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Social progress and international patent collaboration

Abstract

This study focuses on how international patent collaboration (IPC) influences social development at the country level. Although researchers have traditionally stressed the effects of IPC on countries' technological development, there are indications that it can also have important social effects. In this context, this paper provides an empirical evaluation of the influence of different types of patents (i.e., patents invented abroad and patents invented in the focal country by foreign researchers) on the Social Progress Index. Using panel data on a sample of 35 OECD countries over the period 2009-2016, the results support the conclusion that different types of IPC may have different implications for countries' social development. The findings also show that patents invented abroad have a positive influence on those aspects of social progress related to personal rights, freedom and choice, tolerance and advanced education, more than on basic human needs. Overall, this paper is relevant for policy making with regard to the type of IPC that is most beneficial in terms of social impact.

Keywords: Social progress, Patents, Collaboration, Innovation

JEL classification: O33, I3

1. Introduction

Social progress, understood as "*the capacity of a society to meet the basic human needs of its citizens, establish the building blocks that allow citizens and communities to enhance and sustain the quality of their lives, and create the conditions for all individuals to reach their full potential*" (Social Progress Imperative, 2016, p.10), is a priority in public policies. Many initiatives aim to foster social progress, although some are more efficient than others. Studies have shown that in the era of the global economy, technological innovation is one of the essential factors in a country's economic growth and competitiveness (Cohen, 2010; Hall et al., 2014). In this context, international patent collaboration or IPC (i.e., agreements among agents in different countries to jointly develop technological innovations) has become a common phenomenon, receiving increasing attention from scholars in a variety of fields (Belderbos et al., 2014; Giuliani et al., 2016; Montobbio & Sterzi, 2013; Nepelski & De Prato, 2015a, 2015b).

Knowledge spillovers from such collaboration are essential to improving creativity, efficiency and productivity, enhancing a country's ability to develop technological innovations (Lee & Bozeman, 2005; Mariani, 2004). Moreover, this collaboration contributes to the implementation of such innovations by promoting the dissemination of knowledge and technology via expanded social networks (Hertzum, 2008; Lim & Park, 2010; Yin et al., 2006). Given these potential advantages for countries' technological development, public and private investment efforts are increasingly aimed at encouraging international collaboration initiatives.

Although traditionally it has been emphasized that international collaboration has significant impact at a technological level, some scholars have started to note that these transboundary initiatives can also have implications for the social aspects of a country's development (Jiang et al., 2017; Noailly & Ryfisch, 2015). For instance, some recent studies suggest that international technological collaboration can help fulfill basic human needs, enhance access to fundamental knowledge, improve health systems, increase income levels, foster the use of environment-friendly technologies, expand personal freedom and choice, or help generate tolerance and an advanced educational environment (Giuliani et al., 2016; Montobbio & Sterzi, 2013; Noailly & Ryfisch, 2015). The main driver in all these cases has been found to be the new knowledge created and the newly acquired knowledge, skills and capabilities of the human capital.

Beyond these initial findings, however, not much is known about the social effects of IPC. Thus, this study aims to advance understanding of this phenomenon by examining a particular type of international collaboration and its implications for a country's social progress. To analyze social progress, the study provides a holistic, objective, transparent, outcome-based measure of a country's wellbeing that is independent of economic indicators. Examining IPC is particularly relevant for several reasons. First, IPC tends to imply closer and longer-term relationships between partners than other forms of collaboration (Breschi & Lissoni, 2009; Singh, 2005). Second, it usually entails intensive transfer of both implicit and explicit knowledge between the partners (Montobbio & Sterzi, 2013). Finally, the effect of patents on society is more instantaneous than that of other technological inputs because it implies an explicit knowledge that can be used immediately (Awokuse & Yin, 2010).

Additionally, a critical argument made in this study is that the social implications of IPC could differ depending on the type of collaboration. Thus, two types of IPC have been considered. The first, Patents Invented Abroad, aims to reflect the knowledge acquired by the researcher abroad, the spillovers generated by the collaboration and the knowledge associated with the patent. The second variable is Patents Invented by Foreigner, which aims to reflect the spillovers foreign researchers generate in a focal country and the knowledge transfer that stems from the collaboration.

The paper argues that these two types of IPC entail different types of human capital mobility (i.e., incoming versus outgoing) and can therefore be of varying benefit to the focal country's social development (Artuc et al., 2015; Leger, 2005; Singh, 2005). The characteristics of the key participants — in terms of their education, work and entrepreneurial experience, and social relations — thus become a major source of credibility and legitimacy (De Cleyn et al., 2015; Packalen, 2007; Reagans and Zuckerman, 2001).

The study contributes to previous literature by showing that IPC may have important social implications. Moreover, the two types of IPC were explored in order to assess its influence in depth and to determine those public policies that are more advisable in terms of social progress and IPC. The two types differ depending on the kind of human capital mobility the collaboration entails (incoming vs outgoing). Overall, it was found that outgoing mobility (patents invented abroad) has a positive and significant influence on social progress.

For additional results, the Social Progress Index was disaggregated into three dimensions to test IPC's effect on social progress empirically: Basic Human Needs, Foundations of Wellbeing, and Opportunity. Each dimension has four components, encompassing as many valid aspects of the component as possible. The first dimension, Basic Human Needs, assesses whether a society is able and willing to provide what its citizens require to survive. It encompasses nutrition and basic medical care; water and sanitation; shelter; and personal safety. The second dimension, Foundations of Wellbeing, captures whether a society offers building blocks for its citizens to improve their lives. Are people able to get a basic education and obtain access to information and communications to achieve their full potential? Do they benefit from a modern healthcare system and live in a healthy environment that will ensure a long life? (Social Progress Imperative, 2016). The final dimension, Opportunity, provides information about citizens' freedom and opportunity to make their own choices. Personal rights, personal freedom and choice, an environment of tolerance and inclusion, and access to advanced education all contribute to the level of opportunity in a given society.

The paper is structured as follows: First, it provides the conceptual background for the relationship between IPC and social development. Building on these ideas, it sets out the research hypotheses pertaining to the influence of different types of IPC on social progress. Next, it describes the methodology and results. Finally, it discusses the main conclusions, as well as the study's implications and limitations, and suggests promising avenues for future research.

2. Theoretical framework and hypotheses

2.1. International patent collaboration and social progress

IPC is a technological collaboration that involves two or more countries and whose outcome is a patent. It is widely accepted that, for countries, patent development enables the creation of higher-added-value products and services, which increase productivity and improve living standards (Grossman & Helpman, 1993). There are other types of international collaboration that benefits social progress (Bäck and Kohtamäki, 2015), such as R&D collaborations, scientific collaborations (co-publications), governmental and social agreement between policy-makers, citizens and NGOs (Biggiero and Angelini, 2015; Guns and Wang, 2017; Ma et al. 2009; Smith, 1989; Su, 2017). All of them contribute to solving social problems and improving quality of life and they usually imply a technological advance that favours social progress (Niesten et al., 2017). At the same time, it is commonly accepted that most of these international

collaborations imply a technological knowledge transfer and most of the time it is transfer by means of patents (Guan et al., 2015; Guan and Chen, 2012). New patents and the knowledge associated with them can sometimes improve a country's production systems and make its processes more efficient. In these ways, the new patents and the knowledge derived from IPC have an important effect on social progress (Jiang et al., 2017). However, although patents are a key element in industrialization and allow countries to catch up with others that are more advanced (Fu et al., 2011), many authors show that developing new patents is costly and risky. Thus, industrial agents increasingly opt to work with agents of other countries rather than relying on individual development. Nowadays, such collaboration is an alternative method of patent development, allowing higher efficiency and making a greater impact on society (Fleming et al., 2007). IPC is considered particularly fruitful since it implies that highly qualified personnel and significant resources will be involved, and that strong relationships among agents in partner countries will be developed. (Battistoni et al., 2016; Fernández-Esquinas et al., 2015). These relationships often last for long periods and entail close interpersonal contact, which may continue for years after patent filing (Singh, 2008). IPC also has some disadvantages (Adams et al. 2005, Guan and Chen, 2012; Polterovich, 2017). Sometimes, it is difficult to find the correct partner for the collaboration, and the partners may have divergent objectives (Öberg, 2016). This implies that more time will be needed to decide on partners and to obtain the patent, and that the process of integrating agents will be more complex and costly (Adams et al. 2005; Polterovich, 2017). Finally, IPC could discourage technological advances and internal development in each country and limit the technological knowledge creation that it is essential for social progress (Guan and Chen, 2012; Noni et al., 2017; Silva et al. 2017).

Frequently, IPC has made not only a technological impact but a social one (Hoekman et al., 2005; Jiang et al., 2017; Kirim, 1985; Streeten, 1974). This paper argues that, in general, IPC is relevant for social development because the knowledge acquired from the collaboration can help strengthen relationships between countries with regard to basic human needs (e.g. nutrition and basic medical care, water and sanitation, shelter and personal safety); generate common environmental framework aspects (resulting in similar environmental rules in all countries) (Noailly & Ryfisch, 2015); increase the quality of public health services (new techniques and medicines resulting from patents);

generate income (mainly business profits, but also citizens' earnings and public revenues); improve the foundations of wellbeing (access to basic knowledge, information and communications; health and wellness; environmental quality) or increase opportunity by expanding personal rights, personal freedom and choice, tolerance and inclusion, and access to advanced education. Thus, the following hypothesis is put forth:

Hypothesis 1: IPC has a positive impact on a country's social progress.

However, it can be expected that the benefits of IPC for a focal country in terms of social development vary depending on the particular type of collaboration established with the partner country (i.e., whether IPC implies incoming or outgoing mobility of human capital). The study therefore considers two kinds of collaboration: patents invented abroad and patents invented in the focal country by foreigners.

2.2. Patents invented abroad

Patents invented abroad can have an important impact on social development. This type of collaboration implies, for the focal country, outgoing mobility of human capital (Artuc et al., 2015). Research agents sometimes lack the appropriate contextual knowledge in the focal country, so in order to produce new knowledge they move to other countries. This outgoing mobility produces knowledge flow and networks that not only contribute to the production of new patents but also help make countries more socially involved, with more technology dissemination, new relationships in matters of education and health; increased income and improved environmental settings (Artuc et al., 2015; Felsenstein, 2015; Gioli et al., 2016; Montanari, 2012). Thus, patents invented abroad can yield social benefits because they allow the focal country to use and appropriate the patent rents (economic, technological and social benefits), and also to absorb new knowledge, expand access to information, communications and advanced education, enhance personal freedom and choice, strengthen education relationships, improve the health system, increase income, and create new environmental settings (Doern, 1997; Oberthür & Rabitz, 2014).

The driver used is the new knowledge created and its mobility. Moreover, patents invented abroad are especially significant for the focal country because they provide bridges that can lead to agreements in other social areas. This type of collaboration also allows focal countries to enjoy benefits associated with the country hosting its

researchers, such as tacit knowledge and technological infrastructure (Batley & Mcloughlin, 2015; Lall, 1992; Young Chung & Lee, 2015).

Nowadays, IPC involving patents invented abroad is focused on producing and acquiring knowledge and strategic assets essential for social development (education, knowledge, information, health and environment are priority topics), with most IPC being related to pharmaceutical and health products (Fu et al., 2011; Kedron & Bagchi-Sen, 2012; Kirim, 1985). The objective is therefore broader, encompassing not only technological aspects but also social benefits (Ivarsson & Göran Alustam, 2005). A key means of absorbing knowledge is face-to-face interaction (Harirchi & Chaminade, 2014; Van Rijnsoever et al., 2008), because it allows for instantaneous feedback and speeds up problem-solving in research contexts. Overall, the most important benefit of IPC in host countries is the tacit knowledge that researchers and firms absorb and the networks of relationships they establish (Lall, 1992; Young Chung & Lee, 2015). Countries know the social effects of this type of IPC (Fu et al., 2011; Leger, 2005; Schneider, 2005). Based on that, research agents (e.g. firms and public scientific institutions) mostly depend on public financial support for collaborations in a foreign country, and governments usually provide funding for such initiatives so that agents can expand the internal scope of their research activities (Hoekman et al., 2005). Countries allocate greater public resources to stimulate outgoing mobility (Madsen et al., 2002) of their human capital. Thus, the study's next hypothesis is:

Hypothesis 2: Patents invented abroad have a positive impact on a country's social progress.

2.3.Patents invented by foreigners

Patents invented by foreign researchers (i.e., patents that are developed by the visiting agents in the focal country and are fully owned by the foreign country) also have an important effect on social progress. This type of collaboration implies, for the focal country, incoming human capital mobility. The role of foreign knowledge has been studied from different perspectives (Fu et al., 2011; Giuliani et al., 2016; Hoekman et al., 2005), and many of the analyses show that IPC has an influence on living standards (Alnuaimi et al., 2012; Furman et al., 2006; Penner-Hahn & Shaver, 2005; Singh, 2008).

The social benefit of patents invented by foreigners usually depends on knowledge spillovers the collaboration generates (Autio et al., 2003). In this case, unlike in that of patents invented abroad, it is not possible to appropriate the social benefits of the patent.

Nevertheless, this type of IPC is valuable because it provides new and free knowledge, and it is easier for internal agents in the focal country to interact with the visiting agents and thus obtain social advantages. Social networks, consisting of both informal friendships and formal collaborations, contribute to innovation by being conduits for information and facilitating the dissemination of knowledge and technology (Hertzum, 2008; Yin et al., 2006). Specifically, spillovers generated by foreign research agents help countries acquire new knowledge, solve social problems, learn new strategies, establish networks, and, in general, improve their social development (Bryant, 2002; Montanari, 2012; Soete & Arundel, 1995). Incoming human capital mobility provides countries with new information, improves communications, helps create tolerant environments and allows greater access to advanced education, creating the potential for wide-ranging personal opportunity.

Finally, other factors such as policies, regulations, culture, image, transparency, tolerance, safety, freedom of speech and openness could be affected by the presence of foreign researchers. The visiting agents, who reflect their own countries' versions of these social elements, usually interact with the host researchers during the process of creating a new patent. This process is particularly intensive; it takes time and researchers' relationships become strengthened. Additionally, these factors have an important influence on the social impact of patents invented by foreigners. (Youngs, 2009). The effect of the collaboration initiative will be enhanced in those countries with better mechanisms for integrating the visiting researchers and whose policies promote interaction with internal agents (Guan & Chen, 2012). As previously noted, IPC tends to imply closer and longer-term relationships between partners than other forms of collaboration. This is particularly relevant when the type of IPC is patents invented by foreigners. In this case, focal countries have more time to exchange information with these highly qualified researchers and generate formal and informal relationships with them. These links encourage citizens of focal countries to be more tolerant and open minded, raise their level of culture, take advantage of access to more and different knowledge and to advanced education, be more environmentally friendly, and expand their personal freedom and choices, all of which increase social progress. Accordingly, the study's final hypothesis is:

Hypothesis 3: Patents invented by foreign researchers have a positive impact on a country's social progress.

3. Empirical analysis

This section discusses the sample, variables and methodology used in the empirical assessment.

3.1. Sample

To carry out the empirical analysis, data from the Social Progress Imperative non-profit organization was examined as well as the OECD (Organization for Economic Co-operation and Development) database pertaining to the production of patents in the OECD environment (OECD, 2016; Social Progress Imperative, 2016) over the period 2013-2016 (38 countries, 128 observations). The analysis starts in 2013 because the Social Progress Index was first published that year by the Social Progress Imperative, and we also considered a lag of four periods for the rest of the independent and control variables. In order to avoid missing values in the estimates and to have the same sample size in all models, those cases for which there was no information on any of the variables were not considered. As a result, an unbalanced panel of 35 countries and 120 observations was obtained.

3.2. Variables

The literature shows the importance of measuring social progress (Mayer et al., 2017; Thore & Tarverdyan, 2016). International organisms such as the UNDP (United Nations Development Program) proposed an indicator of social development, the HDI (Human Development Index), and the OECD recently proposed another indicator, the Better Life Index. Nowadays, the most relevant and complete social index is the Social Progress Index, which measures the extent to which countries provide for the social and environmental needs of their citizens. It is based on three dimensions: Basic Human Needs (BHN), Foundations of Wellbeing (FOW), and Opportunity (OPO). These dimensions incorporate information on 52 indicators (Table 1). The index is published by the non-profit Social Progress Imperative, and is based on the studies of Amartya Sen, Douglass North and Joseph Stiglitz. It was built by direct observation of social and environmental outcomes, but economic factors were also considered.

[Insert Table 1. Social Progress Index]

In this study, the Social Progress Index (SOCIAL_PROGRESS) is considered as the dependent variable because it incorporates indicators that best differentiate countries' social performances. Moreover, the methodology of this index is appropriate because it uses outcome measures when there are sufficient data available or the closest possible proxies. The index uses principal component analysis (PCA) to determine the weighting

of each indicator within a component. This technique combines indicators into a component that captures the maximum amount of variance in the data while reducing any redundancy among indicators. Through this process it was found that PCA weighted many indicators very near to equally within components, signalling a good selection of indicators to measure the concept of the component (Social Progress Imperative). However, the three dimensions of the Social Progress Index (SPI) are also considered as dependent variables. There are some differences among these indicators (Basic Human Needs, Foundations of Wellbeing, and Opportunity) and the effect of patents may not be the same. Table 1 shows the indicators used for each variable to build the SPI.

Independent variables. The increasing global mobility of researchers today makes it necessary to analyze worldwide cooperation in depth. Researchers are good conduits for moving knowledge around the world, but sometimes this knowledge transferred by means of spillovers could be too general and biased. Another problem that has been detected is the difficulty of measuring how much knowledge has been transferred in this manner. Accordingly, many authors report that patents are a better instrument for measuring knowledge transfer (Roper & Hewitt-Dundas, 2015). They are also a good indicator of spillovers generated by researchers' mobility. Based on that, the study disaggregated IPC into two dimensions: first, the impact of patents produced by researchers (PAT_AB) who leave their own country to work abroad; and second, the impact on social progress of patents produced by foreign researchers (PAT_FOR) in a host country. These variables aim to reflect international flows of knowledge between countries. The study uses the database Main Science and Technology Indicators, constructed by the OECD.

In particular, PAT_AB reflects international flows of knowledge from the inventor country to the applicant countries and international flows of funds for research. Specifically, the study is interested in patents invented in foreign countries by researchers from the focal country. It uses the variable "domestic ownership of inventions made abroad," defined as the "number of patents owned by resident(s) of country x (applicant) that have been invented by at least one foreign resident (inventor) from country" (PATSTAT, 2016). Finally, in order to include this variable in the model, the study takes the percentage of patents invented abroad: the share of the above indicator in total patents owned by resident(s) of country x (applicant). These data were obtained from the Patent Co-operation Treaty. In particular, the OECD database Main

Science and Technology Indicators has been used. This variable has been employed in previous studies (Guellec & Van Pottelsberghe de la Potterie, 2001; Montobbio & Sterzi, 2013).

Similarly, the OECD defines the variable PAT_FOR ("foreign ownership of domestic inventions") as the "number of patents invented by resident(s) of country x (inventor) that are owned by at least one foreign resident (applicant) from country" (PATSTAT, 2016). In particular, the study includes the percentage of patents owned by foreign residents: the share of the above indicator in total patents invented by resident(s) of country x (inventor). These data were obtained from the Patent Co-operation Treaty. The variables have been used in previous studies (Guellec & Van Pottelsberghe de la Potterie, 2001; Montobbio & Sterzi, 2013).

Control variables are grouped into two categories: (i) technological factors and (ii) social factors.

(i) Technological factors. Empirical literature shows that the most relevant technological indicators are R&D investment and patents, as the input and the output of the technological process. Prior research analyzes which of them is more relevant, but there is no consensus (Burhan et al., 2016; Cohen & Levinthal, 1989; Kang & Motohashi, 2014; Nieto & Quevedo, 2005). Both factors are similar: One incorporates the innovative effort of one country and the other incorporates the results of those efforts. However, authors do agree that the effect of patents on society is more instantaneous than the effect of R&D investment. This study considers both factors.

First, a ratio is created between the total patent applications by researchers in a country, measured by the OECD (2016) as the number of applications filed under the PCT and the total population. This is an indicator of patents per capita (PATENTS_PER). Second, a dummy variable is constructed based on R&D investment (INVEST). Thus, the sample is divided into two parts. The variable takes value 1 when the country invests more than the R&D means (period 2009-2012) and 0 in the rest of the cases. (Table 2 lists information about countries in each category).

[Insert Table 2. Country classification about "invest" variable]

(ii) Socioeconomic factors (SOCIAL_CAP). Previous literature shows the influence of social capital on environment (Dodd & Patra, 2002: Kwon & Arenius, 2010; Ng et al., 2015). This study uses the same indicator that was employed in those papers, namely, the measure of "trustworthiness and confidence" set out in the Global Competitiveness Report by the World Economic Forum for the period 2009- 2016.

3.3. Model

To test the hypotheses put forth in the theoretical background, pooled OLS regressions clustered at the country level are used with the STATA12 program[1]. Additionally, in order to control for endogeneity problems in the models proposed, explanatory and control variables are lagged by four years. The possibility of employing a panel data methodology, such as the two-step difference GMM model drawn up for dynamic panel data models by Arellano & Bond (1991), was initially considered. However, as the number of countries is not so large, this methodology was not applied. The results would not be reliable because the number of instruments would be larger than the number of countries.

The model proposed is as follows:

$$\text{SOCIAL\_PROGRESS}_i = a_0 + \beta_1 \text{IPC}_i + \beta_2 \text{PAT\_AB}_i + \beta_3 \text{PAT\_FOR}_i + \beta_4 \text{PATENTS\_PER}_i + \beta_5 \text{INVEST} + \beta_6 \text{SOCIAL\_CAPITAL}_i + \sum_{t=2009}^{2016} D_t + \varepsilon_i$$

where $\sum_{t=2009}^{2016} D_t$ is a set of time dummy variables and ε_i is the error term.

4. Results

Table 3 shows the descriptive statistics while Table 4 lists the correlation coefficients of the variables used in the regression analyses. Although some of the variables show a statistically significant correlation, analysis of the variance inflation factors (VIF) reveals no evidence of multicollinearity as all of them remained under 10 [44].

[Insert Table 3. Descriptive statistics]

[Insert Table 4. Correlation matrix]

Table 5 summarizes the results of the regression analyses. On the one hand, Model 1 considers the overall effect of IPC on the Social Progress Index. The results support Hypothesis 1, that establishing IPC fosters national social progress (β= 0.055; p = 0.036). This finding is in line with previous studies (Jiang et al., 2017) that indicate technological production and collaboration lead to greater social development. As previously noted, technological collaboration with other countries also encourages social progress. The new knowledge acquired from the collaboration can help strengthen relationships between countries with regard to basic human needs, generate common environmental framework aspects (Noailly & Ryfisch, 2015), improve the

1 The cluster option also implies the estimation of robust standard errors.

quality of public health services, generate income, and contribute to the foundations of wellbeing.

On the other hand, Model 2 considers the effect of patent collaboration (PAT_AB and PAT_FOR) on the Social Progress Index. The remaining models separately analyze IPC's effect on the index's three dimensions: Model 3 focuses on Basic Human Needs (BHN); Model 4 on Foundations of Wellbeing (FOW); and Model 5 on Opportunity (OPO).

[Insert Table 5. Main Results]

The results of Model 2 support Hypothesis 2, that patents invented abroad by another country's researchers (PAT_AB) contribute to that country's social progress (β= 0.119; p = 0.011). This finding is in line with previous studies (Azagra-Caro et al., 2017; Na Chiangmai, 2017; Polterovich, 2017; Raiser et al., 2017) that indicate technological production and collaboration lead to greater social development. The explanation might lie in the relevance of patents to social progress, and in the knowledge and benefit associated with patent collaboration.

However, it is not possible to confirm Hypothesis 3, which states that patents invented by foreign researchers in a focal country (PAT_FOR) increase social progress. Although many previous studies argue that the visiting agents contribute to the transfer of knowledge by means of spillovers (Cohen et al., 2002; Tappeiner et al., 2008), it is not possible to confirm this relationship. It could be that the contribution of foreign researchers to social progress is non-specific and therefore not significant.

With regard to control variables, this study shows that patents per capita (PATENTS_PER) has a positive impact on social progress (β= 0,135 p = 0,015). This result is in accord with previous analyses that suggest patents are necessary for technological and social country development. However, INVEST does not seem to significantly influence social progress, but patents may incorporate the INVEST effect. Moreover, the results are in line with previous studies that suggest output of innovation is more relevant than R&D investments (Nieto & Quevedo, 2005).

Nevertheless, social capital (SOC_CAPITAL) does not seem to significantly influence social progress. Although previous studies identify a positive relationship between social capital and entrepreneurship (Ng et al., 2015), innovation (Nahapiet and Ghoshal, 1998), and collaborations (Al-Tabbaa & Ankrah, 2016), it is not possible to confirm those findings in this sample.

Finally, with regard to annual effects, dummy proxies for the years 2014-2016 are positive and significant. This means that, ceteris paribus, in those cases the specific year influenced the dependent variable in a different and positive way in comparison with the situation existing in the reference year 2013.

Robustness of model results

In order to establish the robustness of the results, the estimations were repeated using additional measures for the dependent variable, and additional estimations considering the total samples.

First, Hypotheses 2 and 3 were tested by considering dependent variable Basic Human Needs (BHN), Model 3. It must be emphasized that the number of observations in both sub-samples was not large and consequently it was necessary to be cautious when interpreting the results. In any case, the findings were quite similar to those shown in Model 2 (Table 5) for the whole sample of countries. Hypothesis 2 was also confirmed with a major effect and the same level of significance (β= 0,135 p = 0,015). However, it was not possible to confirm Hypothesis 3 in this model.

Second, Hypotheses 2 and 3 were tested by considering dependent variable Foundations of Wellbeing (FOW), Model 4. The results were quite similar to those shown in Models 2 and 3 (Table 5) for the whole sample of countries. Hypothesis 2 was also confirmed but with a lesser effect and a lower level of significance (β= 0.122 p = 0.066) than in Model 2. In this case, it was possible to show that patents invented abroad have more impact on aspects such as nutrition, basic medical care, sanitation, shelter and personal safety than on access to basic knowledge, information and communication, wellness and environmental quality. However, it was not possible to confirm Hypothesis 3 in this model.

Third, Model 5 (Table 5) was estimated by considering the dependent variable to be the contribution to Opportunity (OPO) of patents invented abroad (PAT_AB) and patents invented by foreigners (PAT_FOR), instead of considering the Social Progress Index as dependent variable. The results were similar. Hypothesis 2 was confirmed, but it was not possible to confirm Hypothesis 3. However, there was another difference in the last model. In this case, the influence of patents invented abroad (PAT_AB) on Opportunity (OPO) was more significant than on Basic Human Needs and on Foundations of Wellbeing, and the effect was also greater (β= 0.262 p = 0.006).

Fourth, when the estimations were repeated by considering the sample as a pooled OLS regressions, the results did not vary significantly.

5. Discussion and conclusions

The recent growth in IPC and its effects on the social and technological sphere has attracted the attention of many scholars (Belderbos et al., 2014; Fu et al., 2011; Giuliani et al., 2016; Guan & Chen, 2012; Jiang et al., 2017; Montobbio & Sterzi, 2013; Noailly & Ryfisch, 2015). As this study has shown in the theoretical section and confirmed empirically, there is a positive relationship between IPC and the Social Progress Index. Another important advantage of collaboration is that researchers try to absorb precise knowledge in other countries in order to obtain instantaneous feedback and faster solutions to their problems. Sometimes this knowledge is essential to improving aspects of social progress, such as the development of new pharmaceutical or medical products. IPC reduces the risks and costs involved in generating new patents, and increases the probability of obtaining high-value patents. In essence, IPC is a mechanism for catching up with the most advanced countries, providing an opportunity to tap external knowledge pools, and thus to acquire valuable tacit knowledge and learn new work methods and advanced techniques (Batley & Mcloughlin, 2015; Lall, 1992; Young Chung & Lee, 2015).

Additionally, IPC was divided into two parts in this study in order to determine which type is better for social progress. While no significant influence was found for patents invented by foreigners in a host country, the results show that patents invented abroad have a positive and significant effect on social progress (Soete & Arundel, 1995). Thus, the findings confirm that research agents who go into foreign countries have "outstanding capacity to internationalize their production activities, and to invest abroad to acquire knowledge and other strategic assets not available in their home countries" (Giuliani et al., 2016: 200). In this sense, countries can benefit from collaboration entailing outgoing human capital mobility (i.e., patents invented abroad) (Artuc et al., 2015; Felsenstein, 2015).

Public policies that promote this type of IPC may therefore contribute to social progress. Countries can appropriate the knowledge acquired outside their borders and create social competitive advantages through interaction with foreign researchers. Therefore, these countries can strengthen their networks of relationships and send highly qualified people abroad. This may lead to countries improving their education systems and promoting other aspects of social progress such as tolerance and personal

freedom. On the other hand, public policies usually stimulate industrial agents, by means of grants and subsidies, to guarantee that IPC has a positive social impact.

While it is not possible to confirm in this study that countries have a stronger ability to profit from collaboration entailing incoming human capital mobility (i.e., patents invented by foreigners), many authors have reported that there are social advantages to be gained by the host countries. (Artuc et al., 2015; Felsenstein, 2015; Ivarsson & Göran Alustam, 2005). Agents in the focal country can appropriate the knowledge and experience of the visitors, which can lead to reducing risk in producing new patents; increasing the probability of obtaining high-tech/high-value patents; creating opportunities to tap internal knowledge pools; learning new methods of work and techniques; forging new relationships; acquiring tacit and codified knowledge; introducing environmentally friendly methods; using new resources and obtaining technologies and other strategic assets. But there is also an important contribution in terms of social aspects, leading to improvements in: sanitation facilities, electricity supply, personal safety, access to basic knowledge, information and communications, health systems and wellness, environmental quality, personal freedom and tolerance, and education systems.

This study also shows that patents per capita is essential for social progress, and is an indicator of the country's appropriability. Moreover, all countries are interested in absorbing new knowledge. Their structural capital favours integration and interaction with foreign researchers in the focal country and therefore improves social progress (Goertzel et al., 2016; Harirchi & Chaminade, 2014; Youngs, 2009).

Finally, this study reaches another interesting conclusion with regard to the effect of patents invented abroad on the three dimensions of social progress: Basic Human Needs, Foundations of Wellbeing, and Opportunity. The results show this effect is particularly relevant for Opportunity. Although this aspect of human wellbeing is often overlooked or separated in thinking about social progress in terms of more foundational and material needs such as nutrition and healthcare, it is essential for the advancement of society. It is necessary to point out that Opportunity measures the degree to which a country's citizens have personal rights and freedoms and are able to make their own decisions, as well as whether prejudices or hostilities within a society prevent individuals from reaching their potential. Opportunity also includes the degree to which advanced forms of education are accessible to citizens who wish to further their knowledge and skills, creating the potential for wide-ranging personal opportunity.

This paper contributes to the policy debate on the effects of IPC. The major presence of IPC and the economic difficulties of all countries require efficient investment that will actually help generate greater social development (Dellmuth, 2011). For this reason, this study aims to analyse different countries in order to determine the best option for international collaboration. This research has important implications for governments because they are responsible for managing and investing public funds. Based on the main results, a general pattern has been established that governments can follow. However, the study has some limitations. The main one is that although it is known that there is mobility in both types of IPC, it is not known whether the mobility is between developed and developed, developed and developing, or developing and developing countries. Another limitation is that the study does not provide data on less developed countries. This might be a future avenue of research. In addition, based on the necessity of doing projects more efficiently and leveraging the different capabilities of scientists, it seems necessary to get an effective project-scientist mapping strategy that allows an efficient analysis of collaborations. In this sense, the method proposed by Jiang (2008) provides the basis for future work.

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Table 1. Social Progress Index

Social progress Index	Basic Human Needs	Nutrition and Basic Medical Care • Undernourishment • Depth of food deficit • Maternal mortality rate • Child mortality rate • Deaths from infectious diseases
		Water and Sanitation • Access to piped water • Rural access to improved water source • Access to improved sanitation facilities
		Shelter • Availability of affordable housing • Access to electricity • Quality of electricity supply • Household air pollution attributable deaths
		Personal safety • Homicide rate • Level of violent crime • Perceived criminality • Political terror • Traffic deaths
	Foundations of Wellbeing	Access to basic knowledge • Adult literacy rate • Primary school enrollment • Lower secondary school enrollment • Upper secondary school enrollment • Gender parity in secondary enrollment
		Access to information and Communications • Mobile telephone subscriptions • Internet users • Press freedom index

		Health and Wellness • Life expectancy at 60 • Premature deaths from non-communicable disease • Obesity rate • Suicide rate
		Environmental quality • Outdoor air pollution attributable deaths • Wastewater treatment • Biodiversity and habitat • Greenhouse gas emissions
	Opportunity	Personal Rights • Freedom of speech • Freedom of assembly • Freedom of movement • Private property rights
		Personal freedom and choice • Freedom over life choices • Freedom of religion • Early marriage • Satisfied demand for contraception • Corruption
		Tolerance and inclusion • Tolerance for immigrants • Tolerance for homosexuals • Discrimination and violence against minorities • Religious tolerance • Community safety net
		Access to advanced education • Years of tertiary schooling • Women’s average years in school • Inequality in the attainment of education • Number of globally ranked universities • Percent of tertiary student enrolled in globally rank

Table 2. Country' classification about "invest" variable

INVEST			
1		**0**	
Canada	China	Australia	Israel
Poland	Russia	Austria	Italy
Spain	Turkey	Belgium	Japan
UK		Brazil	Mexico
		Czech Republic	New Zealand
		Denmark	Norway
		Finland	Portugal
		France	Slovenia
		Germany	South Africa
		Greece	South Korea
		Hungary	Sweden
		Iceland	Switzerland
		India	The Netherlands
		Ireland	USA

Table 3. Descriptive statistics

Variable	Mean [a]	Std. Dev.	Min	Max
SPI	76.174	12.511	39.51	90.09
BHN	83.826	14.611	40.02	96.63
FOW	75.372	11.600	41.6	89.78
OPO	69.567	13.596	36.67	89.58
IPC	40.316	22.721	4.64	108.65
PAT_AB	19.059	15.049	1.84	66.51
PAT_FOR	26.833	12.829	2.52	60.33
PATENTS_PER	0.0001	0.0001	1.29e -06	0.0005
INVEST	0.217	0.414	0	1
SOCIAL_CAPITAL	5.059	0.739	3.3	6.72

The sample consists of 38 countries over the period 2009–2016, 128 observations. Without missing sampling variables, a necessary condition to run regression models, the sample is reduced to 120 observations (35 countries). Robust Corrected Standards Errors are shown in brackets. Pool regressions clustered on the firm level are reported in the table.

[a] For dummy variables, the frequency is reported.

* Statistically significant at .1.

** Statistically significant at .05.

*** Statistically significant at .01.

Table 4. Correlation Matrix

Variable	1	2	3	4	5	6	7	8	9	10
SPI	1									
BHN	0.952***	1								
FOW	0.957***	0.936***	1							
OPO	0.888***	0.735***	0.757***	1						
IPC	0.392***	0.311***	0.337***	0.440***	1					
PAT_AB	0.456***	0.361***	0.393***	0.522***	0.940***	1				
PAT_FOR	0.057	0.067	0.067	0.012	0.575***	0.310***	1			
PATENTS_PER	0.372***	0.318***	0.332***	0.384***	0.154*	0.366***	-0.434***	1		
INVEST	-0.289***	-0.224**	-0.296***	-0.269***	-0.289***	-0.247***	0.006	-0.372***	1	
SOCIAL_CAPITAL	0.068	-0.036	0.037	0.187	0.060	0.078	-0.141	0.274	-0.24***	1

The sample consists of 38 countries over the period 2009–2016, 128 observations. Without missing sampling variables, a necessary condition to run regression models, the sample is reduced to 120 observations (35 countries). Robust Corrected Standards Errors are shown in brackets. Pool regressions clustered on the firm level are reported in the table.

[a] For dummy variables, the frequency is reported.

* Statistically significant at .1.

** Statistically significant at .05.

*** Statistically significant at .0

Table 5. Main results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Dependent variable	SPI[a]	SPI[a]	BHN[a]	FOW[a]	OPO[a]
IPC	0.056**				
	(0.027)				
PAT_AB		0.119**	0.135**	0.122*	0.262***
		(0.047)	(0.055)	(0.066)	(0.096)
PAT_FOR		0.006	0.077	-0.050	-0.011
		(0.090)	(0.080)	(0.092)	(0.161)
PATENTS_PER	302.78**	276.68**	346.67**	206.80*	283.98*
	(128.79)	(120.99)	(136.59)	(108.28)	(1.747)
INVEST	-2.573	-2.262	0.005	-2.073	-1.693
	(3.842)	(3.830)	(3.145)	(2.931)	(5.269)
SOCIAL_CAPITAL	-0.948	-0.724	-1.414	-0.0963	1.583
	(0.954)	(0.949)	(1.214)	(1.207)	(1.747)
Wald test	1076.89***	1697.48***	3491.24***	1679.13***	262.67***
R-squared	0.649	0.665	0.767	0.757	0.505
No. Countries	35	35	35	35	35
No. Observations	120	120	120	120	120

The sample consists of 38 countries over the period 2009–2016, 128 observations. Without missing sampling variables, a necessary condition to run regression models, the sample is reduced to 120 observations (35 countries). Robust Corrected Standards Errors are shown in brackets. Pool regressions clustered on the firm level are reported in the table.

[a]It also tested the same models for the total observations and countries, and the results are equal in terms of significance and similar in terms of β effect.

* Statistically significant at .1.

** Statistically significant at .05.

*** Statistically significant at .01

Table 6. Abbreviations

ABBREVIATION	VARIABLE
BHN	Basic Human Needs
FOW	Foundations of Wellbeing
GMM	Generalized Method of Moments
HDI	Human Development Index
INVEST	R&D Investment
IPC	International Patent Collaboration
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
OPO	Opportunity
PAT_AB	Patent produced by researchers abroad
PAT_FOR	Patent produced by foreign researchers
PATENTS_PER	Patents per capita
PCA	Principal Component Analysis
SOCIAL_CAP	Social Capital
SOCIAL_PROGRESS	Social Progress Index
SPI	Social Progress Index
UNDP	United Nations Development Program
VIF	Variance Inflation Factors