The Effect of Intellectual Property Rights on Agricultural Productivity

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Abstract

This paper explores the impact of strengthening intellectual property (IP) protection on agricultural productivity in a panel of countries for the period 1961-2010. Using an index of IP protection for plant varieties, we study the effect of stronger intellectual property rights (IPRs) on cereal yields and two different types of cereals: open-pollinated (wheat) and hybrid (maize). We found that the strengthening of IPRs has a positive effect on productivity of cereals for high- and low-income countries but it has no significant effect for middle-income countries. We also found that IPRs are uncorrelated with the growth rate of yields and that the the signing of the TRIPS agreement negatively affects cereal yields. Finally, we found evidence of the existence of non-linearities in the effect of IPRs on agricultural yields, both for different IP levels and income levels. The findings support the hypothesis that country specificities are important in determining the effect of IPRs and imply that there is no unique system that fits all.

JEL Codes: O10, O34, O50, Q19

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1 Introduction

Recent changes in global population have raised new challenges for agriculture, mainly related with feeding a growing population with changing dietary preferences and consumption patterns. This objective has to be achieved with a decreasing quantity of available agricultural land and considering the need to attend several environmental concerns (Conway and Toenniessen, 1999; Godfray et al., 2010; Marchal et al., 2011). Thus, there exists a broad consensus on the need for major changes in the global food system towards a more productive but also more sustainable system. In the meantime, there is a contentious debate on how to attain this aim.

The number and composition of population and food demand have been changing leading to an increase in competition for scarce land. This implies that increases in production to fed to growing population will have to be obtained from increases in productivity derived from two sources i) technological changes and ii) restoration of degraded soils and improvement in soil quality.

Several factors affect agricultural productivity: capital, labor and land availability, environmental and climatic factors, technological capabilities, profitability, and institutional factors. Among the institutional factors, recent changes in intellectual property rights (IPRs) systems are expected to affect agricultural productivity in several ways. One of the possible channels is through the incentives that IPRs provide for innovators.

There is no consensus on how IPRs affect productivity and innovation. While some authors argue that tighter IPRs systems in agriculture are likely to increase productivity by increasing incentives to create and diffuse new and more productive plant varieties, other scholars argue that this may have a non-significant or negative impact on productivity by decreasing biodiversity and availability of new plant varieties, specially for farmers in developing countries.

The International Union for the Protection of New Varieties of Plants (UPOV) advocates for harmonized and strong *sui generis* IPRs systems in the agricultural sector and argues that an effective IP protection system will provide an incentive to stimulate new and more effective breeding work at the domestic level (UPOV, 2005). It also argues that, in an international context, IPRs systems can provide important benefits by removing barriers to trade, thereby increasing domestic and international market scope. Also, the UPOV holds that access to foreign-bred varieties enabled by IPRs would improve production and exports. Thus, the UPOV considers that IPRs are an important means of technology transfer, an effective utilization of genetic resources and a means to achieve higher yields and economic benefits.

However, several authors have raised concerns regarding potential negative effects on domestic industries of developing countries derived from the monopoly power of IPRs, which may deter local innovation, productivity, technology transfer and trade (Boldrin and Levine, 2010). In addition, the effect of strengthening intellectual property (IP) protection in developing countries is controversial and was criticized theoretically, for example, by Helpman (1993), and empirically, for instance, by Louwaars et al. (2005).

Despite this, there is a global progressive tightening of IP protection systems, especially since the signing of the agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) (Maskus, 2000; Orsi and Coriat, 2006). Thus, empirical studies addressing the effects of IPRs in different sectors and countries are needed in economics.

This paper studies how IPRs are related with productivity and productivity growth in agriculture. As an indicator of productivity, we use yields of cereals, defined as the total production in tonnes obtained over the total area harvested in hectares.[1] As a measure of IPRs, the paper uses an index that quantifies the strength of IP protection for plant varieties (Campi and Nuvolari, 2015). The index takes a cross-country and historical perspective since it is computed for a group of 69 countries, both developed and developing, for a period of 51 years (1961-2011). It consists of five components that, as a whole, indicate the strength of each country's IP protection system for plant varieties. The index shows that the mean of protection has been steadily increasing over time.

Using this, we investigate the effect of IPRs on cereals yields controlling for other productivity determinants such as capital, agricultural labor, human capital and other agricultural inputs. In particular, we aim to study whether the tightening of IPRs systems have an impact on productivity and productivity growth of cereals and if this effect is different for countries grouped according to their income level.

In addition, we study the effect at a more disaggregated level considering whether the impact of IPRs is different for two relevant cereals (maize and wheat), which have specific characteristics that lead to different expected effect of IPRs. Most used maize seeds are hybrids, which loose their traits in the second generation, not allowing farmers to reuse the harvested seeds. Meanwhile, because wheat is an open-pollinated variety, farmers can reuse the harvested seeds maintaining their genetic characteristics. These features imply that the imitation threat is different for these two crops and also that the incentives of a tighter IPRs system might be different. In the case of maize, seed saving is discouraged given that most used varieties are hybrids and they offer a natural protection from imitation (Galushko,

[1] This information is provided by FAOSTAT (`www.faostat.fao.org`).

2012; Campi, 2014). Thus, IPRs may have a minor role in hybrids. Conversely, we might expect a stronger effect of IPRs in open-pollinated varieties such as wheat.

The existing evidence on this topic is mixed and it is mostly based on cases of study for different crops or countries. This paper contributes to the ongoing debate offering a cross-country study for a time period of 51 years. The results of the econometric estimations show that the general rise of the IP index score over time is positively correlated with yields when considering the full sample of countries. However, we found heterogeneous effects when checking the robustness of the results for the composition of the sample according to income level. The correlation is positive and significant for high-income and low-income countries but no significant for middle-income countries. We also found the same effects when considering wheat and maize yields. Also, we found that IPRs are no significant for explaining growth rates of yields.

The remaining of the paper is organized as follows. Section 2 provides a brief literature review regarding how IPRs are related with R&D, innovation and productivity in agriculture. Section 3 discusses some empirical evidence of the relation between yields and IPRs. In section 4, we carry out multivariate econometric estimations to further study this relation for the panel data. Finally, in section 5, the main conclusions are presented.

2 How are IPRs and productivity related?

There is no unique answer to the question of this section. This issue, as well as how IPRs are related with other economic variables, is still a matter of debate in economics. The key issue of the discussion is how firms manage to appropriate the benefits deriving from their innovations and how this impacts on innovation, productivity and economic growth.

Standard economic theory postulates that by granting a temporary right, IPRs allow firms the appropriation of innovation rents and, by doing so, encourage allocation of resources for R&D that will likely result in innovation and productivity growth (Arrow, 1962; Romer, 1990). This view, based on the existence of a "market failure", has been theoretically criticized by several economists. Dosi et al. (2006) claim that while the main determinants of innovation rates rest within technology-specific and sector-specific opportunity conditions, the differential ability of individual firms to benefit from them derives from idiosyncratic organizational capabilities rather than from IPRs systems. In addition, the monopoly power that IPRs confer to firms can be detrimental to innovation and very costly for society

(Boldrin and Levine, 2010).

The use of IPRs as tools to spur innovation in the manufacturing sector has been sharply criticized. Different empirical contributions have proved that, to protect the profits of inventions, firms use a wide range of mechanisms, other than patents, such as secrecy, lead time advantages, cost and time required for duplication, learning, and the use of complementary marketing and manufacturing capabilities (Mansfield, 1986; Cohen et al., 2000).

Beyond the theoretical critics, the question of how IPRs may affect productivity is difficult to be empirically answered because the impact of IPRs on economic variables is hard to be isolated and measured. Moreover, in occasions, the effect of IPRs on productivity can be indirectly observed. From a teheoretical perspective, IPRs incentive innovation and, in turn, innovation leads to an increase in productivity, competitiveness and economic growth. For the manufacturing sector, Park (2005) found that IPRs did not spur productivity growth directly, but did so indirectly by encouraging investments in R&D, which in turn were found to increase productivity.

While there are several empirical studies addressing the effect of IPRs on innovation and productivity in manufacture, there is much less evidence in agriculture. Like in other sectors, the existing studies that deal with this issue in agriculture offer mixed results.

Several authors have found weak or partial evidence supporting that IPRs are effective in stimulating investments leading to innovation in plant varieties and productivity growth. Alston and Venner (2002) found that the strengthening of IP protection for plant varieties in the US have spurred only public investment in wheat varietal improvement and that it did not cause an increase in experimental or commercial wheat yields. Léger (2005) showed that IPRs played no role in the Mexican maize breeding industry. In a study carried out for five countries, Louwaars et al. (2005) found that IPRs for plant varieties are not a necessary condition for the initial private seed sector development, but they may contribute to its growth and diversification. They concluded that the nature and extent of this contribution will depend on the characteristics of the national seed system. For the case of hybrid corn, Moser et al. (2013) have recently shown that most patented hybrid corns did not improve significantly on prior ones in terms of yields.

Conversely, there is a number of empirical contributions which found positive linkages between IPRs, R&D and productivity in agriculture. Naseem et al. (2005) found that plant breeders' rights (PBRs) have led to a greater development of more productive varieties with a positive impact on cotton yields in the United States. Likewise, Kolady and Lesser (2008, 2009) showed that PBRs have contributed to genetic improvement of wheat varieties in Washington State (US); and, using these findings, they developed a model and extended their conclusions to developing countries. Similarly, employing data for 103 countries, Payumo et al. (2012) investigated the relationship between strengthened IPRs systems and agricultural development, which was represented by agricultural gross domestic product. They found evidence that supports a positive correlation between these two variables both for developed and developing countries. Similarly, Perrin (1999) argued that without IPRs it is unlikely that agricultural productivity rates in developing countries would be able to catch up with those in developed countries.

The causes for these divergent findings are multiple. One explanatory factor is that several scholars have proved that the effect of IPRs depends on the specificities of technologies and sectors, as well as on the development level of the countries (Teece, 1986; Dosi et al., 2006). This prompts the consideration that heterogeneity of the involved countries may probably confound the relation between IP protection and innovation or productivity. Another reason is that, when assessing these relations, economists rely on imperfect data. Moreover, when studying the relationship between IPRs and productivity or innovation, causality is not always uniquely determined. It is possible that more innovative and productive countries may be more likely to implement stronger IP protection systems. Therefore, institutional arrangements, such as IPRs systems, might be, to a certain extent, the consequence and not the cause of innovation and development.

The literature reviewed in this section encompasses valuable empirical cases of study. The mixed results and the open discussion they offer, demand further investigations. As a contribution to this debate, this paper provides a cross-country analysis of the effect of IPRs for plant varieties on agricultural productivity for 51 years (1961-2011), considering whether the effect depends on the income level.[2]

3 Intellectual property rights and agricultural yields: a preliminary outlook

This section presents empirical evidence of the relation between IPRs and productivity in the production of cereals. Productivity is measured by yields, which are defined as the total output in tonnes obtained in a year divided by the total area harvested in hectares. Yields constitute one of the possible measures of productivity among others that are commonly used, such as output per worker or total factor productivity (Mundlak, 2005). Like all productivity indicators, yields present some drawbacks.

[2]See list of countries in the Appendix.

This indicator is a single-dimensional measure; it adds quantities of non homogeneous products; it may be affected differently by land quality; and it may be biased by differences in capital and labor intensities.

Nevertheless, we use yields because this measure presents several advantages with respect to other indicators. First, the data to construct this indicator is more reliable compared with the data needed to calculate, for example, total factor productivity. Second, being based on quantities, output per hectare avoids the problem of price input measures for determining how much prices vary per constant-quality unit (Griliches, 1968). Third, unlike total factor productivity, this indicator does not make the assumption that technology is homogeneous; nor it is represented by a well-defined production function in which an improvement in technology with inputs held constant increases the average productivity of all inputs (Nelson, 1981; Mundlak, 2005). Last, but not less relevant, yields reflect, to a major extent, the effect of technical change in agriculture. During the twentieth century, the sources of agricultural productivity growth mainly derived from biological innovations, fertilization, and culture techniques, rather than mechanization (Kloppenburg, 2004; Olmstead and Rhode, 2008). Most agricultural economists agree that: "Prior to the beginning of the twentieth century, almost all increases in crop and animal production occurred as a result of increases in the area cultivated. By the end of the century, almost all increases were coming from increases in land productivity –in output per acre or per hectare. This was an exceedingly short period in which to make a transition from a natural resource based to a science-based system of agricultural production." (Ruttan, 2002, 161). Thus, the kind of technical change that has characterized agriculture in the past century is more likely to be reflected in output per hectare than in labor productivity and even in total factor productivity, which assumes fixed input coefficients.

We built our indicator of productivity using information provided by FAOSTAT (`faostat.fao.org`). The indicator includes yields of: barley; buckwheat; canary seed; cereals, nes; grain, mixed; maize; millet; oats; quinoa; rice, paddy; rye; sorghum; triticale; and wheat.

To quantify the strength and observe the evolution of IPRs systems, we use an index of IP protection for plant varieties, constructed by Campi and Nuvolari (2015). This index considers five components that, as a whole, indicate the strength of each country's IP protection system for plant varieties. The components are: 1) ratification of UPOV Conventions;[3] 2) length of membership; 3) exceptions; 4) protection length; and, finally, 5) patent scope. The sum of these equally weighted

[3]The UPOV is the International Union for the Protection of New Varieties of Plants.

elements provided a composite index that was shown to represent reasonably and in a comparable way the strength of a country's IPRs system.

The index shows that the mean of protection has been increasing continuously and that most countries have currently an index score that is above the mean of protection. Like in other sectors, more developed countries have been offering IP protection for plant varieties for many years while less developed countries have adopted them mainly after the signing of TRIPS agreement, undertaking high levels of IP protection.

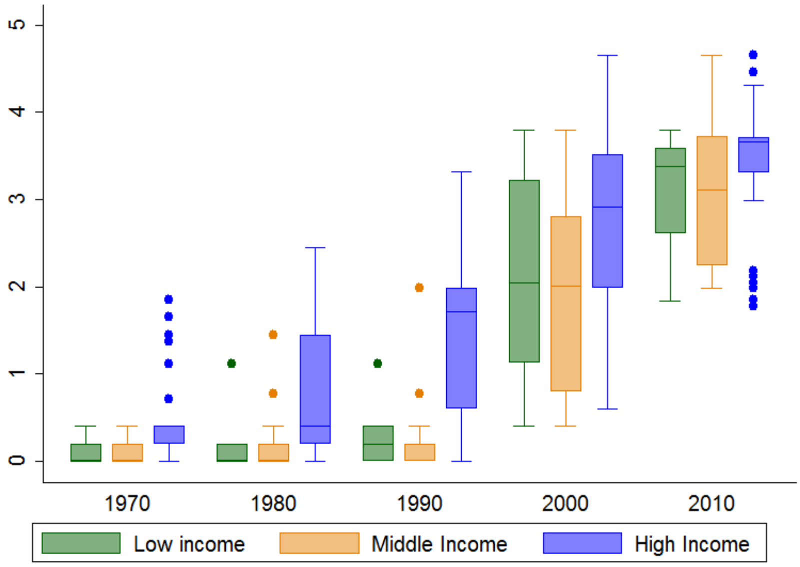

Figure 1: Evolution of the IP protection index according to income level

Figure 1 illustrates the strengthening of IP protection through the different decades. The box plot displays the distribution of the data based on the four quartiles. The upper and lower edges show the index for the higher and lower percentile country. In the boxes of the middle, we observe the two and third quartiles. The horizontal mark is the median index and the dots are outliers. Countries are sorted according to income level in three groups: high, middle and low. The income level classification is taken from United Nations (2013) that classifies countries using data of the year 2011 as High-income that are both OECD and non-OECD High Income economies, middle-income that are Upper Middle Income, and low-income that includes both Lower Middle Income and Low Income. Accordingly, countries with less than \$4,035 gross national income (GNI) per capita are classified as low-income countries, those with GNI per capita between \$4,036 and \$12,475 as middle-income countries, and those with incomes greater than \$12,476 as high-income countries.

In Figure 1, we observe that the index has risen for countries of all income levels over time. Dispersion has fallen, especially in the last decade, for all groups. While in the first three decades, we observe an increase in the index for high-income countries, after the 1990s, there is a steady increase in the index of low- and middle-income countries. This process is driven by the signing of the TRIPS agreement.[4]

Next, we study the correlation between the level of IP protection and agricultural productivity. Figure 2 depicts the scatter plot of the correlation between the index of IP protection and cereal yields. The x axis sort countries according to their GDP per capita, grouping them in three income levels. The y axis presents the correlations between yields (in log) and the index of IP protection for each country, computed with the observations of the whole period (1961-2011). The black dots are significant correlations, while white dots represent no significant correlations.

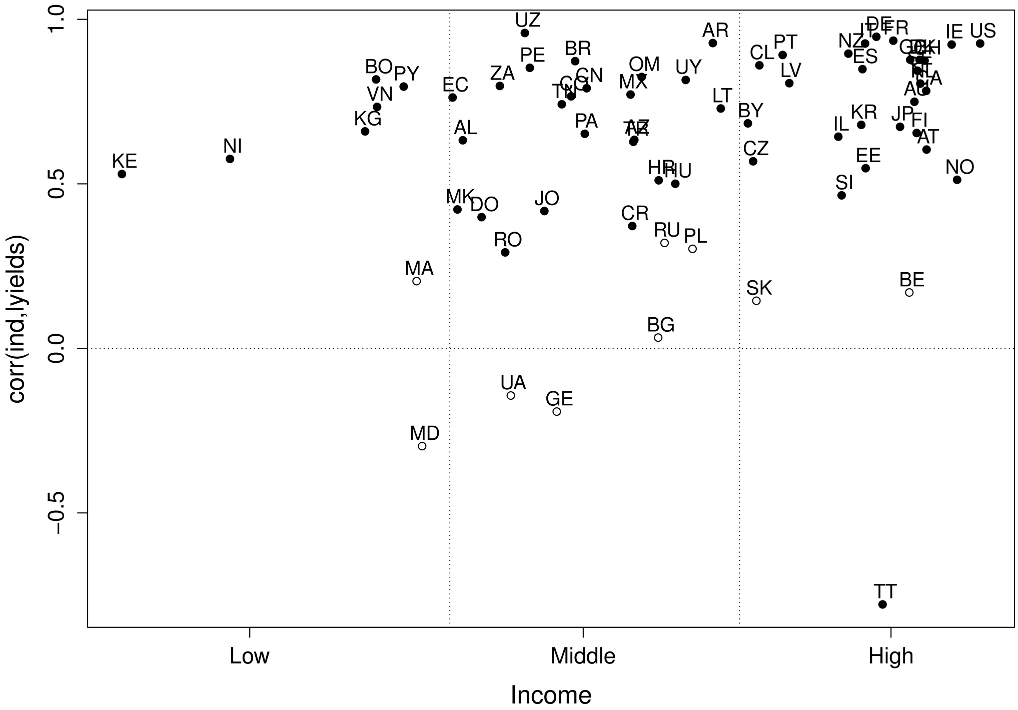

Figure 2: Correlation Between Yields and IP Protection for Plant Varieties (1961-2011)

Note: Black dots are significant correlations. White dots are no significant correlations. Labels are defined in the Appendix.

Correlations are positive for most countries. However, heterogeneity is present: some countries face low levels of correlations in the three groups of income, the values of the correlations are relatively higher for high-income countries, but also there are

[4]A very similar tendency is also observed for the patent index of Ginarte and Park (1997) for the manufacturing sector. See: Maskus (2000).

high correlations in the group of middle-income countries. Given this evidence, the effect of stronger IPRs on yields may be expected to be different and linked to the idiosyncratic capabilities and characteristics of countries.

Next, we move our attention to the cross sections to study how this correlation evolves over time. To this end, we propose the simple model,

$$lyield_t = \beta_1 + \beta_2 ind_t + \mu_t, \tag{1}$$

where $lyield_t$ is the log of yields and ind_t is the index of IP protection.

Table 1 displays the coefficients computed every five years between the log of yields and the index of IP protection. The regressions show that the strengthening of the index over time is correlated with cereal yields, during a part of the period considered. However, the effect of IPRs on yields performance presents a decreasing tendency and the coefficients finally turn out not significant in the last three years considered. We have also found the same behaviour using the lagged index of IP protection to compute the correlation with yields.

Table 1: Correlation between cereals yields and IP protection index

Year	Index		Constant		Observations	R-squared
1965	0.875***	(0.232)	9.590***	(0.078)	48	0.237
1970	0.633***	(0.169)	9.635***	(0.091)	48	0.233
1975	0.469***	(0.121)	9.759***	(0.087)	48	0.247
1980	0.360***	(0.104)	9.901***	(0.088)	48	0.205
1985	0.350***	(0.076)	9.943***	(0.087)	49	0.313
1990	0.312***	(0.065)	10.050***	(0.083)	50	0.324
1995	0.204***	(0.062)	10.010***	(0.102	66	0.145
2000	0.08	(0.062)	10.150***	(0.164)	67	0.025
2005	0.047	(0.060)	10.330***	(0.186)	67	0.009
2010	-0.006	(0.071)	10.560***	(0.237)	67	0.000

Note: The dependent variable is the log of cereals. Standard errors are in parenthesis. Significance level: *** p<0.01, ** p<0.05, * p<0.10.

This process is coincident with the increase of the index score for middle- and low-income countries. The greater heterogeneity within developing countries, compared with richer countries, may help understanding the evolution of these correlations.

Finally, it is also plausible to expect different effects and significance of the index of IP protection for different productivity levels, since more productive countries might be willing to provide higher protection to their agricultural sectors. In order to explore this possible differential impact, we carry on a quantile regression, which provides estimates at different quantiles of the dependent variable.

Figure 3 displays the estimates for the different quantiles of the distribution of the log of yields. The dashed lines represent the ordinary least squares (OLS) estimation with the upper and lower confidence intervals. The OLS estimations do not consider possible heterogeneities in the yields of different countries. On the contrary, the quantile regression provides the regressors for each quantile (solid blue line). The shaded area delimits the confidence intervals.

The first plot provides the coefficients for the whole period (1961-2011). The estimated coefficients are quite close to the OLS estimation for the quantiles in the middle of the distribution. However, for the two lowest quantiles of yields, the effect of IPRs are lower.

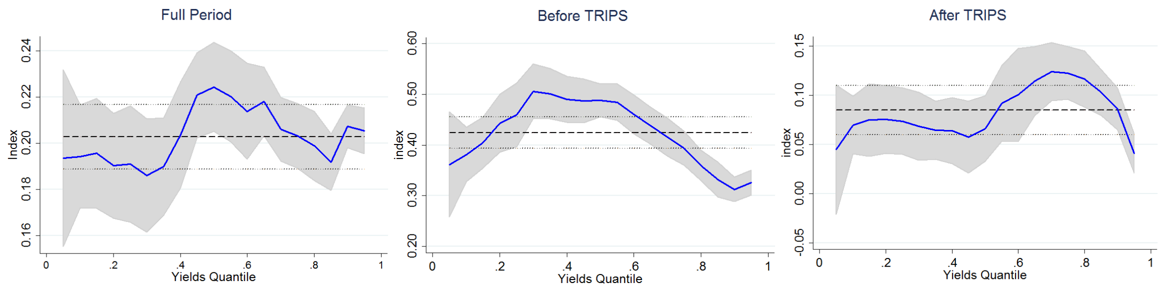

Figure 3: Quantile Regression Estimates. Full Period (1961-2011), before TRIPS (1961-1994) and after TRIPS (1995-2011)

Considering the general changes observed in the index scores after the signing of the TRIPS agreement, we also carried out quantile regressions dividing the data in two sub-periods, before TRIPS (1961–1994) and after TRIPS (1995–2011). The second and third plot in Figure 3 display the results. Before the signing of the TRIPS, we observe that the positive correlation between the index of IPRs and yields is lower in the first deciles. The estimated coefficients reach a maximum between the third and sixth deciles and they decrease afterwards. Meanwhile, after the signing of the TRIPS, the coefficients are lower in general, meaning that the effect of the index on productivity is weaker. Also, the effect is lower for the lowest and highest quantiles of the distribution of yields.

The quantile regressions suggest that the effect of IPRs is non-linear and depends on the yields of the countries. Also, they suggest that after the signing of the TRIPS agreement, the general increase of IP protection has a weak effect on productivity.

Finally, we also explored whether the signing of the TRIPS and the general strengthening of IP protection for plant varieties had a significant effect on the growth rate of yields.

We computed the growth rate of yields as the difference of the log of yields for the three-years mean at the final and the initial time.

$$gryields = lyield_{t_2} - lyield_{t_1}. \tag{2}$$

We use three-years means for each t in order to reduce the volatility of the time series because yields are likely to fluctuate mainly due to climatic factors.

Then, using averaged three-years growth rates of yields for the full period and the three-years lagged index of IP protection, we estimated a quantile regression for two sub-periods: before and after the signing of the TRIPS agreement.

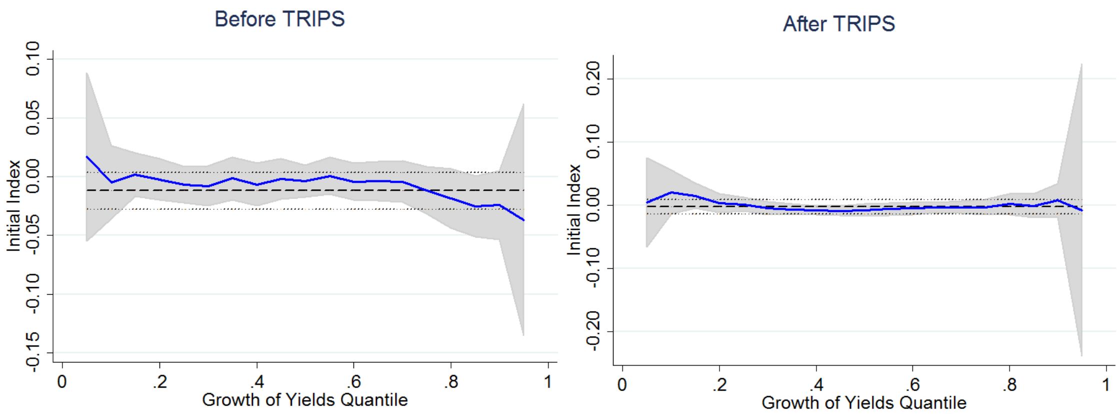

Figure 4: Quantile Regression Estimates for the Growth Rate of Yields. Before TRIPS (1961-1994) and after TRIPS (1995-2011)

Figure 4 shows the estimation results. For both periods, the regressors of the initial index of IP protection showed a no significant effect on the growth rate of yields for all the quantiles of the distribution.[5]

Although interesting, the simple regressions analyzed in this section may, in general, mask more complex relations and could lead to draw mistaken conclusions. Therefore, to deepen the understanding of the effect that the strengthening of IPRs for plant varieties is having on yields and productivity growth, we carry out a multivariate regression.

[5] We have also carried out multivariate econometric regressions using the growth of yields as the dependent variable and different explanatory variables that included the potential for convergence. The variable IPRs turned out no significant in all the different specifications we have tried. For the sake of simplicity, we do not present the results of the econometric estimations but they are available upon request.

4 Estimation results

In this section, we develop a multivariate regression to investigate the effect of IPRs on productivity. We use as the dependent variable the log of cereal yields (*lyield*) and as independent variables the index of IP protection (*IPR*), the year in which the countries have complied the terms of the TRIPS agreement and a set of control variables usually considered as determinants of agricultural productivity.

Schooling (*schoo*) measures the average years of schooling for population of 15 years old and over, which is compiled by Barro and Lee (2010). This indicator of education attainment is a proxy of the stock of human capital in each country. Given the shift of agriculture and plant breeding towards a more science-based sector, we expect human capital to have a positive effect on productivity. As an indicator of the stock of capital, we use the log of tractors (*ltract*) divided by arable land in order to create a comparable indicator of the level of mechanization.[6] Also, we include agricultural labor (*loglabor*) in log from Fuglie (2012).

Besides, we considered two variables that are likely to improve the environmental conditions in which production takes place. The first one is total area equipped for irrigation (*lirrig*).[7] Note that this is an indicator of the stock of equipment for irrigation and not of the effective use of it. Instead, the second variable is total consumption of fertilizers (*lfertil*), in log, which improves the yields of a certain area. With the purpose of removing size differences, both variables are divided by the quantity of agricultural land in the country.

Finally, although all the countries in our sample have signed the TRIPS agreement and also became members of the World Trade Organization (WTO), the signatory countries were given different time periods to apply the provisions of the TRIPS.[8] Therefore, we also included a country-specific variable indicating the year in which each country has compiled the demands of the TRIPS agreement (*TRIPS*), using data of WIPO (`www.wipo.int`).

Table 2 summarizes the independent variables and the data sources. Table 3 shows the correlation matrix and Table A.1 of the Appendix displays the summary statistics.

Using these variables and considering the evidence found in the simple regressions

[6] Arable land includes land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.

[7] It includes areas equipped for full and partial control irrigation, equipped lowland areas, pastures, and areas equipped for spate irrigation.

[8] See detailed information on transition periods at: `http://www.wto.org/english/theWTO_e/whatis_e/tif_e/agrm7_e.htm`, accessed on June 2015.

Table 2: Variables Descriptions and Sources

Variable	Name	Source
Yields (in log)	*lyield*	FAOSTAT
Index of IP protection for plant varieties	*IPR*	Campi and Nuvolari (2015)
Educational attainment for total population aged 15 or over	*schoo*	Barro and Lee (2010)
Agricultural machinery, tractors per 100 sq. km of arable land	*ltract*	FAOSTAT
Agricultural labor (in log)	*loglabor*	Fuglie (2012)
Total area equipped for irrigation in 1,000 hectares (in log)	*lirrig*	FAOSTAT
Fertilizers consumption over agricultural land (in log)	*lfertil*	FAOSTAT
TRIPS agreement	*TRIPS*	WIPO

Table 3: Correlation matrix of independent variables

	IPR	*TRIPS*	*schoo*	*ltract*	*loglabor*	*irrig*	*lfertil*
IPR	1						
TRIPS	0.628	1					
schoo	0.577	0.355	1				
ltract	0.409	0.173	0.565	1			
loglabor	-0.078	0.220	0.169	0.133	1		
lirrig	0.128	0.020	0.023	-0.141	-0.422	1	
lfertil	0.307	0.101	0.482	0.622	0.030	0.057	1

presented before, we test econometrically whether IP protection for plant varieties is a significant determinant of yields and productivity growth in agriculture. In order to exploit the differences among the countries of our panel data, we check the results discriminating by income level.

4.1 Yields regressions

To investigate the effect of the strengthening of IP protection on agricultural yields, we first estimated the following model:

$$\begin{aligned} lyield_{i,t} =& \beta_1 + \beta_2 IPR_{i,t} + \beta_3 TRIPS_{i,t} + \beta_4 schoo_{i,t} + \beta_5 ltract_{i,t} + \\ & \beta_6 loglabor_{i,t} + \beta_7 lirrig_{i,t} + \beta_8 lfertil_{i,t} + \mu_{i,t} \ ; \end{aligned} \tag{3}$$

where $t = \{1961, ..., 2011\}$.

Taking advantage of the panel structure of the data, we estimated the model using fixed effects (FE) and random effects (RE) estimation methods. The Hausmann test rejected the hypothesis that individual effects are random. Hence, we performed the regressions using FE estimation method. Table 4 displays the results of the estimations for different samples of countries.

Table 4: Cereal Yields and Index of IPRs. Fixed Effects Estimates

Model	(1)	(2)	(3)	(4)
Sample	FS	HI	MI	LI
IPR	0.051***	0.080***	0.008	0.055**
	(0.008)	(0.009)	(0.015)	(0.024)
TRIPS	-0.066***	-0.085***	0.000	-0.090*
	(0.017)	(0.020)	(0.034)	(0.047)
Schooling	0.114***	0.107***	0.139***	0.079***
	(0.006)	(0.008)	(0.011)	(0.017)
Tractors	0.010	-0.004	-0.035	0.136***
	(0.008)	(0.008)	(0.023)	(0.033)
Labor	0.022***	0.042***	-0.003	0.009
	(0.004)	(0.005)	(0.007)	(0.010)
Irrigation	0.059***	0.044***	0.051**	-0.023
	(0.011)	(0.013)	(0.023)	(0.062)
Fertilization	0.110***	0.138***	0.137***	0.076***
	(0.007)	(0.016)	(0.014)	(0.015)
Constant	8.434***	8.440***	8.530***	8.741***
	(0.064)	(0.092)	(0.142)	(0.237)
Observations	1,969	910	740	319
R-squared	0.626	0.677	0.670	0.514
Number of countries	53	24	20	9

Note: The dependent variable is the log of cereal yields. Standard errors are in parenthesis. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. FS: Full Sample; HI: High-Income; MI: Middle-Income; LI: Low-Income.

In the fixed effects estimations, most of the coefficients are significant at the 10% level and present the expected signs for the different samples. Schooling turned out significant and positive for all the different samples, verifying the relevance of human capital for a sector that has been increasingly shifting from a natural resourced-based to a science-based sector. Tractors, which is used as a proxy of the stock of capital, is only significant for the sample of low-income countries. This may be because tractors might not be a good indicator but also because other inputs are nowadays more important than capital in agricultural production and productivity. Labor is significant for the full sample and the sample restricted to high-income countries. Irrigation and fertilizers are significant and positive determinants of yields for almost all the estimations.

The index of IP protection turned out significant for the full sample of countries, and the samples of high-income and low-income countries. However, this variable is not significant for middle-income countries. The signing of the TRIPS agreements has a negative and significant effect for the full sample and the sample of high- and low-income countries. These findings suggests that the effect of IPRs on cereal yields is not relevant for middle-income countries and that there exists a positive effect in the case of high- and low-income countries. However, the signing of the TRIPS, which implies a general strengthening of IPRs systems has also a negative effect in these two group of countries. The R-squared of the models are relatively high for all the samples.

Next, we analyze the effect of IPRs at a more disaggregated level, exploring whether the strengthening of IPRs systems has a different effect on yields for two types of cereals: wheat and maize. These two cereals are among the most relevant in terms of quantity produced and consumed worldwide. These two cereals are also relevant for our case because they have different biological characteristics that derive in different imitation threats. Usually, farmers use part of their harvests as seeds for the incoming season. However, most types of maize in the market are hybrids, which are the result of cross-breeding inbred lines which differ in some hereditary factor. Hybrids inherit the best features of their parents and have a better performance in terms of yields. Yet, due to the so-called heterosis, hybrid's offspring present much lower yields. This implies that farmers need to buy seeds of hybrid maize each year. This fact provides a non legal protection as well as an incentive for breeders to invest in the creation of hybrids. Then, we could expect a lower effect of IPRs on maize. On the contrary, wheat is an open-pollinating variety, which implies that farmers can save wheat seeds from their harvests and use them for sowing the following year given that it maintains its features from generation to generation. Certainly, if breeders offer more productive new varieties, farmers will have an incentive to buy them. But, a priori, the enforcement of IPRs would be more valued by breeders in the case of wheat compared to the case of hybrid maize.

Table 5 displays the results of the estimations using the yields of maize as the dependent variable. Like we found in the case of cereals, we observe that the IPRs index is significant for the full sample of countries and for the samples restricted to high- and low-income countries. The effect of IPRs is not significant for middle-income countries. Also, the signing of the TRIPS agreement has a negative effect on yields of maize for the full sample and the samples of high- and low-income countries. The rest of the independent variables are in most cases significant and present the expected signs.

Table 5: Yields of Maize and Index of IPRs. Fixed Effects Estimates

Model	(1)	(2)	(3)	(4)
Sample	FS	HI	MI	LI
IPR	0.117***	0.104***	0.013	0.138***
	(0.022)	(0.018)	(0.026)	(0.032)
TRIPS	-0.209***	-0.093***	-0.033	-0.171***
	(0.043)	(0.033)	(0.058)	(0.062)
Schooling	0.148***	0.139***	0.150***	0.049**
	(0.015)	(0.015)	(0.018)	(0.022)
Tractors	0.085***	0.046***	0.075*	0.048
	(0.016)	(0.012)	(0.039)	(0.043)
Labor	0.041***	0.050***	0.010	0.007
	(0.011)	(0.007)	(0.011)	(0.013)
Irrigation	-0.024	-0.018	0.004	0.072
	(0.046)	(0.025)	(0.038)	(0.081)
Fertilization	0.126***	0.174***	0.192***	0.093***
	(0.017)	(0.028)	(0.024)	(0.019)
Constant	8.323***	8.396***	8.170***	8.576***
	(0.227)	(0.173)	(0.240)	(0.309)
Observations	1,027	702	677	319
R-squared	0.518	0.654	0.534	0.384
Number of countries	28	19	18	9

Note: The dependent variable is the log of yields of maize. Standard errors are in parenthesis. Significance level: *** p<0.01, ** p<0.05, * p<0.10. FS: Full Sample; HI: High-Income; MI: Middle-Income; LI: Low-Income.

Table 6 displays the results of the estimations using the yields of wheat as the dependent variable. Also in this case, we observe that the effect of IPRs is significant for the full sample of countries and for high-income countries. On the contrary, the effect is not significant for middle- and low-income countries. Like in the previous cases, the signing of the TRIPS agreement has a negative effect on wheat yields in the full sample and the samples of high- and low-income countries.

Table 6: Yields of Wheat and Index of IPRs. Fixed Effects Estimates

Model	(1)	(2)	(3)	(4)
Sample	FS	HI	MI	LI
IPR	0.051***	0.059***	0.025	-0.002
	(0.009)	(0.011)	(0.018)	(0.033)
TRIPS	-0.099***	-0.111***	-0.027	-0.133**
	(0.020)	(0.023)	(0.042)	(0.063)
Schooling	0.099***	0.098***	0.111***	0.131***
	(0.007)	(0.010)	(0.013)	(0.028)
Tractors	-0.009	-0.003	-0.103***	-0.002
	(0.009)	(0.009)	(0.030)	(0.076)
Labor	0.034***	0.019***	0.049***	0.035***
	(0.004)	(0.005)	(0.008)	(0.012)
Irrigation	0.097***	0.087***	0.114***	-0.057
	(0.013)	(0.014)	(0.027)	(0.098)
Fertilization	0.121***	0.126***	0.157***	0.112***
	(0.009)	(0.018)	(0.017)	(0.020)
Constant	8.213***	8.344***	8.204***	8.939***
	(0.078)	(0.108)	(0.179)	(0.499)
Observations	1,759	866	651	242
R-squared	0.551	0.568	0.587	0.480
Number of countries	47	23	17	7

Note: The dependent variable is the log of yields of wheat. Standard errors are in parenthesis. Significance level: *** p<0.01, ** p<0.05, * p<0.10. FS: Full Sample; HI: High-Income; MI: Middle-Income; LI: Low-Income.

Thus, even at the more disaggregated level, for cereals with different features related to the possibilities of reproduction by farmers, the effect of IPRs depends on the income level of countries and it is not significant for middle-income countries. The signing of the TRIPS has a negative effect for high- and low-income countries in all the different estimations, meaning that the general rise of IP protection after becoming a member of the TRIPS has a negative effect on agricultural yields.

4.2 Non-linearities between yields and IP protection

The different correlations between the index and the log of yields found for different samples may indicate the existence of non-linearities in this relation. In order to explore further this hypothesis, we use two different methods. In the first one, we simply re-estimate Equation 3 including the square of the index of IP protection (IPR^2). In the second one, we use the index to construct three dummy variables, which split the variable IPRs in three different levels: $ind1_{i,t} \leq 1$ (weak), $1 < ind2_{i,t} \leq 3.0$ (middle) and $ind3_{i,t} > 3.0$ (strong). Using these new variables that represent different levels of IP protection, we performed a fixed effects estimation using Equation 3. We included in the regression $ind2_{i,t}$ and $ind3_{i,t}$, and, naturally, $ind1_{i,t}$ is the base for comparison. Table 7 displays the results.

Table 7: Non-Linearities in the Relation Between Cereal Yields and IP Protection

Model	(1)	(2)	(3)	(4)	(5)	(6)
Sample	HI	MI	LI	HI	MI	LI
IPR	0.065***	0.109***	0.151**			
	(0.019)	(0.036)	(0.066)			
IPR^2	0.004	-0.027***	-0.028			
	(0.004)	(0.008)	(0.018)			
IPR2 (middle)				0.053***	0.071**	-0.030
				(0.017)	(0.033)	(0.050)
IPR3 (high)				0.180***	0.009	0.052
				(0.030)	(0.052)	(0.075)
TRIPS	-0.087***	-0.030	-0.103**	-0.046**	-0.024	-0.035
	(0.020)	(0.035)	(0.048)	(0.019)	(0.033)	(0.045)
Schooling	0.108***	0.136***	0.075***	0.122***	0.142***	0.090***
	(0.008)	(0.011)	(0.017)	(0.008)	(0.011)	(0.017)
Tractors	-0.003	-0.034	0.140***	-0.004	-0.035	0.125***
	(0.008)	(0.023)	(0.033)	(0.008)	(0.024)	(0.034)
Labor	0.043***	-0.003	0.008	0.043***	-0.002	0.012
	(0.005)	(0.007)	(0.010)	(0.005)	(0.007)	(0.010)
Irrigation	0.047***	0.055**	-0.029	0.054***	0.051**	-0.019
	(0.013)	(0.023)	(0.062)	(0.013)	(0.023)	(0.063)
Fertilization	0.139***	0.122***	0.072***	0.142***	0.126***	0.077***
	(0.016)	(0.015)	(0.015)	(0.016)	(0.015)	(0.015)
Constant	8.409***	8.530***	8.775***	8.302***	8.536***	8.716***
	(0.098)	(0.142)	(0.238)	(0.097)	(0.145)	(0.241)
Observations	910	740	319	910	740	319
R-squared	0.677	0.674	0.517	0.663	0.672	0.508
Number of countries	24	20	9	24	20	9

Note: The dependent variable is the log of yields of cereals. Standard errors are in parenthesis. Significance level: *** p<0.01, ** p<0.05, * p<0.10. FS: Full Sample; HI: High-Income; MI: Middle-Income; LI: Low-Income.

In the first three models, we have included the square of the index to detect the existence of a non-linear effect of IPRs. We observe that the estimated coefficients of the index are positive and significant for high- and low-income countries, like in the previous estimations. In these two cases the squared-index turns out not significant. For the case of middle-income countries, the estimated effect of IPRs is now positive and the squared-index of IP protection is positive and statistically significant. This implies the existence of a non-linear relation between IPRs and yields for middle-income countries and that the return of increasing IP protection diminishes yields.

In models 4 to 6, we use the new variables that indicate three different levels of protection. The estimated results show that, for high-income countries, changing from a weak level of IP protection towards both a middle and a strong level of IPRs has a positive and statistically significant effect on yields. In the case of middle-income countries, only increasing the level of IP protection up to a certain middle level has a positive effect on yields. In the case of low-income countries, we found that increasing the level of IPRs from a low level has no significant effect on cereal yields.

Overall, these results evidence the existence of non-linearities both in the effect of the index of IP protection when considering different levels of protection, but also for countries of different income levels.

5 Concluding remarks

Currently, there is a great pressure towards developing, low- and middle-income countries to adopt strong and harmonized IP protection systems. This global process has been taking place despite the fact that there is no clear evidence determining the convenience for these countries to tighten their IPRs systems.

The empirical and econometric analysis performed in this paper showed that the strengthening of IPRs for plant varieties has no equal effect on agricultural yields for countries of different income levels. The effect seems to be contingent upon the specificities of countries. The econometric regressions showed that the index of IP protection was positively and statistically correlated with productivity for high-income countries, and in some cases with low-income countries. However, it was found to be not significant for middle-income countries. In addition, we found that the strengthening of IP protection since the signing of the TRIPS agreement had a negative effect on yields.

Moreover, we studied whether the effect of IPRs is different for two crops: maize and wheat. We expected possible different effects because, being open-pollinated, wheat can be reproduced by farmers without loosing its characteristics while maize, given certain biological characteristics of hybrids, cannot be reproduced by farmers.

However, we found similar results in these two cases.

The results evidence the existence of non-linearities in the effect of stronger IPRs on yields. The hypothesis was tested by further estimations that proved the existence of non-linearities both in the effect of the index of IP protection when considering different levels of protection, as well as for different levels of income. Also, the quantiles regressions showed that IPRs have different effects on countries of different levels yields.

This is consistent with evidence found by other authors. For example, Falvey et al. (2006) found that the effect of stronger IPRs on economic growth is positive and significant for low- and high-income countries, but not for middle-income countries. The authors suggest that, despite IP protection promotes innovation in high-income countries and technology flows to low-income countries, middle-income countries are likely to suffer loses derived from the reduced scope for imitation.

Similar conclusions are plausible of being applied to our case of study. The evidence suggests that tighter IPRs do not lead automatically to greater innovation and productivity growth. Despite there is a correlation among IPRs and productivity, the relation is mediated and affected by several factors, which seem to be related with the idiosyncrasy of each single country in terms of innovation capabilities. In addition, the heterogeneity among countries and their distinctive economic, political and social characteristics, may be also an explanation for the different effects found when dividing the samples according to income levels.

In terms of policy implication, this empirical analysis provides strong evidence against the idea that there is a unique system of IP protection that fits all. On the contrary, these findings support the hypothesis that country specificities are important in determining the effect of IPRs.

References

Alston, J. and R. Venner (2002). The effects of the US Plant Variety Protection Act on wheat genetic improvement. *Research Policy 31*(4), 527–542.

Arrow, K. (1962, January). Economic welfare and the allocation of resources for invention. In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, NBER Chapters, pp. 609–626. National Bureau of Economic Research, Inc.

Barro, R. and J. Lee (2010). A New Data Set of Educational Attainment in the World, 1950-2010. *NBER Working Paper No 15902*.

Boldrin, M. and D. K. Levine (2010). *Against Intellectual Monopoly*. Cambridge: Cambridge University Press.

Campi, M. (2014). Protecting Plants: Incentives to Innovate and Access to Biological Resources. A Historical Overview, Available at SSRN: http://ssrn.com/abstract=2478312.

Campi, M. and A. Nuvolari (2015). Intellectual property protection in plant varieties. a new worldwide index (1961-2011). *Research Policy 4*(44), 951–964.

Cohen, W. M., R. R. Nelson, and J. P. Walsh (2000). Protecting their intellectual assets: Appropriability conditions and why u.s. manufacturing firms patent (or not). Working Paper 7552, National Bureau of Economic Research.

Conway, G. and G. Toenniessen (1999). Feeding the world in the twenty-first century. *Nature 402*, C55–C58.

Dosi, G., L. Marengo, and C. Pasquali (2006). How much should society fuel the greed of innovators?: On the relations between appropriability, opportunities and rates of innovation. *Research Policy 35*(8), 1110–1121.

Falvey, R., N. Foster, and D. Greenaway (2006, November). Intellectual property rights and economic growth. *Review of Development Economics 10*(4), 700–719.

Fuglie, K. O. (2012). Productivity growth and technology capital in the global agricultural economy. In K. Fuglie, S. Wang, and V. Ball (Eds.), *Productivity Growth in Agriculture: An International Perspective*, pp. 335–368. Wallingford: CAB International.

Galushko, V. (2012). Do stronger intellectual property rights promote seed exchange: evidence from us seed exports? *Agricultural Economics 43*(s1), 59–71.

Ginarte, J. and W. Park (1997). Determinants of patent rights: A cross-national study. *Research policy 26*(3), 283–301.

Godfray, H. C. J., J. R. Beddington, I. R. Crute, L. Haddad, D. Lawrence, J. F. Muir, J. Pretty, S. Robinson, S. M. Thomas, and C. Toulmin (2010). Food security: the challenge of feeding 9 billion people. *Science 327*(5967), 812–818.

Griliches, Z. (1968). Agriculture: Productivity and technology. *International Encyclopedia of the Social Sciences 1*, 241–245.

Helpman, E. (1993). Innovation, imitation, and intellectual property rights. *Econometrica 61*(6), 1247–80.

Kloppenburg, J. (2004). *First the Seeds. The Political Economy of Plant Biotechnology, 1492-2000.* University of Wisconsin Press: Madison.

Kolady, D. E. and W. Lesser (2008). But are they meritorious? Genetic productivity gains under plant intellectual property rights. *Journal of Agricultural Economics 60*(1), 62–79.

Kolady, D. E. and W. Lesser (2009). Does plant variety protection contribute to crop productivity? Lessons for developing countries from US wheat breeding. *The Journal of World Intellectual Property 12*(2), 137–152.

Léger, A. (2005). Intellectual property rights in Mexico: Do they play a role? *World Development 33*(11), 1865–1879.

Louwaars, N. P., R. Tripp, D. Eaton, V. Henson-Apollonio, R. Hu, M. Mendoza, F. Muhhuku, S. Pal, and J. Wekundah (2005). Impacts of strengthened intellectual property rights regimes on the plant breeding industry in developing countries. Technical report, commissioned by the World Bank, Wageningen, The Netherlands.

Mansfield, E. (1986). Patents and innovation: an empirical study. *Management Science 32*(2), 173–181.

Marchal, V., R. Dellink, D. Van Vuuren, C. Clapp, J. Chateau, B. Magné, and J. van Vliet (2011). OECD environmental outlook to 2050. The consequences of inaction. *Organization for Economic Co-operation and Development*.

Maskus, K. E. (2000). *Intellectual Property Rights in the Global Economy.* Peterson Institute Press: All Books. Peterson Institute for International Economics.

Moser, P., J. Ohmstedt, and P. Rhode (2013). Patent citations and the size of patented inventions. Evidence from hybrid corn. *Available at SSRN: http://ssrn.com/abstract=1888191*.

Mundlak, Y. (2005). Economic growth: Lessons from two centuries of american agriculture. *Journal of Economic Literature*, 989–1024.

Naseem, A., J. F. Oehmke, and D. E. Schimmelpfennig (2005). Does plant variety intellectual property protection improve farm productivity? Evidence from cotton varieties. *AgBioForum 8*(2&3), 100–107.

Nelson, R. R. (1981). Research on productivity growth and productivity differences: dead ends and new departures. *Journal of Economic Literature 19*(3), 1029–1064.

Olmstead, A. L. and P. W. Rhode (2008). *Creating Abundance.* Cambridge University Press.

Orsi, F. and B. Coriat (2006). The new role and status of intellectual property rights in contemporary capitalism. *Competition Change 10*(2), 162–179.

Park, W. (2005). Do Intellectual Property Rights Stimulate R&D and Productivity Growth? Evidence from Cross-National and Manufacturing Industry Data. In J. Putnam (Ed.), *Intellectual Property Rights and Innovation in the Knowledge-Based Economy*. Ottawa: Industry Canada.

Payumo, J., H. Grimes, and P. Wandschneider (2012). Status of national intellectual property rights (iprs) systems and its impact to agricultural development: a time series cross section data analysis of trips member–countries. *International Journal of Intellectual Property Management 5*(1), 82–99.

Perrin, R. K. (1999). Intellectual property rights and developing country agriculture. *Agricultural Economics 21*(3), 221–229.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy 98*, 71–102.

Ruttan, V. W. (2002). Productivity growth in world agriculture: sources and constraints. *The Journal of Economic Perspectives 16*(4), 161–184.

Teece, D. (1986). Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy 15*, 285–305.

United Nations (2013). World Economic Situation and Prospects 2013. Technical report, United Nations, New York.

UPOV (2005). Report on the Impact of Plant Variety Protection, available at http://www.upov.int/export/sites/upov/about/en/pdf/353_upov_report.pdf.

Appendix

List of Countries

High-Income Countries

Australia (AT); Austria (AU); Belgium (BE); Canada (CA); Croatia (HR); Czech Republic (CZ); Denmark (DK); Estonia (DO); France (FR); Germany (DE); Hungary (HU); Iceland (IS); Ireland (IE); Israel (IL); Italy (IT); Japan (JP); Netherlands (NL); New Zealand (NZ); Norway (NO); Oman (OM); Poland (PL); Portugal (PT); Republic of Korea (KR); Slovakia (SK); Slovenia (SI); Spain (ES); Sweden (SE); Switzerland (CH); Trinidad and Tobago (TT); United Kingdom (GB); United States of America (US).

Middle-Income Countries

Argentina (AR); Azerbaijan (AZ); Belarus (BY); Brazil (BR); Bulgaria (BG); Chile (CL); China (CN); Colombia (CO); Costa Rica (CR); Dominican Republic (DO); Ecuador (EC); Jordan (JO); Latvia (LV); Lithuania (LT); Mexico (MX); Panama (PA); Peru (PE); Russian Federation (RU); South Africa (ZA); The former Yugoslav Republic of Macedonia (MK); Tunisia (TN); Turkey (TR); Uruguay (UY).

Low-Income Countries

Albania (AL); Bolivia (BO); Georgia (GE); Kenya (KE); Kyrgyzstan (KG); Morocco (MA); Nicaragua (NI); Paraguay (PY); Republic of Moldova (MD); Ukraine (UA); Uzbekistan (UZ); Vietnam (VN).

Table A.1: Summary Statistics

Variable	Mean	St. Dev.	Min	Max
Full Sample				
lyield	8.27	0.65	6.46	10.24
ind	1.35	1.36	0	4.66
schoo	7.55	2.63	0.47	13.10
ltract	5.33	1.67	-2.14	9.90
loglabor	3.81	2.32	0.01	6.90
irrig	0.87	0.11	0	0.54
lfert	3.42	1.84	-3.63	10.23
High-Income Countries				
lyield	8.59	0.59	6.94	10.24
ind	1.61	1.33	0	4.66
schoo	8.87	2.13	3.20	13.10
ltract	6.32	1.64	-2.14	9.9
loglabor	3.96	2.17	0.014	6.90
irrig	0.09	0.14	0	0.55
lfert	4.48	1.41	-2.08	10.23
Middle-Income Countries				
lyield	8.05	0.54	6.46	9.75
ind	1.06	11.34	0	4.66
schoo	6.38	2.22	0.91	11.52
ltract	4.59	0.85	2.07	7.13
loglabor	3.47	2.41	0.02	6.90
irrig	0.06	0.06	0	0.32
lfert	2.66	1.25	-2.37	6.85
Low-Income Countries				
lyield	7.7	0.40	6.58	8.85
ind	1.17	1.33	0	3.8
schoo	5.67	2.64	0.47	11.12
ltract	3.79	1.08	0.23	5.74
loglabor	4.10	2.45	0.01	6.90
irrig	0.10	0.11	0	0.45
lfert	1.73	2.09	-3.63	6.35