on previous inventions, then patents hinder the use of inputs for further inventions.

In the following sections we describe the literature relating these points and explain how they relate with economic development.

2.1.1 Knowledge, technology and industry effects

Many theoretical works point out the positive relationship between IPR and innovation (Cadot and Lippman, 1995; Horowitz and Lai, 1996; Furukawa, 2010). However, they also derive the existence of an inverted-U curve between these variables, as the one shown in figure 1. This suggests that, up to some point, tighter IPR deter innovation, which implies that there may exist a single level of IPR that maximizes the rate of innovation.

The benchmark model that explains the fact that too strong IPR can harm innovation growth is the one developed by Bessen and Maskin (2009). They show that, when considering a dynamic setting where imitation is a key element of innovation, the proposition "stronger is better" no longer applies since it would hinder not only "knockoff" imitation, but the one that is necessary for the inventions to keep evolving.

Hence, the different paths to innovation are essential to determine the relevance of patent protection. Woo et al. (2015) present a synthesis of the argument based on previous literature. They classify innovation paths into sequential (when it is based on previous inventions) and discrete (when inventions do not arise from former inventions, as in the chemical industry).

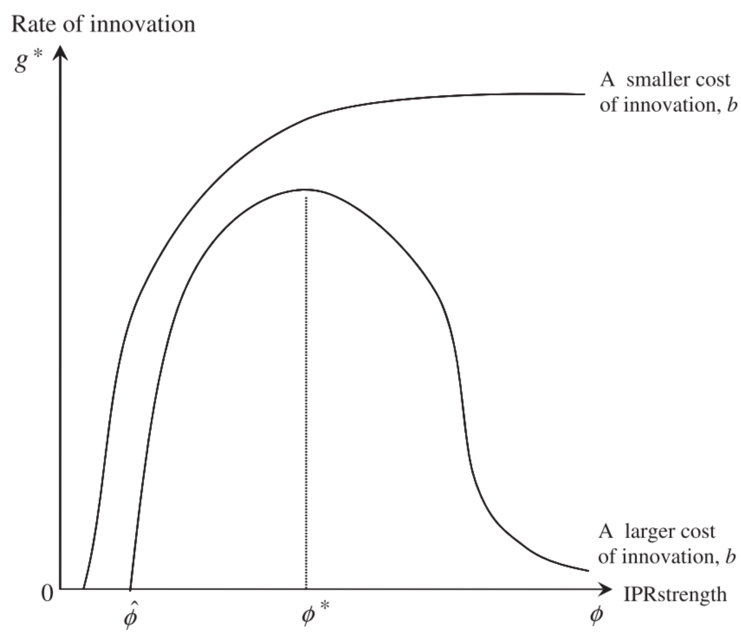

Figure 1. *Inverted-U Relationship between innovation and IPR. Note: taken from* Furukawa, (2010)

Also, following previous works (Balconi, 2002; Grimaldi and Torrisi 2001), Woo et al. (2015), divide knowledge into tacit (learnt by practice and not easily reproducible) and codified (prone to be written down and easily transferable).

According to this frame, it would be expected that tight IPR hinder innovation in industries characterized by sequential innovation and codified knowledge. In contrast, a strong IPR system may foster innovation in industries with discrete innovation.

Their empirical results (Woo et al., 2015) confirm these theoretical insights. That is, according to them, stronger IPR increase innovation in the chemical industry (discrete innovation) while diminishes it in the machinery and electronics industries (sequential innovation).

This result is confirmed by other empirical works that use different approaches. One of the most famous is the paper by Galasso and Shakerman (2014), where they estimate the effect of patent invalidation by U.S courts on subsequent research related to that patent. They find that invalidation increases further innovation in some industries (those characterized by sequential innovation and codified knowledge) and has no effect on the rest.

In an alternative setting, using an experimental approach, Brüggemann, Crosetto, Meub and Bizer (2016) find that the introduction of Intellectual Property Rights in the experiment not only reduces the frequency of innovation but also their complexity, which suggests a "strategic patenting" behavior.

The results of all these works imply that, in order to foster sequential innovation and competition, softer forms of IPR are necessary. Otherwise, imitation will remain highly blockaded and firms will have to "navigate" through patent thickets and spend many resources trying to escape them or benefiting from them (Ziedonis, 2004), instead of using them for R&D activities.

2.2 Intellectual Property and Economic Development

The following hypothesis emerges from all the former discussion: if a country's innovation activity is mainly sequential, that is, highly based on imitation and adaptation of past technologies, tight IPR are not necessarily its best innovation policy. Furthermore, some authors (e.g. Stiglitz, 2008; Chang, 2002) argue that it is impossible for a developing country to innovate if it lacks the knowledge for producing the simplest technologies. This knowledge is acquired mainly by imitation (learning by doing) and reverse engineering, processes that are not in line with strong IPR protection.

Moreover, conducting an historical analysis, Chang (2002) shows that Intellectual Property protection was not a key element for the industrialization of now developed countries. Instead, imitation and industrial espionage played an essential role in learning and adapting new technologies and processes of production. With nowadays parameters, that would have represented a huge violation of the Intellectual Property regime.

Chang (2002) also argues that, when generalizing a patent system for all the world, developed countries are "kicking away the ladder" to developing countries, since they are impeding them the access to many technologies which would allow them to create its own path to innovation. This argument was the basis for the opposition of developing countries to the TRIPS agreement during its negotiation in 1994 (Rodrik, 2018).

However, theoretical and empirical evidence about the relation between IPR, innovation and economic development is diverse. Despite this fact, there is a growing consensus that this relation is by no means simple.

Theoretical models analyzing it are relatively recent. Chen and Puttitanun (2005) develop a model illustrating the trade-off between imitating technologies "from the North" (developed countries) and encouraging domestic innovation in "the developing South". They find that it is always beneficial for developing countries to increase Intellectual Property protection to enhance innovation.

Complementarily, Hwang, Wu and Yu (2016) argue that the problem of all former theoretical models is that they assume that developed countries always innovate while developing countries only imitate. In their model, where both innovation and imitation are endogenously determined, the authors find that innovation increases relative to imitation as a country develops and that IPR and development exhibit a U-shaped relationship. However, in contrast to former theoretical works, in their model IPR protection affects differently innovation among developing countries: those with high income benefit from tightening IPR while those with median or low income not necessarily.

The empirical findings are even more diverse. Some authors conclude that strong IPR are good for both developing and developed countries. Kanwar and Envenson (2003) and Kanwar (2007) conduct empirical analysis using panel data and conclude that IPR always have a positive effect on innovation, and that this effect “amplifies” as IPR’s intensity increases, thus discarding the existence of an inverted-U relationship between IPR and innovation.

In the same line, Gould and Gruben (1995) point out that stronger IPR always foster economic growth, especially in open economies, which suggests that technology transference through trade and Foreign Direct Investment heavily relies on the quality of the Intellectual Property system.

Alternatively, Chen and Puttitanun (2005) perform an empirical investigation using a simultaneous equations model. Their results confirm their theoretical insights that IPR positively affects innovation in developing countries and that IPR depend nonlinearly on development, first decreasing as income rises, and then increasing.

In contrast, there are also less optimistic views about the role of IPR in developing countries. Allred and Park (2007) find that the effect of IPR reform on innovation depends nonlinearly on the level of development of each country and the initial level of Intellectual Property protection. The main finding is that stronger patent protection diminishes patent applications in developing countries and has no significant effect on R&D expenditure at firm level.

Similar results are obtained by Schneider (2005), Ginarte and Park (1997) and Kim, Lee, Par and Choo (2012). All this papers conclude that increasing IPR fosters either R&D investment or patent applications in developed countries and has no effect or harms developing countries.

All these authors conclude that an alternative Intellectual Property regime is necessary. As an example, Kim et al. (2012) suggest the implementation of “utility models”: a softer form of Intellectual Property protection which, according to their results, would be more effective in the promotion of innovation than traditional patent systems. We seek to contribute to this line of research by implementing some important novelties in the analysis.

2.3 Smooth Transition and Economic Complexity: the Two Basic Papers in this Research

All the preceding empirical estimations present two main problems: (1) the variables used to measure innovation not necessarily reflect effective innovation in a country and (2) the ex-ante definition of developed and developing countries by median or average income does not capture the complex relations between IPR, economic development and innovation. These two problems were addressed separately by the two following papers, which constitute the basis of this research.

The first one, by Sweet and Eterovic Maggio, (2015) is pioneer in the use economic complexity as a proxy for innovation. All the former research in the topic used either the number of patents granted to residents of a country or expenditure in R&D. These two measures face some problems, which will be analyzed in the next section.

The Economic Complexity Index (ECI) is a measure of applied innovation that captures the export sophistication of countries. The authors estimate a panel model with the System Generalized Method of Moments for the period 1965-2009 with 94 countries. They divide the sample according to GDP per Capita level (below and above average income) and also according to IPR protection level (below and above average protection). They find that only countries above average income perceive an improvement in economic complexity due to a stricter IPR system. On the contrary, IPR intensity is not significant for developing countries or reduces their innovation.

Despite the novel aspect of incorporating economic complexity to measure innovation, this paper suffers from the second shortcoming mentioned at the beginning of the section, that is, that the division between develop and developing countries is made ex-ante, since it is based on median income. After dividing the sample, they perform the estimation. The problem with this is that it is not necessarily true that the effect of IPR on innovation changes brutally around median GDP per Capita. Hence, although the result provides important insights, there are several limitations in their interpretation.

The paper by Hudson and Minea (2013) addresses this problem by using the novel econometric method Panel Smooth Transition Regression (PSTR) to estimate the heterogeneous effects of Intellectual Property on innovation. They use a sample of 62 countries for the period 1980-2009. This method determines the optimal functional form of the relation between IPR and innovation. Hence, the division between those who benefit from IPR and those who do not is determined endogenously, as a step of the estimation, which improves the fit of the models and enriches the interpretation of the results.

Their results are that the effect of IPR on innovation is nonlinear: it is positive for low and high levels of IPR protection and negative for intermediate values. That is, IPR and innovation exhibit an inverted-U relationship. This is shown in figure 2. However, this effect will also depend on the level of economic development of each country. GDP per Capita shifts the curve in figure 2 upwards or downwards, and hence there is a different curve like the one shown in figure 2 for each country.

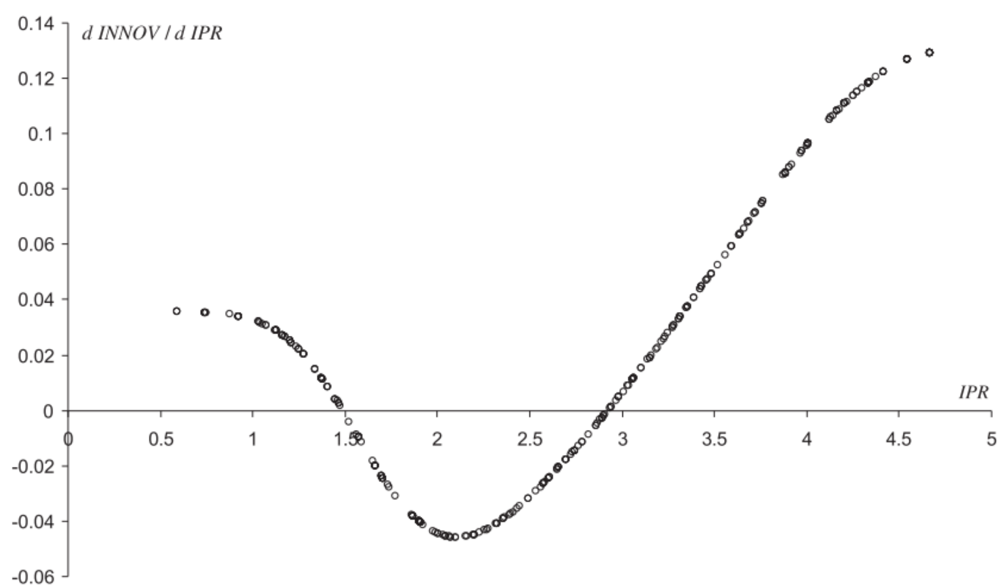

Figure 2. *The influence of the IPR level on the Innovation /IPR derivative. Note:* taken from Hudson and Minea (2013)

With this unified analysis, the impact of IPR on innovation results to be negative for several levels of initial IPR and GDP per Capita. In conclusion, the combination of initial IPR and economic development will determine if a country benefits from tightening IPR and the amount of these benefits. They conclude that the uniform

Intellectual Property regime that arose from the TRIPS agreement is not optimal for developing countries.

This is the first research to find such complex dependencies, which was possible by using the PSTR model. However, their work gives rise to the following question: how sensitive are their results to alternative measures of innovation? They use the number of patents granted to each country. As we will argue in the next section, this variable has some disadvantages.

Hence, the contribution of our work is to combine the PSTR setting with the ECI as a measure of applied innovation. By doing so, we will try to discover how important are IPR to increase economic sophistication, and how this effect depends on economic development and IPR intensity.

Section 3

Measuring Innovation and Intellectual Property Rights

Both innovation and IPR are complex phenomena that involve several and interrelated aspects of daily economic, political and legal activity. Hence, every attempt to reduce them to a single-dimension quantitative measure will inevitably exclude several of their constituent elements. In this section we present the two variables that we chose to approximate innovation and IPR and explain their advantages over alternative options.

3.1 Economic Complexity Index: A Measure of Applied Innovation

As Sweet and Eterovic Maggio, (2015) point out, there is an increasing literature exploring the effects and determinants of a nation's economic complexity. According to this literature, the positive effects of exporting more complex goods go from fostering future development to reducing inequality (Hartmann, Guevara, Jara-Figueroa, Aristarán and Hidalgo, 2017). Hausman et al. (2013) argue that the ECI is an essential indicator, since it synthetizes what a country produces, and "what countries make reveals what they know" (Hausman et al., 2013).

The ECI is constructed from two variables. The first one is diversity: how many different goods does a country export? The second one is ubiquity: how many countries export a particular good? These are essential determinants of a country's productive and innovative capacity due to the following reasons:

- Diversity of products relates to how much knowledge a nation has to produce different things. Countries with too little production diversity are not likely to innovate looking for better methods of productions or different products, but to exploit areas where they enjoy comparative advantage. Exports of natural resources are the extreme case.
- Ubiquity is important since the exclusivity in the production of a good (as long as it is not a scarce natural resource) is a good proxy of how hard it is to produce it. That is, a good that can only be produced in one or two countries is very likely to

have a huge amount of embedded knowledge such that it is extremely hard for other countries to imitate it.

Furthermore, by combining both variables, the index captures the diversity in the production of ubiquitous products of a country. Hence, an increase in the level of the index can be interpreted as an expansion of a country's capabilities of producing sophisticated goods. That is why this index is considered a measure of applied innovation.

The ECI takes values between -4 and 4, where a higher number means a more complex economic structure, capable of producing more and more sophisticated goods. It is published annually by the Observatory of Economic Complexity (OEC) in collaboration with the MIT Media Lab. Each publication includes data for countries with population greater or equal to 1.25 million, with traded value greater than 1 billion and with more than 10 million traded products.

This index has some advantages over the other two variables commonly used in the literature to measure innovation. These variables are the number of patents granted to local inventors and Research and Development (R&D) investment. These two variables face several shortcomings.

Regarding the number of patents, there are two great disadvantages. On the one hand, many innovations are "tacit" and hence are not patented. That is, in daily productive activity, new methods of production and organization arise from direct experience. These innovations are not necessarily patented because they do not fill all the requirements or because they are so small to compensate the costs of patenting. However, they contribute to a nation's productivity and economic sophistication (Nelson, 2005).

In line with this point, "patenting culture" is an important fact to be taken into account, since many countries are not used to patent all their inventions (Varsakelis, 2001; Lerner, 2002). This is the case mainly in developing countries, as theoretical and empirical literature show. This fact also constitutes a disadvantage of the IPR measure will we use in this work.

The other problem goes in the opposite direction, that is, when patenting is not done to exploit the benefits of a worth invention but only to deter entrance (Jaffe and Lerner, 2004) or to earn rents from licensing fees from other firms who may need to use similar inventions (Shapiro, 2001). The outcomes of this behavior are “patent thickets”: sets of patents gotten just for commercialization and entry deterrence. When this is a common phenomenon, then the number of patents may not be capturing well current innovation in valuable products or methods of production.

The other measure of innovation, R&D investment, also faces several problems. According to Sweet and Eterovic Maggio, (2015), the main one is that R&D spending does not represent how effective it is being to foster real innovation. R&D is then a measure of “potential innovation”, since it creates the possibility for innovation but we cannot know whether it is taking place.

Also, they argue that “the data are skewed toward large firms, missing much of the innovative investments and advances achieved by small and medium players” (Sweet and Eterovic Maggio, 2015), and they refer to Brouwer & Kleinknecht (1997), who conducted a survey in the Netherlands and found that R&D represents a quarter of total product innovation. Finally, data on R&D spending is more scattered and inconsistent in developing countries.

From the argumentation above, it is clear that the ECI does not present these shortcomings as it measures applied innovation. However, the ECI does not lack problems. Its main disadvantage is that the data used (UN COMTRADE) only includes exports of goods, not production for the local market or exports of services.

Although what a country exports is an important determinant of growth and development (Hausman et al., 2013), this fact constraints the explanatory capacity of the index. Furthermore, there are some cases of countries (mainly developing countries) with very complex exports carried out by multinational corporations (MNC), with a low degree of technology transference. In these cases, the value of the index may be biased and not reflecting correctly the real amount of “know how” the country has.

Despite these limitations, the ECI tells us how the productive capacity of a country is advancing over time, whether it is exporting new products or specializing at a world level in some goods. These reasons have contributed to put the determinants of economic complexity at the center of current economic research.

3.2 The Ginarte and Park Index

One of the main problems of economic research on innovation and Intellectual Property had been the immanent difficulty of correctly measuring the degree of IPR protection. However, as patents became the central element of Intellectual Property regimes along the world, the task substantially simplified. Ginarte and Park (1997) made the first effort for precisely measuring IPR. They developed the Ginarte and Park Index (GPI) for the period 1960-2005. The index is computed on a five year base. The first version of this index included data for 110 countries. Then Park (2008) actualized the index for 122 countries. Recently, he updated the index up to 2015. That last version is the one used in this work.

The GPI takes into consideration five elements of a country's patent system. They are "(1) extent of coverage, (2), membership in international patent agreements, (3) provisions for loss of protections, (4) enforcement mechanisms, and (5) duration of protection" (Ginarte and Park, 1997). For each category, the maximum score is one. Hence, the index takes values from zero (no protection) to five (extremely tight IPR).

Since its appearance in 1997, this index has been the reference in cross-country intellectual property econometric investigations. Despite its simplicity, it captures the main institutional features regarding Intellectual Property protection in each country and allows to easily observing the evolution of IPR patterns across time. Nevertheless, it presents some problems that have been pointed out both by the authors and more recent empirical research.

The first one is that the index considers only the formal institutions related to Intellectual Property. As said before, it is clear that real practices do not necessarily coincide with what is stated in the law. This has been particularly indicated as a problem for developing problems. Furthermore, the authors also mention the existence of country-specific laws or practices which are not included in the index. According to Sweet and

Eterovic Maggio, (2015), the kind of country-specific elements that are not included in the index but affect real Intellectual Property protection are compulsory licenses, secret rights systems and the legal consequences of violating patents restrictions by governmental institutions.

Alternative measures of Intellectual Property have been developed. Woo et al. (2015) use an index created by the World Competitiveness Center, which is based on surveys to senior business leaders. Unfortunately, this index only covers the period 1995-2012 and only for 60 countries. Since it does not cover the generalized increase in IPR protection followed by TRIPS and free trade agreements in developing countries, it is not useful for the purpose of this research. Additionally, using the same explanatory variables as in former literature allows us to compare our results and identify the key differences.

Section 4
Data and Descriptive Statistics

In this research we use a sample of 62 countries. The period of time considered goes from 1970 to 2014. Each observation represents a five-year period. Hence, we have 9 time periods. This leaves us with a total of 558 observations. The criterion for choosing the countries was to have all the periods for our three primary variables: Innovation (ECI), Intellectual Property Rights (GPI) and economic development (GDP per Capita).

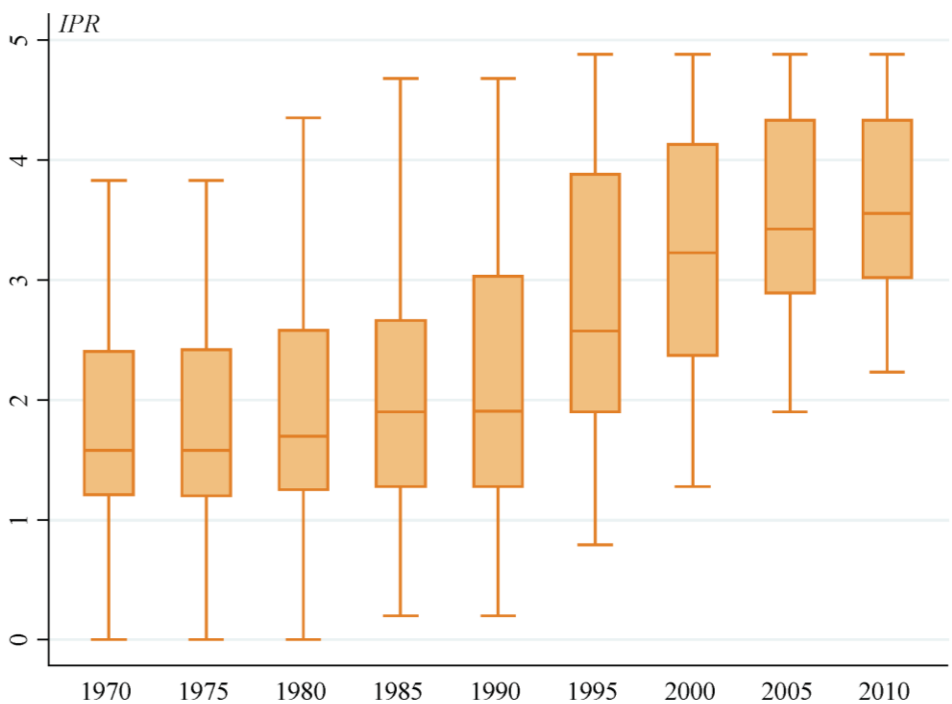

Figure 3. *IPR over time*

Figure 3 shows the evolution of IPR protection over time. There are two observable trends. The first one is that during the period 1970-1994 the level of protection remained almost constant, with mean values between 1.5 and 2. The second trend begins in 1995 with an increase in the average level of protection and a reduction in the dispersion of the data, which means that fewer countries have weak patent systems.

As stated before, the TRIPS agreement came into force in 1994 for all the members of the World Trade Organization (WTO). And it is just in that year (1995) when there is a jump in the mean of the index, from almost 2 to 2.5. Furthermore, it remained increasing since then. This is consistent with the claim of Rodrik (2008) that subsequent trade agreements and an initiative of the United States called TRIPS-plus contributed to tighten IPR even more. The mandatory character of TRIPS explains the reduction in the dispersion.

In Figure 4 we perform an inspection exercise and see a heterogeneous relation between economic complexity and IPR depending on the level of GDP per Capita (GDPCAP). According to this figure, there is a negative correlation between IPR and economic complexity for countries with GDP per Capita below the median income, as can be seen in the negative slope of the blue line. On the contrary, the correlation is positive for levels of development above median GDP per Capita.

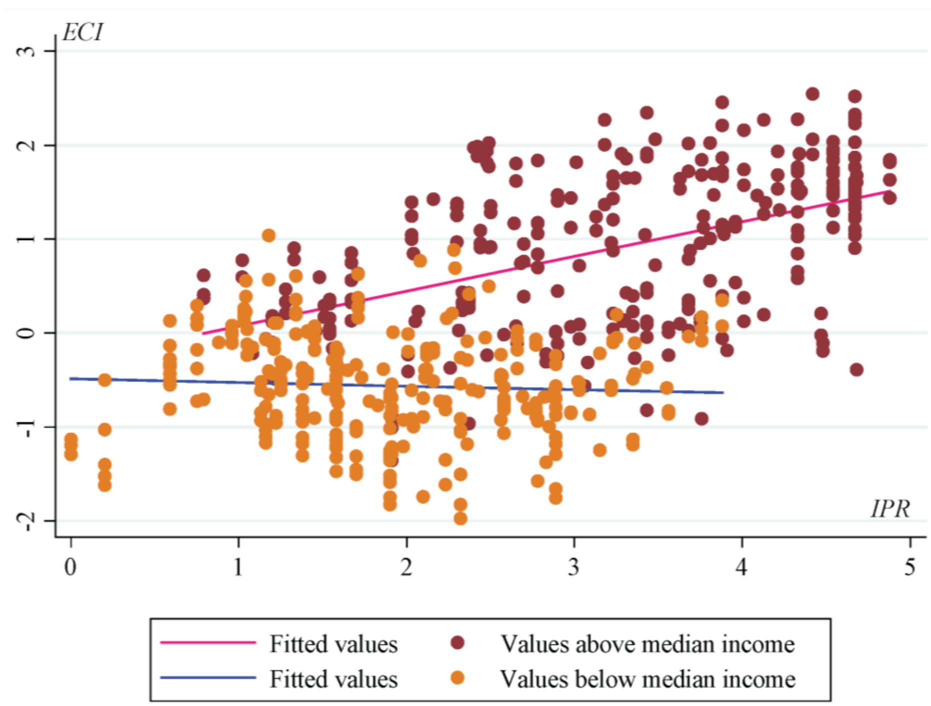

Figure 4. *ECI and IPR*

Finally, Figure 5 shows a positive correlation between GDPCAP and Intellectual Property Rights: in general, richer countries have stricter patent institutions. Hence, at least by simple inspection, it is not possible to see the inverted-U relation between IPR and economic development found in the literature.

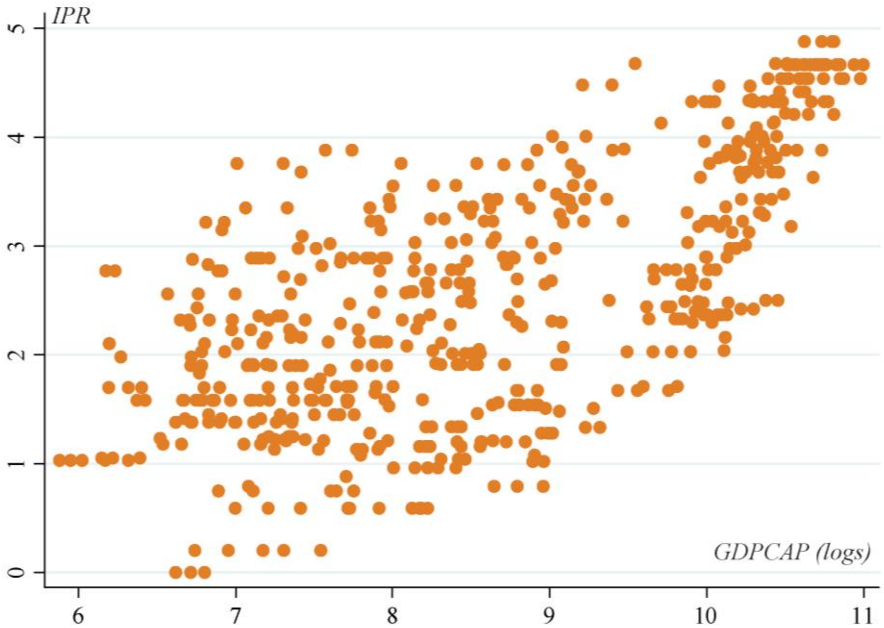

Figure 5. *IPR and GDPCAP*

In Table 1, we present the descriptive statistics of our primary variables. As we said before, for those three variables our panel is balanced.

Table 1

Descriptive statistics of primary variables

Variable	Obs	Mean	Std. Dev.	Min	Max
IPR	558	2.5553	1.1774	0	4.88
ECI	558	0.1716	1.0128	-1.9730	2.5441
GDPCAP	558	12253.11	14348.89	357.5743	59718.76

In the selection of control variables we follow Hudson and Minea (2013) who, in turn, rely on previous literature in the topic. We use four control variables. The first one is the percentage of enrollment in tertiary education (EDUC). This variable is taken from the Barro and Lee (2010) database and it serves as a measure of human capital, which has been found to be a key determinant of innovation (Dakhli and De Clercq, 2004).

Secondly, we include infrastructure (INFRA) to capture the potential positive externalities it causes spreading knowledge. To approximate it we use total electric power consumption. Finally, in order to apprehend technology transfers due to international economic activities, we include the level of openness (OPEN), which is equal to total trade as a percentage of GDP, and Foreign Direct Investment (FDI), which is net FDI investment as a percentage of GDP. These last three variables where obtained from the World Bank Development indicators database. GDPCAP, OPEN and FDI are used in logs.

Section 5
Methodology

We use a Panel Smooth Transition Regression model (PSTR), which was developed by González, Teräsvirta and Van Dijk (2005). In this model, the effect of one or many variables (called threshold variables) on the dependent variable depends on the level of another one, called transition variable. This model allows for estimating the heterogeneous effects of the threshold variable without imposing an ex-ante polynomial form. The threshold and transition variables can be the same, which is particularly useful when a variable exerts a nonlinear effect over the dependent variable.

A "regime" is an interval of values of the transition variable for which this effect does not change of sign or brutally. PSTR is a generalization of the Panel Transition Regression (PTR) model, with the difference that the former allows for a smooth transition among regimes, whereas the latter implements a brutal transition. To better see the difference, consider the following model with two alternative transition functions.

$$INNOV_{it} = \alpha_i + \beta_0 IPR_{it} + \beta_1 IPR_{it} g(Q_{it}, \bar{Q}) + \sum_{j=1}^{J} \phi_j X^j{}_{it} + \varepsilon_{it} \qquad (1)$$

PTR: $$g(Q_{it}, \bar{Q}) = \begin{cases} 0, if\ Q_{it} < \bar{Q} \\ 1, if\ Q_{it} \geq \bar{Q} \end{cases} \qquad (1.1)$$

PSTR: $$g(Q_{it}; \gamma, \bar{Q}) = \left[1 + \exp\left(-\gamma \prod_{h=1}^{H} (Q_{it} - \bar{Q}_h)\right)\right]^{-1} \qquad (1.2)$$

Where IPR_{it} is the value of the GPI of country *i* in year *t*. For all the other variables, observation *it* corresponds to the average of the variable for years *t*, *t+1*, *t+2*, *t+3* and *t+4* for country *i*.

In this model, *IPR* is the threshold variable, *Q* the transition variable, *g (.)* the transition function, X^j a control variable and $\bar{Q}$ in equation (1.2) is a vector of thresholds. Considering equation (1.2), if *H=1*, then the only difference between the two models is that with (1.2) a smooth transition between regimes is allowed due to the logistic form of the function, since it is continuous in all its domain, whereas in (1.1) there is a brutal jump for values smaller and greater than $\bar{Q}$.

This has important interpretation implications (Hudson and Minea 2013): if we chose a brutal transition model, and suppose we select GDPCAP as transition variable, it would be hard to justify why the effect of IPR on innovation changes so drastically for slightly different values of GDP per Capita, those slightly smaller and greater than $\overline{GDPCAP}$. This is why a smooth transition setting is more accurate for our purposes.

The specific form of the transition function in (1.2) depends on the parameters γ, H, and $\bar{Q}_h$. γ is the slope parameter. To understand it, let's consider the extreme cases:

1) When $\gamma \rightarrow 0$, the transition function g *(.)* approximates to 0.5 and the model collapses to a linear panel model.

2) If $\gamma \rightarrow \infty$ the transition function g *(.)* becomes a dummy, which is equal to 0 if Q is greater than the threshold and 1 otherwise. Thus, the model collapses to a brutal transition model.

3) The case $0 < \gamma < \infty$ corresponds to a smooth transition. Following this reasoning, it is clear to see that, the smaller γ, the smoother the transition from one regime to another (Hudson and Minea 2013).

H is the number of thresholds, which is equivalent to the number of regimes, and $\bar{Q}_h$ is threshold h.

With this in mind, we explain how to determine the best specification. As stated before, the justification of using the PSTR setting is the existence of nonlinearities in the effect of IPR on innovation. However, this existence must be tested. Furthermore, by doing that, we can determine the optimal number of thresholds H. Hence, we have to test for differences between a PSTR model and a simple panel linear model. This can be done by testing the null hypothesis H_0: $\gamma=0$, since when that is the case the model collapses to a linear model.

Nevertheless, this test cannot be done using equation (1) with transition function (1.2), because under the null hypothesis "the PSTR model contains unidentified nuisance parameters" (González et al., 2005). Hence, following González et al. (2005) and Hudson and Minea (2013), we must approximate the PSTR model with a first-order linearization of our transition function around $\gamma=0$, that is:

$$\theta(.;\gamma \to 0) = g(Q_{it}, 0, \bar{Q}) + g'(Q_{it}, 0, \bar{Q})(\gamma - 0) = 0.5 + \gamma \frac{\prod_{h=1}^{3}(Q_{it} - \bar{Q}_h)}{4} \qquad (2)$$

We then substitute (2) into (1) so that we get:

$$INNOV_{it} = \alpha_i + \beta_0^* IPR_{it} + \beta_1^* IPR_{it} Q_{it} + \beta_2^* IPR_{it} Q_{it} + \beta_3^* IPR_{it} Q_{it} + \sum_{j=1}^{J} \phi_j X^j{}_{it} + \varepsilon_{it} \qquad (3)$$

Where β_1^*, β_2^* and β_3^* are multiples of γ, which means that if $\gamma=0$, then $\beta_i^*= 0$ for $i=1, 2, 3$. With equation (3) the test is straightforward. The procedure is the following:

(1) Test the null hypothesis $H_0^*\colon \beta_i^* = 0 \; \forall \; i > 0$. If this hypothesis is rejected, then a PSTR model with *H=3* thresholds is better than a linear model. If that is the case, move to step (2), otherwise estimate a linear model.

(2) Test the following null hypotheses: $H_{03}^*\colon \beta_3^* = 0$, $H_{02}^*\colon \beta_2^* = 0 \mid \beta_3^* = 0$ and $H_{01}^*\colon \beta_1^* = 0 \mid \beta_3^* = \beta_2^* = 0$. If the strongest rejection (lowest p-value) arises with H_{02}^*, choose *H=2*, otherwise select *H=1* (Teräsvirta, 1994).

It is important to notice that we are imposing the condition *H<3* due to estimation restrictions. As proposed by González et al., (2005), we can extend this procedure to select the best transition variable, which would be the one that gives rise to the strongest rejection of any of the null hypotheses in step two. Hence, this procedure provides us the number of thresholds *H* and transition variable *Q*.

Once the best specification is defined, the next step is to estimate the parameters, which is done combining the Fixed Effects estimator and nonlinear least squares (NLS) (Gonzalez et al., 2017). The first step is to eliminate individual specific effects by subtracting individual means. This step, trivial in linear models, presents a complication in a PSTR setting. The issue is the existence of a parameter dependent variable; in our model, the individual mean of $IPR_{it} g(Q_{it}, \gamma, \bar{Q})$ depends on both the slope parameter γ and the vector of thresholds $\bar{Q}$. However, we do not have them at the beginning of the estimation, so the individual mean "must be recomputed at each iteration in the NLS optimization" (González et al., 2005).

The key of this estimation is that slope parameters β_i and ϕ_j are estimated by Fixed Effects (OLS), whereas the parameters of the transition function γ and $\bar{Q}$ are obtained by NLS. This is the case because, for any given values of γ and $\bar{Q}$, parameter β_1 is linear and hence can be estimated by OLS. In contrast, for any given values of β_i and ϕ_j, γ and $\bar{Q}$ must be computed by NLS such that they minimize the concentrated sum of square errors.

For mere purposes of illustration, we elaborated an estimation algorithm that summarizes what we have said[1]. If we select *n* iterations, and denote $\hat{\zeta}_i^k$ as the estimate of parameter ζ_i obtained at iteration *k*, where ζ is equal to *β, ϕ, γ* or $\overline{Q}$, then the estimation algorithm goes as follows:

(1) Estimate $\hat{\beta}_i^1$ and $\hat{\phi}_j^1$ by Fixed Effects (OLS), omitting the transition function *g(.)*

For each $k \in \{1, 2, \ldots, n\}$

(2) Estimate $\hat{\gamma}^k$ and $\hat{\bar{Q}}^k$ by NLS to minimize the sum of concentrated errors, taking $\hat{\beta}_i^k$ and $\hat{\phi}_j^k$ as given

(3) End if *k*=*n*, otherwise move to step (4)

(4) Estimate $\hat{\beta}_i^{k+1}$ and $\hat{\phi}_j^{k+1}$ by Fixed Effects (OLS) taking $\hat{\gamma}^k$ and $\hat{\bar{Q}}^k$ as given

(5) Return to step (2)

This illustrates the procedure followed by statistics software to estimate a PSTR model.

[1] Each software code presents several details and specificities. In this explanation we stick to Colletaz (2018) code developed for the Regression Analysis for Time Series (RATS) software, which was used in this research.

Section 6

Results

In this section, we present the results of the specification tests, the estimation of the parameters and its interpretation. The first thing we have to do is to define whether a PSTR setting is the most accurate for our data and purposes. By doing that, we determine which is the optimal transition variable and how many thresholds to include. Following previous literature discussed in section one, we consider two potential transition variables: Intellectual Property Rights (IPR) and GDP per Capita (GDPCAP).

The results of the tests are presented in Table 2. Following the literature, we implement two tests for each hypothesis: a traditional Lagrange Multiplier Test and a robust version F-test.

Table 2

Identification of the PSTR model: nonlinearities in the IPR and GDPCAP level

		Q=IPR		*Q=GDPCAP*	
Nonnlinearities	LM test	17.6475***	(0.0005)	11.4869***	(0.0094)
(H_0^*)	F test	4.2753***	(0.0054)	3.6972**	(0.0119)
One threshold	LM test	**10.5745*****	**(0.0011)**	**8.6338*****	**(0.0033)**
($\boldsymbol{H_{03}^*}$)	F test	**10.9016*****	**(0.0010)**	**9.6054*****	**(0.0021)**
Two thresholds	LM test	1.4195	(0.2335)	0.4253	(0.5143)
(H_{02}^*)	F test	1.7786	(0.1830)	0.4959	(0.4817)
One threshold	LM test	0.1189	(0.7302)	1.2612	(0.2614)
(H_{01}^*)	F test	0.1031	(0.7483)	0.9628	(0.3270)

Note: The tests are based on the linearized version form of regressions [I4] and [G4] below. Emboldened values signal the highest rejection of the null hypothesis. P-values in brackets

***Significance at the 1% level

** Significance at the 5% level

The first line is the test for the existence of nonlinearities. For both transition variables the null hypothesis of a linear panel model is rejected at the 1% level of significance with the LM test. This is also the case for IPR with the F-test, while for GDPCAP it is rejected at a 2% level of significance. This implies that using either IPR or GDPCAP as transition variables in a PSTR setting is better than a simple linear model.

We then have to decide which of these transition variables to use and how many thresholds to include. Following the same logic, the best transition variable is the one that provides the strongest rejection to the remaining tests. The lowest p-value is associated to IPR with one threshold. However, the difference between the p-values of IPR and GDPCAP with one threshold is not large enough to consider that IPR is substantially better as transition variable than GDPCAP.

Ideally, we could also test if including another transition function or other transition variable is optimal. If that was the case, the estimated model could include two or more transition variables[2].

In this work we will estimate two models, which will allow us to separately analyze how the effect of IPR on innovation does varies with economic development and IPR intensity. The implications of this procedure will be discussed later. These models are represented by the following equations:

$$INNOV_{it} = \alpha_i + \beta_0 IPR_{it} + \beta_1 IPR_{it} g(IPR_{it}) + \sum_{j=1}^{J} \phi_j X^j{}_{it} + \varepsilon_{it}$$
$$g(IPR_{it}; \gamma, \overline{IPR}) = [1 + \exp(-\gamma(IPR_{it} - \overline{IPR})]^{-1} \quad (4)$$

$$INNOV_{it} = \alpha_i + \beta_0 IPR_{it} + \beta_1 IPR_{it} g(GDPCAP_{it}) + \sum_{j=1}^{J} \phi_j X^j{}_{it} + \varepsilon_{it}$$
$$g(GDPCAP_{it}; \gamma, \overline{GDPCAP}) = [1 + \exp(-\gamma(GDPCAP_{it} - \overline{GDPCAP})]^{-1} \quad (5)$$

The only difference between the two models is the transition variable being used. In model (4), the effect of IPR on innovation depends on initial IPR level. In model (5), it depends on GDP per Capita. The results of the estimations of equation (4) are presented

[2] We leave this task as an extension of the present paper

Table 3

The impact of IPR on innovation, subjected to the IPR level

Innovation	[I1]	[I2]	[I3]	[I4]	[I5]	[I6]	[I7]	[I8]
IPR	0.1287***	0.1510**	0.1608***	0.1512***	0.1226**	0.0051	0.0050	0.0122
	(0.0538)	(0.0596)	(0.0621)	(0.0578)	(0.0560)	(0.0218)	(0.0549)	(0.0581)
IPR^2							-0.0035	-0.0056
							(0.0102)	(0.0109)
IPRg(IPR)	-0.1181**	-0.1289***	-0.1455***	-0.1261***	-0.1042***	-0.0378***		
	(0.0392)	(0.0414)	(0.0455)	(0.0446)	(0.039)	(0.0110)		
GDPCAP	0.2281***	0.2591***	0.1829**	0.1842**	0.2005**	0.2388***	0.2140**	0.2293***
	(0.0702)	(0.0789)	(0.0855)	(0.0858)	(0.0856)	(0.0815)	(0.0891)	(0.0869)
EDUC		-0.0037	-0.0042	0.0021	-0.0040	0.0076**	0.0047	-0.0009
		(0.0036)	(0.0037)	(0.0035)	(0.0037)	(0.0034)	(0.0034)	(0.0037)
INFRA			0.0722	0.0576	0.0823	0.0074	0.0280	0.0539
			(0.0527)	(0.0558)	(0.0553)	(0.0618)	(0.0546)	(0.0560)
FDI				-0.0377***		-0.0347***	-0.0368***	
				(0.0117)		(0.0120)	(0.0118)	
OPEN					-0.0851	-0.0488		-0.1077*
					(0.0574)	(0.0594)		(0.0572)
γ^{IPR}	17.1147	16.4284	14.2367	15.6243	21.9170	12.7124		
$\overline{IPR}$	1.5624	1.5645	1.5559	1.5192	1.6058	4.4163		
N/countries	558/62	558/62	558/62	509/62	549/62	500/62	509/62	549/62
Sum of sq. resid.	31.2795	31.1965	31.0110	23.817	28.7717	21.7319	24.2861	29.2355

Note: Regressions [I1]-[A6] were estimated by the PSTR method presented in the last section. Regressions [I7] and [I8] were estimated by Fixed Effects. N denotes the number of observations.
*Denotes significance at the 10% levels. **Denotes significance at the 10% levels. ***Denotes significance at the 1% levels.

in Table 3. Columns [I1] to [I6] in Table 3 are the estimations using the PSTR approach including different control variables. In each of these columns there are also estimates of the slope parameter γ and the threshold $\overline{IPR}$.

The results are relatively robust, since neither the sign nor significance of the main variable's coefficients change substantially when including the controls. The same can be said about the slope parameter γ and the threshold $\overline{IPR}$. The only problem seems to appear in column [I6], when including the four controls. The estimated threshold is almost three points larger than in all previous models. Also, IPR in its linear form is no longer significant. This can be due to colinearity problems between Openness and Foreign Direct Investment. Given that, we abstain from discussing results of specification [I6].

The signs of *GDPCAP* and *INFRA* are positive, which is consistent with past literature (Hudson and Minea, 2013). However, EDUC is never significant and in some specifications it is negative. The most surprising fact is FDI, which is negative and highly significant in all specifications. In previous literature, FDI was positive but insignificant. Hence, an interesting task would be to analyze the relationship between Foreign Direct Investment and the complexity of exports. Nevertheless, that issue is beyond the scope of this research.

The results of the estimation show the existence of positive and negative significant effects of IPR on economic complexity. IPR in its linear form is always positive and significant. When interacted with the transition function, it is always negative and significant. The estimated threshold varies between 1.50 and 1.61 and the slope parameter between 17 and 22.

The fixed effects models, besides providing a worse fit according to the sum of square residuals than its PSTR equivalent, fail to capture the complexities of the nonlinear relationship between IPR and innovation. To better see the dynamics of this effect, we analyze the derivative of innovation with respect to IPR, which is represented by the following equation:

$$\frac{\partial INNOV_{it}}{\partial IPR} = \beta_0 + \beta_1 g(IPR_{it}; \gamma, \overline{IPR}) + \gamma g(IPR_{it}; \gamma, \overline{IPR})[1 - g(IPR_{it}; \gamma, \overline{IPR})]\beta_1 \quad (6)$$

This derivative is a function of IPR intensity. It is depicted in figure 6. This figure is in line with the one found by Hudson and Minea, (2013), depicted in figure 1. They argue that they are the first ones to find an inverted U-relationship between IPR and Innovation, with positive effects for small and high values of IPR and negative effects for intermediate protection. Furthermore, the first turning point, where the effect becomes negative, is more or less the same. In their study it occurs at 1.5, whereas in ours at 1.36.

Nevertheless, there are also important differences. First, in our curve, for values smaller than 1.1, the positive effect is almost constant, while in their work it decreases. Second, according to our estimations, the effect becomes positive again at a level of 1.8, while in their research it happens almost at a level of 3. Finally, we find that after 1.8, the effect is positive again, but it is very small and constant. In contrast, in Hudson and Minea, (2013) this new positive effect is crescent.

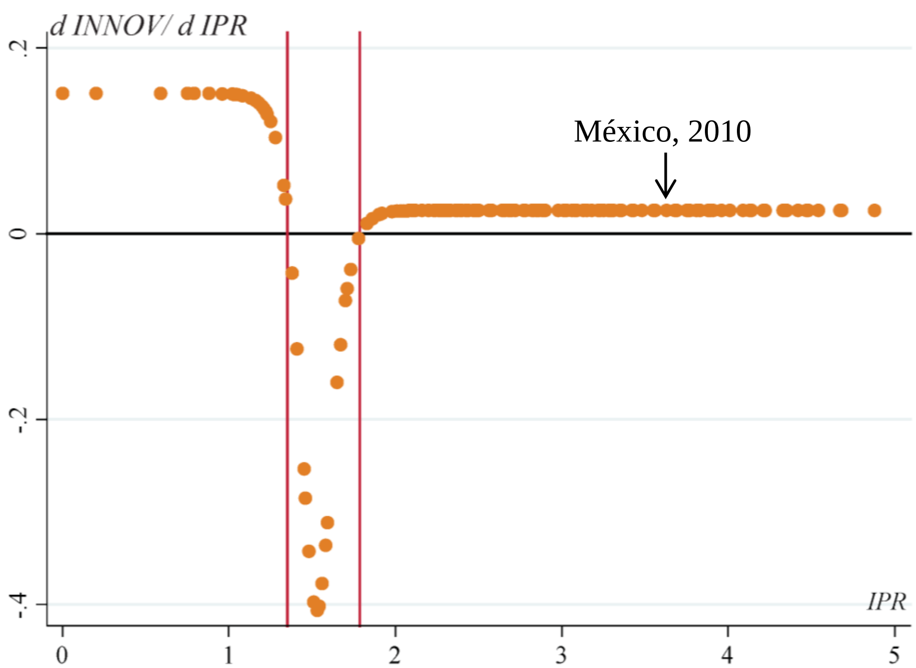

Figure 6. *The influence of the IPR level on the Innovation /IPR derivative. Note: derived from regression [I4]*

The interpretation of our results, however, is more or less the same. While the strictly negative effects of IPR on innovation are restricted for a small interval of IPR intensity, after a relatively small level of protection the benefits of increasing it are almost zero.

But the specific curve we found encloses a very important fact. Approximately, 1.8 is the value of the index from which stronger IPR do not increase innovation by a substantial amount. Since 1995, almost all countries have had higher levels of IPR, and in 2010, the minimum value was equal to 2.23, well above 1.8. This suggests that, currently, stronger IPR is not a very efficient strategy to elevate economic sophistication. We could even say that almost all the benefits from tightening IPR have already been exploited.

Nevertheless, there is a substantial problem with this estimation. It assumes that the curve in figure 1 is the same for all countries, regardless their level of economic development. For example, consider two very different countries, Morocco and New Zealand. In 2010, the IPR protection was equal to 3.55 for the former and to 3.68 for the latter. Our results imply that both countries would benefit almost the same from increasing IPR, despite the fact that the GDP per Capita of New Zealand is more than ten times larger than Morocco’s. This, as the test for GDPCAP as transition function shows, is not a realistic assumption.

The next step would be, as stated at the beginning of the section, to add to equation (4) a new transition function with GDPCAP as transition variable, as in the following equation.

$$INNOV_{it} = \alpha_i + \beta_0 IPR_{it} + \beta_1 IPR_{it} g(IPR_{it}) + \beta_2 IPR_{it} g(GDPCAP_{it}) + \sum_{j=1}^{J} \phi_j X^j{}_{it} + \varepsilon_{it} \tag{7}$$

If we estimated equation (7), there would be a different curve like the one in figure 6 for each level of GDP per Capita. This curve would be shifted upwards or downwards depending on the level of economic development. In the example we are elaborating, we would expect the derivative of innovation with respect to IPR to be significantly larger for New Zealand than for Morocco, given the huge gap in economic development between these two countries.

Table 4

The impact of IPR on innovation, subjected to the GDPCAP level

Innovation	[G1]	[G2]	[G3]	[G4]	[G5]	[G6]	[G7]	[G8]
IPR	-0.0865***	-0.0821**	-0.0889***	-0.0517*	-0.0638*	-0.0209	-0.1062	-0.0596
	(0.0324)	(0.0329)	(0.0323)	(0.0302)	(0.0327)	(0.0238)	(0.0884)	(0.0866)
IPR×GDPCAP							0.0111	0.0069
							(0.0099)	(0.0099)
IPRg(GDPCAP)	0.0932***	0.0976***	0.0995***	0.0749**	0.0807**	0.0435**		
	(0.0357)	(0.0366)	(0.0371)	(0.0330)	(0.0372)	(0.0213)		
GDPCAP	0.1741**	0.1922**	0.1345	0.1367	0.1571*	0.1446*	0.1609*	0.1722*
	(0.0737)	(0.0814)	(0.0844)	(0.0896)	(0.086)	(0.0882)	(0.0919)	(0.0912)
EDUC		-0.0026	-0.0031	0.0028	-0.0031	0.0029	0.0026	0.0028
		(0.0035)	(0.0035)	(0.0033)	(0.0035)	(0.0033)	(0.0036)	(0.0035)
INFRA			0.0531	0.0421	0.0675	0.0653	0.0501	0.0617
			(0.0529)	(0.0542)	(0.0554)	(0.0581)	(0.0548)	(0.0594)
FDI				-0.0332***		-0.0385***	-0.0359***	-0.0396***
				(0.0117)		(0.0117)	(0.0118)	(0.0111)
OPEN					-0.0947	-0.0485		-0.0481
					(0.058401)	(0.0593)		(0.0600)
γ^{GDPCAP}	5.1506	4.6554	3.9427	3.3107	4.2221	12.8714		
$\overline{\text{GDPCAP}}$	7.7761	7.8365	7.9366	8.2627	7.9281	8.6186		
N/countries	558/62	558/62	558/62	509/62	549/62	500/62	509/602	500/62
Sum of sq. Resid.	31.4250	31.3846	31.2870	24.0276	28.9461	21.8985	24.2389	22.0683

Note: Regressions [G1]-[G6] were estimated by the PSTR method presented in the last section. Regressions [G7] and [G8] were estimated by Fixed Effects. N denotes the number of observations.
*Denotes significance at the 10% levels. **Denotes significance at the 10% levels ***Denotes significance at the 1% levels

However, since in the present paper we would not conduct this analysis, we proceed to estimate equation (5), which only uses GDPCAP as transition variable. This separated analysis will help us to infer the implications of different IPR intensity and economic development on the effect of IPR on innovation, although an alternative estimation would be to estimate the unified version of the model in equation (7), as done by Hudson and Minea (2013).

The results of estimating equation (5) are presented in Table 4. As before, columns [G1] to [G6] show the results of different PSTR specifications with different control variables, and columns [G7] and [G8] their Fixed Effects equivalents. The sign and significance of control variables are the same as before. The main difference is that, now, GDP per Capita is not always significant. Just as before, the inclusion of Openness and FDI in the same specification causes the slope parameter gamma and the threshold to increase. In all other specifications, parameter gamma takes values between 3.9 and 5.1, while the threshold $\overline{\text{GDPCAP}}$ between 7.8 and 8.3. The relatively small size of these intervals suggests that the estimations are robust.

Once again, the results clearly show the positive and negative effects of IPR on innovation depending on the level of economic development of each country. In this model, however, the linear form of IPR is negative and significant at the 10% level, while IPR interacted with the transition function is positive and significant at the 5% level. To better understand this effect we analyze the evolution of the derivative of innovation with respect to IPR, which is given by the following expression:

$$\frac{\partial INNOV_{it}}{\partial IPR} = \beta_0 + \beta_1 g(GDPCAP_{it}; \gamma, \overline{GDPCAP}) \tag{8}$$

Now, the effect of IPR on innovation does not depend on IPR intensity but on the level of GDP per Capita. Equation (8) is depicted in figure 7. The main implication is that there is a bunch of countries for whom it is (or was not) good to tighten their patent systems.

The turning point we found is 8.51, which in levels (at 2010 dollars) is equal to $4964.20. Hence, according to this threshold, countries with a smaller GDP per Capita are harmed by increasing IPR protection. Curiously, this level is almost at the median of the sample, which is $4750. Also, for very low (high) levels of GDP per Capita, the impact of tighter IPR on economic complexity is flat and very damaging (positive).

However, to identify the limitations of these estimations, we will consider the following numeric example. The average GDP per Capita of Mexico for the whole period is equal to $7584.81, while in 2010 it was of $9313.36. Hence, according to our results, Mexico would benefit from increasing IPR.

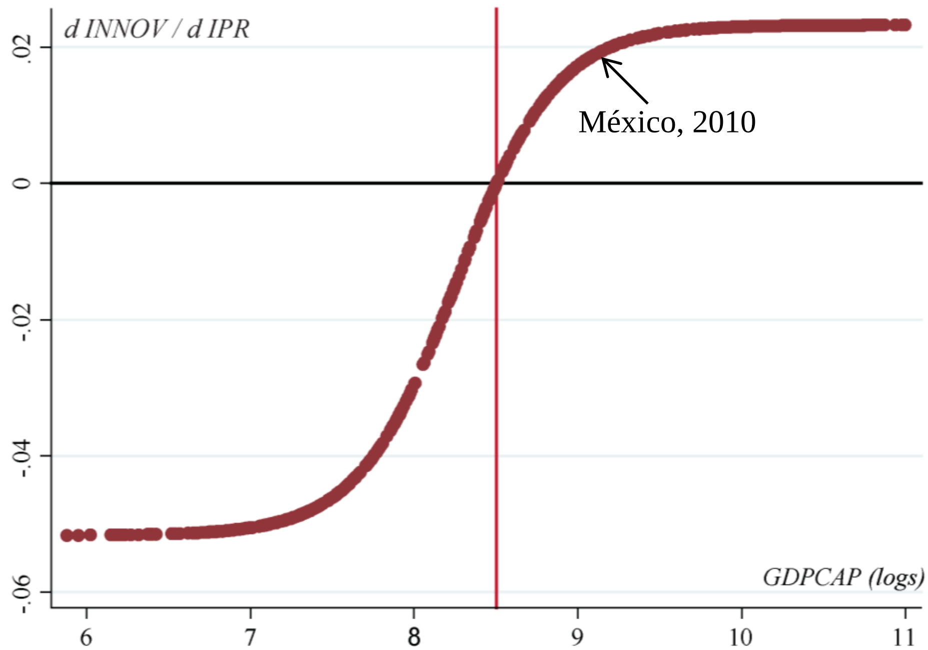

Figure 7. *The influence of the GDPCAP level on the Innovation /IPR derivative. Note:* derived from regression [G4]

Nevertheless, this estimation suffers from the same shortcomings as the last one, but in the contrary sense. That is, we are assuming the same Innovation/IPR relationship independently of the initial level of IPR protection. For example, Mexico's IPR level in 2010 was of 3.75. In 1970, Portugal's GDP per Capita was $10176.40 (very similar to 2010's Mexico), but their IPR protection level was equal to 1.33. This estimation predicts that the effect of increasing IPR would be positive, and more or less the same for both countries.

But taking into account the results of equation (4), it would be logic to expect a substantially different effect for 1970's Portugal than for 2010's Mexico, given the low level of IPR of the former. This is an example of the considerations that must be taken into account before interpreting the results, which cannot be taken at face value. Despite this, our results provide important insights about the complex effects of IPR on economic sophistication, which had not been addressed by preceding works on the subject.

Section 7
Conclusions

In this research we estimated the effect of IPR on innovation using a sample of 62 countries for a 44 years period. The novel aspect of this research was to combine the use of the Economic Complexity Index (ECI) to measure innovation with the PSTR technique to capture the heterogeneities of this effect. The ECI captures diversity and ubiquity in countries' exports and hence it is a measure of applied innovation, since it only includes innovations that are being implemented in production processes. The PSTR model allows identifying how the initial level of IPR and economic development influence the effect of a stricter patent system on innovation without imposing any ex-ante polynomial form or a division between developing and developed countries, as is commonly done in the literature.

There are two main findings. The first one is that, keeping GDP per Capita fixed for all countries, stronger IPR are not necessarily good for fostering innovation. In particular, we found that countries should avoid IPR levels (measured with the Ginarte and Park Index) between 1.3 and 1.8, since inside this interval IPR exert a negative effect on innovation. Furthermore, from that level onwards, the impact of increasing IPR is positive but very close to zero. Hence, the possibility of obtaining benefits from stronger IPR seems to end at a relatively low level. Moreover, in 2010 all countries in the sample had an IPR level larger than 1.8, which would imply that almost all benefits in terms of innovation from IPR have already been exploited.

The second result is that, keeping IPR fixed for all countries, the Innovation/IPR relationship is positively related to the level of development of each country. We find that for levels of GDP per Capita smaller than $4964.20, IPR exert a negative effect on economic complexity, while richer countries benefit from tightening IPR. Hence, the incentives for strengthen national patent systems are heterogeneous and depend on the level of income.

In summary, our results suggest, on the one hand, that making IPR systems more rigorous is not necessarily optimal and, on the other hand, that poorer countries do not have short term incentives to fortify their patent systems.

Nevertheless, the main limitation of this research is that we conducted this analysis separately, rather than in a unified manner. This means that we cannot know the joint influence of initial IPR and economic development on the IPR/Innovation relationship. This can be seen in two ways. Our first model implies that for the same level of IPR, the effect of increasing them on innovation will be the same for all countries, independently of their level of economic development. Our second model assumes that the impact of tightening IPR on innovation is the same for countries with same level of development, independently of their current level of protection. Thus, the results we present should be considered as preliminary.

Notwithstanding this, our research contributes to the literature by providing evidence in a novel manner over two general points. The first one is that stronger IPR do not necessarily increase innovation or may even reduce it. The second one is that benefits from strict patent systems are unevenly distributed between countries, depending on their level of economic development.

The main implication of this is that a uniform Intellectual Property regime, like the current one, is not optimal. The TRIPS agreement compelled nations to warrantee a minimum level of protection of Intellectual Property. For example, the duration of patents was set in 20 years, a duration which many of the people involved considered excessive (Rodrik, 2018).

The biggest adjustments had to be done by developing countries, since they started from a smaller level of protection and had to create many organisms and institutions in order to be able to enforce the agreement. Among many others, this was the case of Mexico, which had an IPR level of 1.02 in 1990, whereas in 1995, after TRIPS, it was of 2.68. That is, in an extremely short period of time, IPR protection more than doubled.

In the long run, a high level of IPR protection could be considered optimal but only if there is convergence in economic development. In contrast, in the short run, developing countries may find it better to get technology transfers by imitation, reverse engineering and learning by doing processes which are incompatible with a very tight patent regime.

Hence, an important and urgent task would be to consider reforming the global Intellectual Property regime, so that it considers the particularities of each country while warrantees fair conditions and correct incentives for world trade, investment and R&D activities. As Sweet and Eterovic Maggio (2015) point out, a reformed IPR regime should give enough “room for *manouvre*” to developing countries so that they can implement their best innovation policy. This would be an important step towards a better distribution of the benefits created by globalization and economic integration.

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