AgBioForum, 27(1): 110-121. ©2025 ***AgBioForum***

Supplying Agricultural Commodities to China: The Case of Argentina and the Impact of Property Rights on Production and Yield

Andres A. Gallo
University of North Florida, United States.
Email: agallo@unf.edu

Jay P. Kesan
University of Illinois at Urbana-Champaign, United States.
Email: kesan@illinois.edu

In recent decades, China has had strongly influence the demand for agricultural commodities in global markets. Argentina is one of the main suppliers of soybeans in the world, and a key trading partner with China. Accordingly, it is in the best interest for both countries to continue to maintain high productivity levels. One of the most important issues in agriculture is the impact of biotechnology, and specifically, the impact of new seed varieties on yield. This paper uses data from seed varieties and yields in corn, soybean and wheat for the last forty years in Argentina. Then, we applied different times series techniques, including structural breaks, and vector autoregressive models to analyze the statistical causality between yields and new varieties. We demonstrate how introducing new varieties in Argentina positively affects yields, especially for soybeans and wheat. These results are important as Argentina has struggled to reach a political consensus on the implementation of property rights to create the right incentives to produce new varieties. Given the importance of these new varieties in yields, there are significant economic gains from the implementation of more secure property rights. These empirical results are essential to inform the discussion and the efforts to implement legislative changes in countries like Argentina, which could benefit from such reforms. Furthermore, it highlights the importance of property rights in Agriculture in emerging economies participating in international markets.

Keywords: Argentina, Property Rights, Seed Varieties, Biotechnology and Agriculture, International Agricultural Markets, China, Brazil, United States.

Introduction

In the last two decades, the rise of China in the global economy introduced impressive changes to commodity markets (Jepson, 2020). China, India, and other emerging economies developed quickly, and their demand for commodities, raw materials, and other resources seems never-ending. Furthermore, forecasts for the next decade highlight the still strong influence of China in the growth of global demand (USDA, 2023). As a result, several countries rich in natural resources came to play an essential role in providing these necessary resources. As this paper shows, the growth in demand impacted agricultural markets, and countries with exceeding exporting surpluses, like Argentina, Brazil, and the United States, became willing partners facilitating growth in these emerging markets (Feenstra & Hong, 2022; Klein & Luna, 2023; Klein & Vidal Luna, 2021; Phélinas & Choumert, 2017). Furthermore, high commodity prices and growing demand incentivized these countries to grow crops constituting agricultural commodities. The international integration of agricultural markets continues to advance, and the exporter countries seek to find ways to increase production and support the growing global demand (Klein & Vidal Luna, 2021).

Nonetheless, given the difficulty of expanding land use without displacing other crops or cattle production, the main determinants of growth are agricultural technology, chemicals, and investment in research and technology, with a particular emphasis on biotechnology (Fuglie, 2018; Klein & Vidal Luna, 2021). One of the booming innovation markets in this area is the one for new seed varieties (Kesan & Gallo, 2007; Kolady & Lesser, 2009b). Accordingly, investment in research and development in new varieties is one of the most promising areas to keep increasing yields and, simultaneously, to develop eco-friendly and sustainable technologies that enables continuous improvements in yields (Naseem, Oehmke, & Schimmelpfennig, 2005). In addition, these countries rich in agricultural output need to develop an institutional and legal regulatory environment that fosters this type of investment, which could positively impact productivity and trade (Entine et al., 2021).

Accordingly, this paper analyses the case of Argentina, Brazil, and the U.S. and the evolution of production, yields, and new seed varieties in three main commodity crops: corn, soybean, and wheat. These countries are the leading exporters of these three crops, and developing their productive capabilities is necessary to keep these agricultural commodity markets functioning properly. Furthermore, they have different intellectual property rights regimes. While the United States has a robust property rights system with extensive protection for property rights, Argentina is still in the process of finding better ways to protect innovation, and property rights protections for innovations in seed varieties could be stronger. This paper addresses the critical relationship between new seed varieties as they come to the market. It focuses on Argentina's case, the evolution of property rights in new varieties, and its relationship to yields. This paper employs a time-series analysis and develops a model for endogenous structural breaks to determine the pattern of new varieties and yields over forty year. Then, this study uses a VAR model to show that introducing new varieties of seeds Granger-causes yields. This result highlights the need to create appropriate regulatory environments that allow for secure property rights and high investment in research and development to foster growth in both yields and productivity. Emerging countries like Argentina will significantly benefit by making institutional changes a reality. This paper is organized as follows. The second section presents the impressive strength of China in international agricultural markets and its impact on the leading grain exporters. The third section shows the evolution of property rights for new seed varieties in soybean, corn, and wheat in some of these countries. This paper contrasts the evolution of these markets in Argentina with that of the U.S. and Brazil. Given the productive background and the evolution of property rights on seeds, the fourth section utilizes data from Argentina's yields and seed varieties in these three crops to establish the relationship between these two variables. This analysis utilizes time series analysis and dynamic modeling to establish the type of time-series variables and a causal relationship between these variables. The fourth section discusses the results and provide interpretation in the policy arena. Finally, the conclusions highlight the empirical evidence that yields are determined by the number of new varieties in Argentina, especially in soybean and wheat crops.

China's impact on International Agricultural Markets. A Review of Literature

In the last few decades, international agricultural markets have boomed due to the solid economic growth of emerging countries like China and India. These countries, especially China, exhibited strong economic growth, a growing middle class, and the consequent need for agricultural products to support their population (Bussolo et al., 2012). In this environment, since the early 2000s, the boom of the Chinese economy needed a reliable supply of raw materials and agricultural products (Fukase & Martin, 2016). These authors provide evidence of the changes in food demand in China and the need to expand food imports to account for increasing food demand due to economic growth and diet changes (Fukase & Martin, 2016). However, the Chinese economy could not supply all the needed materials (Jamet & Chaumet, 2016). As they explain, China faced the dilemma between producing Soybean and Corn, and the decision to focus its resources on the latter while expanding imports of Soybean had an impact on international markets (Jamet & Chaumet, 2016). Accordingly, the Chinese government sought to expand its economic and political linkages worldwide to secure such goods and services. Countries like Argentina and Brazil became critical providers of agricultural products for the Chinese economy. In particular, the provision of soybeans and soybean oil and meal were the main highlights of the economic relationship between the exporting countries and China. In addition, corn and wheat are also important in international trade in agriculture. These factors increased commodity prices, promoting efforts to supply the necessary crops. Soybean prices went from $164.23 a metric ton in the second quarter of 2001 to $615.85 by the third quarter of 2012 (it stands at $554 in the first quarter of 2023).[1] Similarly, corn prices went from $90 a metric ton in August 2001 to $332 in July 2012 (the current price is $284 in March 2023).[2] Finally, the price of wheat was $104 a metric ton in August 2001 and reached $318 by November 2012. The current price of wheat is $312 in April 2023.[3] This section analyzes the role of China in international agricultural markets in the context of north-south and south-south trade.

The steady growth of China, and the demand for commodities around the world, have emphasized understanding the role of Latin America and other regions in this pattern of economic development. As Casanova, Xia, & Ferreira (2016) find, there is evidence that the export dependency of Latin American countries on China has increased since the early 2000s. Most of this dependency is focused on the export of commodities to China (Casanova et al., 2016). The Chinese national strategy to reach out for commodities, particularly agricultural ones, is supported by the actions of the China Oil and Foodstuffs Corporation (COFCO). As Fares (2023) explains, the Chinese government has positioned COFCO as an essential instrument for economic development and has provided a substantial advantage for China in international agribusiness (Fares, 2023).

Furthermore, the export dependency from Latin America and the need for China to secure markets for their manufacturing goods has reinforced the partnership between Latin American countries and China. According to Giraudo (2020), the Chinese government's strategies include several instruments: land purchases, acquisitions and investments, investment in infrastructure and financial support, and veto of "technological events." (Giraudo, 2020). Accordingly, the author concludes that "[a] closer look at China-Latin America relations through the lens of dependency analysis has proven effective in problematizing the discourse South-South cooperation and positive current account balances, as well as highlighting imbalances underpinning the asymmetric relations at play. However, trade should not be understood as the *cause* of this core-periphery dynamic, but rather as a *reflection* of the sterilization of economies in South America" (Giraudo, 2020, at 73-74).

In this context, we would like to understand better how the domestic policy decisions in Latin American countries affect their insertion in the international patterns of trade. Smith & Katovich (2017) utilized a gravity trade model to analyze if the different G.M.O. policies affect the trade relationships between Argentina and Brazil. They found that G.M.O. policies are significant for trade relationships in the case of Argentina but less critical for Brazil (Smith & Katovich, 2017). This evidence highlights the importance of property rights regimes in agribusiness international relations, especially in the case of Argentina. If we consider not just G.M.O. seeds but the general framework for the production of new varieties and the regulatory regime in place to secure property rights, we can better understand the impact of these regimes on the productivity of the

[1] See FRED Economic data from the I.M.F. at https://fred.stlouisfed.org/series/PSOYBUSDQ
[2] See FRED Economic data from the I.M.F. at https://fred.stlouisfed.org/series/PMAIZMTUSDM
[3] See FRED Economic data from the I.M.F. at https://fred.stlouisfed.org/series/PWHEAMTUSDM

agricultural sector and its impact on international trade. As Chen et al. (2022) explain, "since the soybean supply chain is detailed and complex, the execution of rules, regulations, and systems requires excellent central coordination with easy and comprehensive information access. A national designated body with a clear role and responsibility to coordinate different stages in the supply chain is a must for success." (Chen et al., 2022, at 11). Furthermore, Zhou, Sheldon, & Eum (2018) demonstrated that recognizing property rights in seed varieties increases technology transfer from developed countries, like the U.S., to developing ones. Therefore, having a solid system for managing property rights in varieties is extremely important. This importance cannot be overstated, as international agricultural markets are highly competitive. In addition, Yan et al. (2023) analyze the market structure for soybean and they demonstrate that there is no market power from either China or countries like Brazil, Argentina, and the U.S. in the international soybean market. This result suggests that market competition an important characteristic for developing competitive advantages in agriculture.

In China, the movement from agriculture to industry mobilized workers to cities and opened the opportunity to improve productivity in agriculture (Deng et al., 2008). At the same time, a growing urban population with rising income pushed the demand for food and other natural resources needed in industrial production (Jiang, Seto, & Bai, 2015). Accordingly, the Chinese government faced a political dilemma in deciding which agricultural products to focus their production and investment efforts to reach the most efficient result. China then increased its production of corn, while decreasing the area for soybeans and wheat (http://www.fao.org/faostat/en/#data) In this environment, China's economic growth created the need to buy soybeans from international markets. For example, China's soybean oil production increased rapidly since 1995, from 1.2 million tons in 1995 to 16.6 million in 2019, increasing 1216.5% (http://www.fao.org/faostat/en/#data). In order to sustain this industrial growth, China resorted to international markets for the needed raw material, and imports of soybeans boomed in the same period. This demand growth in international markets made countries like Argentina, Brazil, and the U.S., the leading suppliers of agricultural commodities to China and other emerging economies. While most of China's agricultural imports stayed almost constant throughout the period or increased at modest rates, the increase in soybean imports is impressive. From 1995 until 2021, imports of soybeans went from 2.91 million tons to more than 99 million tons, an increase of 3304%. During the same period, corn imports increased by 178.4% (all this growth in 2020 and 2021), while soybean oil and wheat imports decreased by 24.9% and 13.4%, respectively (http://www.fao.org/faostat/en/#data).

China's increase in international demand for soybeans would have impacted international prices, given the importance of China in global demand. Accordingly, the growing participation of China in global markets is determined by specific Chinese production policies. Furthermore, these policies have consequences for the countries supplying soybeans. Accordingly, Chinese participation in global demand increased from less than 10% of World imports in 1995 to more than 60% in 2019 (http://www.fao.org/faostat/en/#data).

In particular, the Chinese expansion increased agricultural prices, displaced some crops to others, and created a race for innovation in new technologies to improve yields and foster productivity (Rositano et al., 2022). In this highly competitive environment, investments in new seed varieties, and the emerging role of biotechnology, became helpful tools for countries to position themselves in the international arena (Smith & Katovich, 2017). One of the most important tools to capture investments in research and development is establishing an effective legal environment to accompany these market opportunities.

This paper focuses on the increase in production of corn, soybeans, and wheat, three of the main cash crops in Argentina. In the case of soybeans, the three top producers (U.S., Brazil, and Argentina) produce nearly 80% of the world's supply (http://www.fao.org/faostat/en/#data). Countries have expanded production in the last twenty years by increasing the harvested area. However, the increase in production is much higher than the growth in the harvested area, highlighting strong growth in yields. The most significant productivity improvements came from emerging markets like Russia, Ukraine, Brazil, Argentina, and Bolivia (http://www.fao.org/faostat/en/#data). This result highlights the importance of technology to agriculture, as improved yields are the most critical source of sustainable growth. Furthermore, the high concentration of production in a few countries emphasizes these countries' role in export markets, as we will explain below. We can show a similar pattern in the case of corn production. The four more important producers are Argentina, Brazil, China, and the United States, representing almost 67% of world production (http://www.fao.org/faostat/en/#data). As in the case of soybeans, most of the gains in the last twenty years are due to yield improvements, with Russia, Ukraine, Brazil, Indonesia, Romania, and India being the countries with the highest increase in productivity. Nonetheless, all these countries are far below the high yields obtained in the United States.

There is more diversification among producing countries in wheat production. The top four producers in the world represent just 47.5% of total world production. In addition, in the last twenty years, the countries with the highest increases in production are Russia, Ukraine, Argentina, India, and Pakistan. The strong presence of China in international markets and the boom in agricultural products in the countries described above have created exceptional opportunities for growth and investment. As mentioned before, one of the main drivers of yields is innovation in seed varieties, especially in biotechnology. Accordingly, strong property rights protection will attract innovations and support continuous growth. The following section describes the evolution of these rights in Argentina, Brazil, and the U.S.

Property Rights in Seed Varieties in the U.S., Brazil and Argentina

In recent decades, innovation in plant varieties has become one of the most critical drivers of yields and technology in agriculture (Kolady & Lesser, 2009a). These authors provide evidence of the positive effect of strong intellectual property rights protection, new varieties and increased yields in Wheat production. New seeds and genetic innovations are constantly discovered, and many companies, universities, and other governmental organizations compete to innovate in this field. As a result, there is a large and growing market for seed varieties internationally[4]. This market is expected to grow both in new varieties and investments in biotechnology, which will lead the way to the future of agriculture (OECD, 2018). Furthermore, the extreme competition has led to the concentration of the seed market in several multinational companies with a global reach (OECD, 2018). In order to understand the growing importance of new seeds in agriculture, this section describes how property rights in new varieties are assigned in different countries.

Two main mechanisms exist to register a new variety in the United States. First, inventors can use the Plant Variety Protection Act (PVPA) certificate[5], instituted by the Plant Variety Protection Patent Act of 1970.[6] Second, inventors can obtain a utility patent, which provides much more substantial property rights protection (Patent Act of 1952).[7] Patents for agricultural seeds were reinforced and defined by the U.S. Supreme Court, which allowed for patented vegetable organisms through the critical case of Diamond v. Chakrabarty,[8] and in J.E.M. Ag Supply, Inc. v. Pioneer Hi-Breed Int'l, Inc.[9] In most other countries, utility patents are not allowed for plant innovation, and the standard certificate for new seed varieties is the one supported by the UPOV-78 and UPOV-91 agreements.[10] As a result, Argentina and Brazil are signatories of UPOV and have certificates following these regulatory prescriptions. UPOV certificates are similar to the PVPA ones granted in the U.S. Since regulatory frameworks are not homogeneous, there may be some differences in definitions, enforcement, and management of the UPOV regulatory systems across these countries. Furthermore, using property rights protection in emerging countries is not necessarily the only tool for reaping the benefits of investment in innovation, but it is an important one.[11]

Looking at the evolution of applications and granting of rights for new seed varieties, we can observe a boom and steady growth in some certificates (Figure 1). First, there was a boom in the number of patents granted in the United States. The opening of the patent system to new seed varieties in the 1980s produced a boom in this type of rights. Inventors perceive that patents grant more robust property rights protection and prefer applying for them. As a result, applications increased from 253 in 1984 to 1,406 in 2013 (the highest level), representing a 455% increase. This increase is mirrored by the increase in new patents granted, which grew from an average of 200 patents per year in the mid-1980s to an average above 1,000 patents a year in the late 2010s (Figure 1). Second, while there is an increase in PVPAs in the U.S., the volume of applications is far from that of patents (Figure 1). Nonetheless, the number of applications has almost doubled since the 1980s.

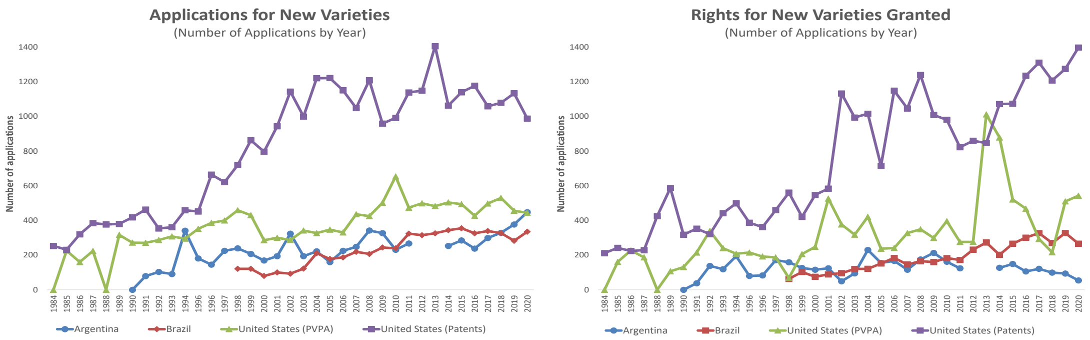

Figure 1

Source: Own elaboration based on data from UPOV database, at https://www.upov.int/portal/index.html.en

[4] The global seed market reached an estimated 63 billion in 2021 and is expected to grow to 86.8 billion by 2026. GlobeNewswire, *The global seed market size is estimated to be valued at USD 63.0 billion in 2021 and is projected to reach USD 86.8 billion by 2026, recording a CAGR of 6.6%,* at https://www.globenewswire.com/news-release/2021/04/08/2206399/0/en/The-global-seed-market-size-is-estimated-to-be-valued-at-USD-63-0-billion-in-2021-and-is-projected-to-reach-USD-86-8-billion-by-2026-recording-a-CAGR-of-6-6.html (last accessed on 6/30/2021).

[5] *See* 7 U.S.C. § 2351(a) (2000).

[6] *See* The U.S. Plant Variety Protection Act (PVPA), 7 U.S.C. §§ 2321-2582, was enacted by Congress in 1970 to encourage the development of new varieties of crops and to make them available to the public.

[7] *See* 35 U.S.C. § 101 (2000)

[8] 447 U.S. 303 (1980)."In *Chakrabarty*, decided in 1980, the Court ushered in the age of biotechnology patenting, holding in a 5-4 split that genetically modified bacteria fell within the scope of patent-eligible subject matter." Mark D. Janis & Jay P. Kesan, *U.S. Plant Variety Protection: Sound and Fury . . .?*, 39 Hous. L. Rev. 727 (2002), at 7.

[9] 534 U.S. 124 (2001)

[10] International Convention for the Protection of New Varieties of Plants, Dec. 2, 1961, (as revised at Geneva on Oct. 23, 1978, and on Mar. 19, 1991) available at UPOV Lex

[11] *See*, Tripp, Robert, Louwaars, Niels, and Eaton, Derek. "Plant variety protection in developing countries. A report from the field." *Food Policy.* 32 (2007): 354-371. The authors provide evidence of the adoption of plant variety protection systems in developing countries and the performance of these systems. See also, Srinivasan, C. C. "Plant Variety Protection, Innovation, and Transferability: Some Empirical Evidence." *Review of Agricultural Economics.* V. 26, N. 4: 445-471. Providing empirical evidence on the advantages of introducing these property rights regimes in developing countries. The author presents evidence of the importance of these regimes for local breeders.

Third, there is a substantial increase in the number of certificates in Argentina and Brazil. While the number of applications is less impressive than patent applications in the U.S., patents in Brazil increased from an average of about 100 applications in the late 1990s to an average of about 330 applications in the late 2010s. Argentina shows an increase from an average of nearly 200 in the mid-1990s to 330 in the later 2010s (Graph 1). Finally, the number of applications and the growth of patent applications in the U.S. is much higher than the evolution of requests in Argentina and Brazil. This underscores the size of the market but also due to the more robust protection offered by patents.

Given the global nature of the market for new seeds, there is a particular interest in knowing how the regulatory system attracts international inventors to register their varieties in the particular local country. In this regard, Argentina shows a mixed performance. While in the 1990s, non-residents overtook residents in applying for new varieties; there was a sudden reversal in 2003 when non-residents' applications dropped significantly (Figure 2).

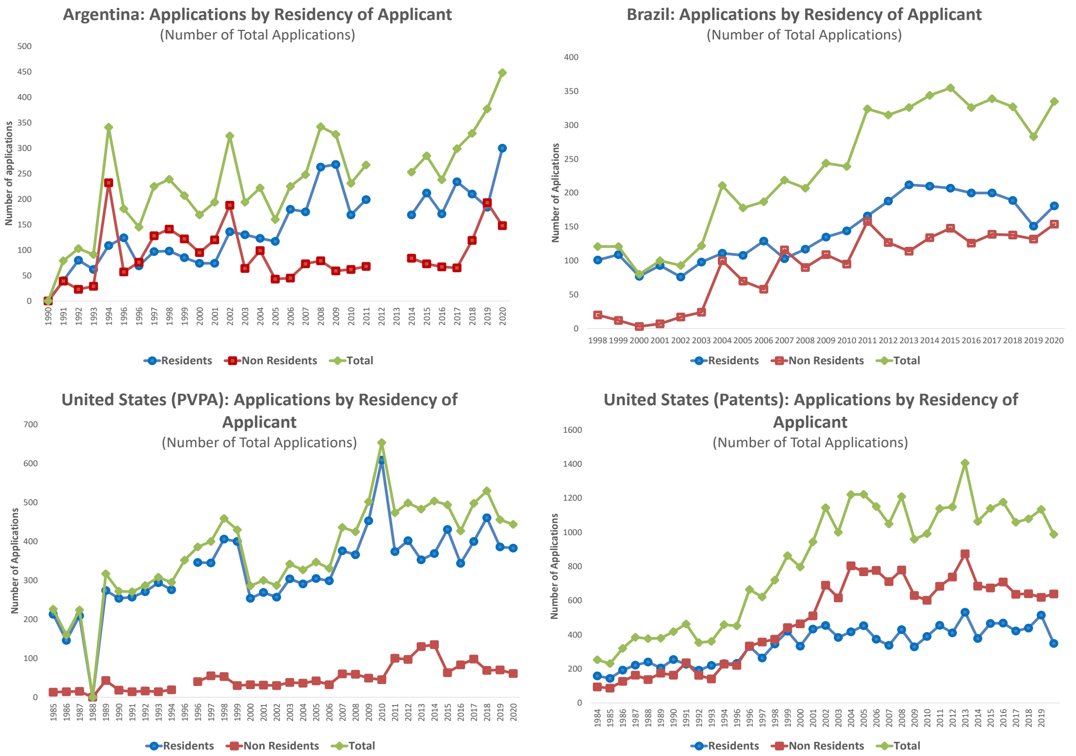

Figure 2

Source: Own elaboration based on data from UPOV database, at https://www.upov.int/portal/index.html.en

This drop-in non-resident application coincides with the phenomenal expansion of production, especially in soybeans (Zhou et al., 2018). As these authors explain, statistical evidence shows that countries with a UPOV-type regime receive more imports of new seed varieties from the U.S. than countries without such a system. Accordingly, the authors highlight the importance of property rights in the transfer of innovation. However, the poor performance of non-residents in Argentina may be related to the contentious relationship between some multinational companies, particularly Monsanto, and the government. Monsanto tried to obtain patent protection for its seed varieties, and the company sued the Argentine government (Filomeno, 2013a; Varella & Marinho, 2013). Even though the lawsuit failed, it produced a confrontational situation between the government and multinational companies. In the case of Brazil, there is no such drop in the participation of non-resident applicants (Figure 2).

In the case of the U.S. regulatory framework, there is a clear distinction between the PVPA and the utility patent system. Non-residents prefer the utility patent system, which provides stronger property rights protection than the PVPA (Figure 2). This preference indicates why international investors sought similar protection levels in other emerging markets, like Argentina and Brazil.

Nonetheless, in Brazil and the U.S., the participation of non-residents' applications increased throughout the period (Figure 3). But this is not the case in Argentina, where the participation of non-residents declined after 2001 and did not recover until 2017 (Figure 4). This behavior is the opposite compared to Brazil and may be an indication of the Argentine regulatory framework's perceived difficulties and contentious characteristics.

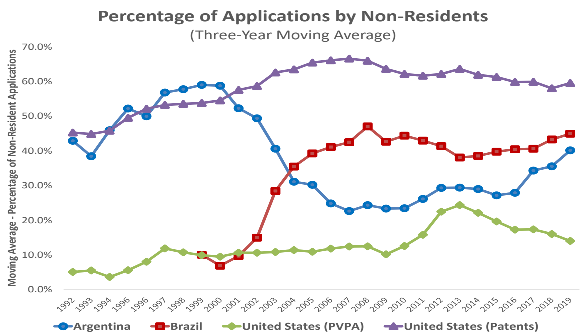

Figure 3

Source: Own elaboration based on data from UPOV database, at https://www.upov.int/portal/index.html.en

Additionally, there is a difference in the rates of approval of applications. While in Brazil and the U.S., the number of applications and the number of rights awarded increase over time, in Argentina, there is a divergence between these two variables (Figure 4). Even though there may be some delay between applications and the number of granted certificates in the U.S., we observe a close positive correlation between both variables (Figure 4). Furthermore, this correlation is similar for the PVPA and the patent systems. We see a similar situation in Brazil, where the correlation is also positive (Figure 4). However, in Argentina, we observe a divergence between these series (Figure 4). While the number of applications increased over time, the number of certificates awarded decreased. This behavior is at odds with the situations in Brazil and in the U.S. and provides some evidence of the contentious relationship between the Argentine government and its agencies with the companies investing in new varieties.

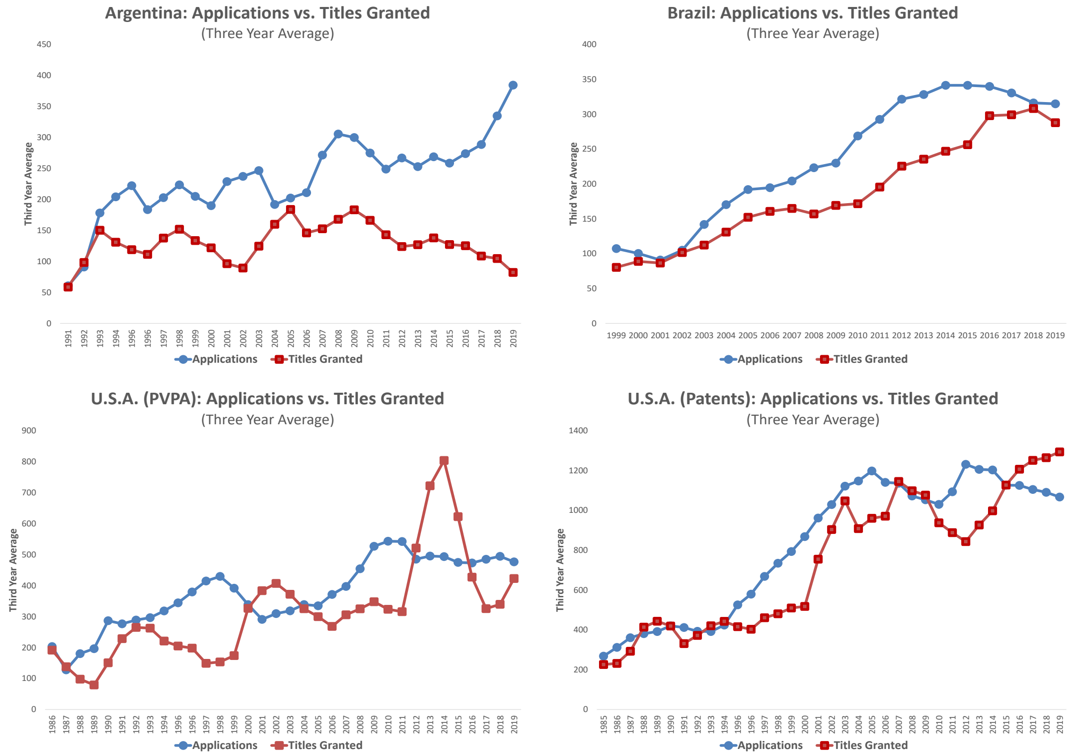

Figure 4

Source: Own elaboration based on data from UPOV database, at https://www.upov.int/portal/index.html.en

In short, this section provides evidence of the growing need to invest in new technologies to foster productivity in agriculture, and the benefits for countries like Argentina, Brazil, and the U.S., to benefit from the increasing demand from China and other faster-growing economies (Brookes & Barfoot, 2020). The authors provide evidence of the additional farm revenue created by genetically modified agricultural seeds. They estimate these benefits to be significant and almost evenly distributed among farmers in developed and developing countries. Furthermore, almost 70% of the gains come from increases in yields (Brookes & Barfoot, 2020). Then, a well-defined property rights framework is necessary for integrating new seed varieties into different crops to appropriate the benefits of these new technologies. Nonetheless, we observe differences in the setup of the regulatory systems in these countries, which creates different incentives for investors. In particular, the contentious relationship between the Argentine government and the agricultural sector is well documented (Filomeno, 2013a). The author explains the differences in state capacity in I.P. and research and development as the main factors in determining the strength of the I.P. regime. In particular, the author applies this framework to explain the differences in Argentina, Brazil, and Paraguay (Filomeno, 2013b). Fuck et al. (2008), also describe the differences in I.P. regimes in Argentina and Brazil. Given Argentina's weak property rights protection and the continuous political debate about the importance of having secure property rights, we need to establish the relationship between these property rights and yields. That is, by establishing the relationship between productivity and the legal rights on new varieties, we can determine if having more secure property rights is going to produce the expected results in agriculture. The following section explores the relationship between new varieties and the yield of different crops in the case of Argentina. This evidence is important to determine the need for a well-defined property rights system and a more collaborative relationship between the regulatory agencies and the companies investing in research and development.

Property Rights and Yields: A Time Series Analysis

The previous section analyzed how the different regulatory systems for property rights generate different evolution of innovations and the presence of available varieties in each country. This section presents a time series statistical analysis for Argentina, showing a positive relationship between new seed varieties and productivity (McArthur & McCord, 2017). Such a relationship is vital in establishing effective property rights systems that promote innovation in new varieties. Since Argentina has struggled to reach a political consensus on this matter, establishing this statistical relationship is essential and can help to highlight the need to advance adequate changes to the current regulations.

Data

For our statistical analysis, we use data from the Instituto Nacional de Semillas (INASE), the official agency that registers new seed varieties for the country[12]. While agriculture has been significant in Argentina, the INASE started to register new varieties in 1978 (Gallo & Kesan, 2006). Accordingly, we collected information on the new varieties of corn, wheat, and soybeans presented to the INASE each year. We also collected yield data from the Food and Agriculture Organization (F.A.O.), which contains a complete database for our analysis[13]. The Argentine government also compiles these databases, so we use official Argentine data to establish our statistical model.

Time Series Methodology

When dealing with time series, one of the main issues is the presence of non-stationarity. Accordingly, we run unit root tests to see if the variables are stationary. In addition, another issue may be the presence of structural changes in the time series, especially when it comes to government permits (seed varieties) and agricultural yields. Regulatory changes can influence the first variable, while the second is subject to weather changes, international conditions, and prices. Accordingly, we use unit root tests with endogenous breaks to detect some of these changes. We employed the Ben-David, Lumsdaine, & Papell (2003) methodology to test for two structural breaks in the data. We determined the break endogenously by letting the data self-select the break date. Finding these breaks is essential in identifying shocks in any of the variables. Furthermore, analyzing these structural breaks can shed light on the patterns in the evolution of seed varieties analyzed in the previous section. Once we establish the time structure of these variables, we use a V.A.R. analysis to see if these variables are related to each other. We also provide cointegration tests to see if there is a long-term relationship between these variables and a Granger Causality test. As explained above, we are not building a parametric econometric model, given the need for more information and variables. However, we are using time series analysis to corroborate the existence of a relationship between property rights and productivity in main crops in Argentina.

Unit Root Tests and Structural Breaks

First, we use a simple Dickey-Fuller and the Phillips-Perron tests for unit roots to assess the stationarity of the time series. These tests will help us determine the dynamic process that characterizes each variable (Table 1). These results show we can reject the unit root hypothesis for all these variables. In most cases, the variables are trend stationary, exhibiting a long-term trend, which we will consider in our analysis.

Table 1: Unit Root Tests.

	Phillips-Perron Test			Augmented Dickey-Fuller Test			
Variable	**Rho**	**Z**	**Trend**	**t_α**	**α**	**Trend**	**Lags**
Corn New Varieties	-16.348 (**)	-3.874 (***)		-2.445	-0.300		2
	-36.771 (***)	-5.429 (***)	0.041 (0.0126)	-1.959	-0.441	0.011 (0.0154)	2
Corn Yield	-2.327	-1.096		-0.561	-0.037		2
	-38.973(***)	-5.385 (***)	0.021 (0.0043)	-3.330 (*)	-0.676	0.016 (0.0054)	1
Soybean New Varieties	-27.602 (***)	-4.295 (***)		-3.157 (**)	-0.395		5
	-42.442 (***)	-6.115 (***)	0.045 (0.0134)	-3.363 (**)	-0.813	0.0386 (0.0166)	1
Soybean Yield	-25.870 (***)	-4.176 (***)		-2.387	-0.400		1
	-46.888 (***)	-7.568 (***)	0.0134 (0.0025)	-4.534 (***)	-1.22	*0.0129* (0.0036)	1
Wheat New Varieties	-32.654 (***)	-4.814 (***)		-1.029	-0.141		3
	-38.290 (***)	-7.233 (***)	0.0384 (0.0093)	-2.203	-0.739	0.0292 (0.0151)	3
Wheat Yield	-7.219	-2.126		-0.137	-0.014		5
	-32.327 (***)	-6.137 (***)	0.0151 (0.0029)	-6.232 (***)	-1.765	0.0265 (0.0047)	2

Note: (***) Significant at 1%, (**) Significant at 5%, and (*) Significant at 10%. Trend: Standard Errors in parenthesis.

To further explore the evolution of these variables over time, this section also explores the presence of structural breaks in these time series. Accordingly, we can relate these changes to further policy or economic developments, which may have affected the typical trajectory of these variables. Then, we perform a unit root test with two breaks in the trend in two different unknown tests (Lumsdaine & Papell, 1997). Following Lumsdaine & Papell (1997), the augmented Dickey-Fuller test can be represented by

[12] *See* INASE at https://www.argentina.gob.ar/inase
[13] *See* FAOSTAT at http://www.fao.org/faostat/en/.

$$\Delta y_t = \mu + \beta t + \theta_1 DU1_t + \gamma_1 DT1_t + \theta_2 DU2_t + \gamma_2 DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} \Delta y_{t-i} + \varepsilon_t \quad (1)$$

Where we assume that TBj (j=1,2) is the time breaks. The dummy variables take the following values: DUj_t=1 and DTj_t=t-TBj if t>TBj and 0 otherwise. This model is estimated for all possible pairs (TB1, TB2) where TBj=2,…, T-1, j=1,2, and T is the number of observations after adjusting by the first differencing and the lag length k.[14] For each TB_j, the number of lags, k, is determined by selecting an *a priori* value of k and running the model. If the lag k is significant, choose this number of lags; otherwise, reduce the number of lags by one and repeat the procedure until a lag becomes significant. If no lags are significant, then k=0.

We then compute the t-statistic α for all the possible distinct pairs of break dates TB1 and TB2. The break dates are the values for TB1 and TB2, for which the t-statistics of α are minimized. If the minimum t-statistic is lower than the critical value, the null hypothesis of unit root is rejected. This methodology allows for endogenously identifying structural breaks in the time series. As a result, we can offer statistically significant support to the presence of a structural break in a given moment.

We estimate three different models. First, Model A.A. assumes two breaks in the intercept but no breaks in the slope of the function (γ_1=γ_2=0). Second, Model CA assumes two breaks in the intercept and one break in the slope (γ_2=0). Finally, Model CC assumes two breaks in both the intercept and the slope.

Model AA

$$\Delta y_t = \mu + \beta t + \theta_1 DU1_t + \theta_2 DU2_t + \alpha y_{t-1} + \sum_{i=1}^{k} \Delta y_{t-i} + \varepsilon_t$$

Model CA

$$\Delta y_t = \mu + \beta t + \theta_1 DU1_t + \gamma_1 DT1_t + \theta_2 DU2_t + \alpha y_{t-1} + \sum_{i=1}^{k} \Delta y_{t-i} + \varepsilon_t$$

Model CC

$$\Delta y_t = \mu + \beta t + \theta_1 DU1_t + \gamma_1 DT1_t + \theta_2 DU2_t + \gamma_2 DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} \Delta y_{t-i} + \varepsilon_t$$

The results show some structural changes in the evolution of these time series (Table 2). The new varieties in the three main crops exhibited a structural change around 1997. This is interesting, as Argentina entered the UPOV-78 agreement in 1991, and there was an initial rush to register new varieties. In addition, the country entered a recession in 1998, which, together with low international agricultural commodity prices, could have impacted investment in research and development.

Table 2: Unit Root Test with Two Breaks.

Variable	t_α	$t_{\theta 1}$	$t_{\theta 2}$	$t_{\gamma 1}$	$t_{\gamma 2}$	TB1	TB2	Lags
Corn New Varieties	-11.56 (***)	-1.73 (*)	-1.95 (***)	-0.34 (***)		1998	1986	1
Corn Yield	-8.451 (***)	-3.39 (***)	3.29 (***)			2011	2000	1
Soybean New Varieties	-10.07 (***)	2.62 (**)	1.68	-4.85 (***)	-5.93 (***)	2012	1997	4
Soybean Yield	-9.55(***)	-2.71 (**)	2.21 (**)	2.68 (**)		1997	2008	1
Wheat New Varieties	-9.52 (***)	6.27 (***)	3.05 (***)			1997	2006	1
Wheat Yield	-7.10 (**)	-2.77 (**)	-3.49 (***)	-2.26 (**)		2003	1987	4

Note: Critical values (Source Ben-David et al., 2003)
Model AA: -6.74 (1%), -6.43 (2.5%), -6.16 (5%), -5.89 (10%)
Model CA: -7.19 (1%), -6.86 (2.5%), -6.62 (5%), -6.37 (10%)
Model CC: -7.19 (1%), -6.95 (2.5%), -6.75 (5%), -6.48 (10%)

Corn yields had a positive increase in 2000, which reverted by 2011. This behavior may indicate the increase in commodity prices starting in the early 2000s and the corresponding decrease with the global crisis in 2008. Soybean yields exhibit a similar pattern, with a positive change in slope in 1997 and a negative shock in 2008. Finally, wheat exhibits a slightly different behavior, with a negative break in 1987 and another in 2003. In the 2000s, most of the price boom in agricultural commodities corresponded to soybeans, indicating the changes in wheat yield.

To assess the dynamic relationship between yields and new varieties in each of these crops, we perform a Vector Autoregressive model (V.A.R.) between these variables. Furthermore, we use this vector autoregressive model to test for Granger Causality (Hamilton, 1994). As a result, we should assess the direction of the statistical causality between these variables. This V.A.R. follows a general form,

$$y_{1t} = c_1 + A_1' x_{1t} + A_2' x_{2t} + \varepsilon_{1t} y_{2t} = c_2 + B_1' x_{1t} + B_2' x_{2t} + \varepsilon_{2t} (16)$$

Where the variables of the V.A.R. are categorized into two groups represented by the (n_1x1) vector $\mathbf{y}_{1t}$ and the (n_2+1) vector $\mathbf{y}_{2t}$. $\mathbf{x}_{1t}$ is an ($n_1$px1) vector containing lags of $\mathbf{y}_{1t}$ and the ($n_2$px1) vector $\mathbf{x}_{2t}$ containing lags of $\mathbf{y}_{2t}$.[15] The (n_1x1) and (n_2x1) vectors $\mathbf{c}_1$ and $\mathbf{c}_2$ contain the constant terms of the V.A.R., while the Matrices A_1, A_2, B_1, and B_2 contain the autoregressive coefficients. Following Hamilton (1994), "the group of variables $\mathbf{y}_1$ is said to be block-exogenous in the time series sense with respect to the variables in $\mathbf{y}_2$ if the elements in $\mathbf{y}_2$ are of no help in improving a forecast of any variable contained in $\mathbf{y}_1$ that is based on lagged values of all

[14] Finally, the errors terms ε_t are assumed to be a martingale difference sequence and satisfies $E(\varepsilon_t^2|\varepsilon_{t-1},\ldots)=\sigma^2$, $E(|\varepsilon_t|^i|\varepsilon_{t-1},\ldots)=\kappa_i$ (i=3,4), $\sup_t E(|\varepsilon_t|^{4+\xi}|\varepsilon_{t-1},\ldots)=\kappa<\infty$ for some ξ>0.

[15] Accordingly, $\boldsymbol{x}_{1t} = \begin{bmatrix} \boldsymbol{y}_{1,t-1} \\ \boldsymbol{y}_{1,t-2} \\ \vdots \\ \boldsymbol{y}_{1,t-p} \end{bmatrix}$ $\quad \mathbf{x}_{21t} = \begin{bmatrix} \boldsymbol{y}_{2,t-1} \\ \boldsymbol{y}_{2,t-2} \\ \vdots \\ \boldsymbol{y}_{2,t-p} \end{bmatrix}$

the elements of $\mathbf{y}_1$ alone" [pp. 309]. In order to determine the optimal number of lags, k, we run the V.A.R. model setting the number of lags equal to five and using the Schwartz-Bayes Information Criterion (SBIC) to choose the optimal number of lags. The V.A.R. results show the dynamic interaction between these variables:

Table 3: V.A.R. Model for Corn Varieties and Yield.

	$CornV_t$	$CornY_t$
$CornV_{t-1}$	-0.059 (-0.38)	0.007 (0.23)
$CornV_{t-2}$	0.313 (2.12)	0.058 (1.85)
$CornV_{t-3}$	0.173 (1.19)	0.023 (0.75)
$CornY_{t-1}$	0.092 (0.14)	0.314 (2.16)
$CornY_{t-2}$	-0.463 (-0.68)	0.145 (1.00)
$CornY_{t-3}$	1.207 (1.84)	0.294 (2.11)
Constant	-4.80 (-1.07)	1.804 (1.88)
Chi-Squared	55.62 (***)	269.93 (***)

Note: t-values in parenthesis.
The V.A.R. system satisfies stability conditions as all the eigenvalues lie inside the unit circle.

Table 4: V.A.R. Model for Soybean Varieties and Yield.

	$SoyV_t$	$SoyY_t$
$SoyV_{t-1}$	0.192 (1.16)	0.028 (1.04)
$SoyV_{t-2}$	0.327 (1.93)	0.084 (3.02)
$SoyY_{t-1}$	0.103 (0.12)	0.032 (0.22)
$SoyY_{t-2}$	0.572 (0.67)	0.175 (1.22)
Constant	-3.75 (-0.45)	5.840 (4.19)
Chi-Squared	14.42 (***)	30.40 (***)

Note: t-values in parenthesis.
The V.A.R. system satisfies stability conditions as all the eigenvalues lie inside the unit circle.

Table 5: V.A.R. Model for Wheat Varieties and Yield.

	$Wheat_{on}$	$WheatY_t$
$WheatV_{t-1}$	0.170 (1.20)	0.062 (1.50)
$WheatV_{t-2}$	0.118 (0.88)	0.051 (1.29)
$WheatV_{t-3}$	-0.127 (-1.15)	0.006 (0.19)
$WheatV_{t-4}$	0.303 (3.01)	0.080 (2.71)
$WheatY_{t-1}$	0.611 (1.15)	0.276 (1.79)
$WheatY_{t-2}$	0.449 (0.83)	-0.099 (-0.63)
$WheatY_{t-3}$	-0.897 (-1.65)	0.051 (0.32)
$WheatY_{t-4}$	1.094 (2.14)	0.148 (0.99)
Constant	-8.583 (-1.54)	4.458 (2.73)
Chi-Squared	78.35 (***)	94.25 (***)

Note: t-values in parenthesis.
The V.A.R. system satisfies stability conditions as all the eigenvalues lie inside the unit circle.

In this case, we are interested in evaluating if the number of new varieties Granger-causes yield in the respective crop. Accordingly, the Granger Causality tests show that for corn, the number of new varieties does not cause yields, nor yields cause the number of new varieties (Table 6). This result is consistent with Galushko (2012), who shows that property rights protection is less important for hybrid crops than genetically modified ones. There is strong evidence that the number of varieties Granger-cause the soybean yields, but yields do not cause the number of new varieties. Finally, new wheat varieties seem to cause yields, while yields weakly cause the number of varieties (Table 6).

Table 6: Granger Causality Test Results.

	CornV		CornY	
Excluded Variable	**Chi-Squared**	**P-value**	**Chi-Squared**	**P-value**
CornY	4.4607	0.216		
CornV			4.2606	0.235
	SoyV		SoyY	
	Chi-Squared	P-value	Chi-Squared	P-value
SoyY	0.493	0.782		
SoyV			11.364	0.003
	WheatY		WheatV	
	Chi-Squared	P-value	Chi-Squared	P-value
WheatY	8.5986	0.072		
WheatV			9.6321	0.047

Accordingly, these results show a relationship between the number of varieties and yields. Furthermore, the direction of the causality is from the number of new varieties towards the yields, implying that having more investment in new varieties should lead to improvements in yields. This relationship is solid in the case of soybeans and more moderate for wheat. However, there is no clear indication for the case of corn. This evidence is aligned with the evolution of the legal/regulatory system in Argentina and previous work in this area. First, as explained in previous research, there is a difference in the need for substantial property rights in soybeans and endogamic plants and corn, which is a hybrid (Kesan & Gallo, 2005). As the authors show, in Argentina, there is an overinvestment in new varieties for corn, whose biological characteristics offer more secure property rights protection than soybean. Accordingly, this overinvestment could explain the lack of causality of new corn varieties on yields, since most of the economic benefits have already been exhausted. Second, multinational companies and the Argentine government engaged in contentious litigation regarding the patenting of soybean seed varieties, which are the ones that show a more substantial effect on yields. Finally, there is an intense debate concerning changes to the legal/regulatory system. Different stakeholders and political parties realize that the system needs updates to capture new technologies and investments in innovation. However, there needs to be a clear path to a consensus regarding the characteristics of the new system. This evidence shows the potential benefits of reaching an agreement among different parties and enacting legislation that allows for better integration of innovation in the agricultural sector.

Interpretation and Discussion of Results

The previous results show that there is a relationship between legal rights for plant varieties and yields, especially in the case of wheat and soybeans. The time series analysis provides evidence of the causal direction of the relationship between the number of new varieties and the yields in each of these crops. These results highlight the importance of having secure property rights to promote continuous gains in yields. We can highlight the impact on the following issues.

Despite the recent slowdown in Chinese economic growth, it is expected that the demand growth for agricultural products in international markets is expected to continue (USDA, 2023). This will require countries like Argentina to produce policies and foster investments that promote growth and allow them to sustain, or increase, their participation in international markets. Nonetheless, given the land competition with other crops and uses, the gains should come from productivity improvements. In this arena, innovation in new seed varieties and advances in biotechnology are crucial elements for success. Then, having a property rights system that rewards innovation, and promotes the use of biotechnology in agriculture is an economic necessity to the agricultural sector. This paper shows that Argentina does not have a strong protection like the U.S., or a system like Brazil, and then there are continuous problems to institute better legislation. Furthermore, this paper also shows that despite the insecure property rights in Argentina, there is a strong statistical causality from the new varieties introduced in the market and the yields in soybean and wheat. This empirical evidence is significant in informing the legislative disputes and highlighting the losses due to lack of agreement. We can infer that Argentina's continuous success in supplying the need of international markets depends on its investment in property rights protection, among other investments. Furthermore, these results can inform efforts in property rights protection in other countries, which can assess how innovations affect agricultural productivity.

Conclusions

This paper used data from new seed varieties and yields in Argentina to show the importance of new varieties in productivity. Argentina is one of the leading agricultural exporters in the world, and the country has benefited from the impact of China on international agricultural markets. This paper highlights the strong growth in demand in the last two decades from China, and the rush from several countries to meet that demand. In particular, Argentina, Brazil, and the U.S. are the leading exporters of corn, soybeans, and wheat. In this context, the evidence underscores the need to improve yields, given the low availability of new lands and the cost of substituting other crops and reducing production elsewhere, which could lead to misalignments in the productive structure of a given country. If these countries want to continue selling to China, and maintain their competitive status, they must find ways to keep increasing their production.

In this context, one of the essential tools for increasing productivity is the adoption of GMOs and new seed varieties in agriculture. The explosion of investment in innovation and the development of new seeds worldwide introduced opportunities and challenges for these countries to take advantage of these discoveries. In particular, this paper shows the workings of the regulatory systems in Argentina, Brazil, and the U.S. in increasing the number of new varieties in agriculture.

In this context, this paper uses data to analyze the case of Argentina, establishing the relationship between new varieties and yields. The statistical evidence shows a strong causality between new varieties and yields for soybeans and wheat, while the evidence is inconclusive for corn. As explained before, given the lack of secure intellectual property rights, there is an overinvestment in the number of corn varieties in Argentina, which could lead to diminished productivity effects on yields. Nonetheless, the strong positive effects for soybeans and wheat underlie the relationship between innovation and yields and the losses for having an insecure property rights system in place.

This empirical evidence highlights the need for an adequate regulatory system to capture new varieties and incentivize research and development investment. This is particularly important in the case of Argentina, where there are intense confrontations between the government, private companies, and different stakeholders from the agriculture sector. As the confrontation persists and the parties cannot reach an agreement, there are productivity losses in agriculture due to the uncertainty in the regulatory system.

This study opens the door for further avenues of research. First, it would be interesting to address the effects of changes in property rights and productivity in countries that make legislative efforts to improve property rights protections. Second, given the positive results from this study, we could analyze the political economy of property rights. What other political factors or groups prevent countries from implementing in better regulatory systems? Finally, we could analyze how the expansion of innovation and the adoption of property rights definitions around the globe enhances the perspectives for growth in innovation both at the local and international levels.

References

Ben-David, D., Lumsdaine, R. L., & Papell, D. H. (2003). Unit Roots, Postwar Slowdowns and Long-run Growth: Evidence From Two Structural Breaks. *Empirical Economics, 28*(2), 303-319. doi: https://doi.org/10.1007/s001810200132

Brookes, G., & Barfoot, P. (2020). GM Crop Technology Use 1996-2018: Farm Income and Production Impacts. *GM Crops & Food, 11*(4), 242-261. doi: https://doi.org/10.1080/21645698.2020.1779574

Bussolo, M., de Hoyos, R. E., Medvedev, D., & van der Mensbrugghe, D. (2012). Global Growth and Distribution: China, India, and the Emergence of a Global Middle Class. *Journal of Globalization and Development, 2*(2), 1-29. doi: https://doi.org/10.1515/1948-1837.1041

Casanova, C., Xia, L., & Ferreira, R. (2016). Measuring Latin America's Export Dependency on China. *Journal of Chinese Economic and Foreign Trade Studies, 9*(3), 213-233. doi: https://doi.org/10.1108/JCEFTS-08-2016-0022

Chen, S.-P. J., Li, M.-W., Wong, H.-Y., Wong, F.-L., Wu, T., Gai, J., et al. (2022). The Seed Quality Assurance Regulations and Certification System in Soybean Production—A Chinese and International Perspective. *Agriculture, 12*(5), 624. doi: https://doi.org/10.3390/agriculture12050624

Deng, X., Huang, J., Rozelle, S., & Uchida, E. (2008). Growth, Population and Industrialization, and Urban Land Expansion of China. *Journal of Urban Economics, 63*(1), 96-115. doi: https://doi.org/10.1016/j.jue.2006.12.006

Entine, J., Felipe, M. S. S., Groenewald, J.-H., Kershen, D. L., Lema, M., McHughen, A., et al. (2021). Regulatory Approaches for Genome Edited Agricultural Plants in Select Countries and Jurisdictions Around the World. *Transgenic Research, 30*(4), 551-584. doi: https://doi.org/10.1007/s11248-021-00257-8

Fares, T. M. (2023). China's Financialized Soybeans: The Fault Lines of Neomercantilism Narratives in International Food Regime Analyses. *Journal of Agrarian Change, 23*(3), 477-499. doi: https://doi.org/10.1111/joac.12536

Feenstra, R., & Hong, C. (2022). China's Import Demand for Agricultural Products: The Impact of the Phase One Trade Agreement. *Review of International Economics, 30*(1), 345-368. doi: https://doi.org/10.1111/roie.12568

Filomeno, F. A. (2013a). How Argentine Farmers Overpowered Monsanto: The Mobilization of Knowledge-users and Intellectual Property Regimes. *Journal of Politics in Latin America, 5*(3), 35-71. doi: https://doi.org/10.1177/1866802x1300500302

Filomeno, F. A. (2013b). State Capacity and Intellectual Property Regimes: Lessons From South American Soybean Agriculture. *Technology in Society, 35*(2), 139-152. doi: https://doi.org/10.1016/j.techsoc.2013.01.002

Fuck, M. P., Salles-Filho, S., de Carvalho, S. P., & Bonacelli, M. B. M. (2008). Intellectual Property Protection, Plant Breeding and Seed Markets: A Comparative Analysis of Brazil and Argentina. *International Journal of Technology Management & Sustainable Development, 7*(3), 223-235. doi: https://doi.org/10.1386/ijtm.7.3.223_1

Fuglie, K. (2018). R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture. *Applied Economic Perspectives and Policy, 40*(3), 421-444. doi: https://doi.org/10.1093/aepp/ppx045

Fukase, E., & Martin, W. (2016). Who Will Feed China in the 21st Century? Income Growth and Food Demand and Supply in China. *Journal of Agricultural Economics, 67*(1), 3-23. doi: https://doi.org/10.1111/1477-9552.12117

Gallo, A. A., & Kesan, J. P. (2006). Property Rights Legislation in Agricultural Biotechnology: United States and Argentina. *Minnesota Journal of Law, Science & Technology, 7*(2), 565-598. Retrieved from https://scholarship.law.umn.edu/mjlst/vol7/iss2/7

Galushko, V. (2012). Do Stronger Intellectual Property Rights Promote Seed Exchange: Evidence From U.S. Seed Exports? *Agricultural Economics, 43*(s1), 59-71. doi: https://doi.org/10.1111/j.1574-0862.2012.00620.x

Giraudo, M. E. (2020). Dependent Development in South America: China and the Soybean Nexus. *Journal of Agrarian Change, 20*(1), 60-78. doi: https://doi.org/10.1111/joac.12333

Hamilton, J. D. (1994). *Time Series Analysis*. Princeton University Press. doi: https://doi.org/10.1515/9780691218632

Jamet, J.-P., & Chaumet, J.-M. (2016). Soybean in China: Adaptating to the Liberalization. *OCL - Oilseeds and Fats, Crops and Lipids, 23*(6), D604. doi: https://doi.org/10.1051/ocl/2016044

Janis, M. D., & Kesan, J. P. (2002). US Plant Variety Protection: Sound and Fury...? *Houston Law Review, 39*, 727-778. Retrieved from https://www.repository.law.indiana.edu/facpub/430

Jepson, N. (2020). *In China's Wake: How the Commodity Boom Transformed Development Strategies in the Global South*. Columbia University Press. Retrieved from https://cup.columbia.edu/book/in-chinas-wake/9780231187978

Jiang, L., Seto, K. C., & Bai, J. (2015). Urban Economic Development, Changes in Food Consumption Patterns and Land Requirements for Food Production in China. *China Agricultural Economic Review, 7*(2), 240-261. doi: https://doi.org/10.1108/CAER-11-2013-0150

Kesan, J. P., & Gallo, A. A. (2005). Property Rights and Incentives to Invest in Seed Varieties: Governmental Regulations in Argentina. *AgBioForum, 8*(2&3), 118-126. Retrieved from https://agbioforum.org/wp-content/uploads/2021/02/AgBioForum_8_23_118.pdf

Kesan, J. P., & Gallo, A. A. (2007). Insecure Property Rights and Plant Varieties: The Effects on the Market for Seeds and on Farmers in Argentina. In J. P. Kesan (Ed.), *Agricultural Biotechnology and Intellectual Property: Seeds of Change* (pp. 216-230). CABI Publishing. doi: https://doi.org/10.1079/9781845932015.0216

Klein, H. S., & Luna, F. V. (2023). *Brazilian Crops in the Global Market: The Emergence of Brazil as a World Agribusiness Exporter Since 1950* (1st ed.). Palgrave Macmillan Cham. doi: https://doi.org/10.1007/978-3-031-38589-6

Klein, H. S., & Vidal Luna, F. (2021). The Growth of the Soybean Frontier in South America: The Case of Brazil and Argentina. *Journal of Iberian and Latin American Economic History, 39*(3), 427-468. doi: https://doi.org/10.1017/S0212610920000269

Kolady, D. E., & Lesser, W. (2009a). But are they Meritorious? Genetic Productivity Gains under Plant Intellectual Property Rights. *Journal of Agricultural Economics, 60*(1), 62-79. doi: https://doi.org/10.1111/j.1477-9552.2008.00171.x

Kolady, D. E., & Lesser, W. (2009b). 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. doi: https://doi.org/10.1111/j.1747-1796.2009.00354.x

Lumsdaine, R. L., & Papell, D. H. (1997). Multiple Trend Breaks and the Unit-Root Hypothesis. *Review of Economics and Statistics, 79*(2), 212-218. doi: https://doi.org/10.1162/003465397556791

McArthur, J. W., & McCord, G. C. (2017). Fertilizing Growth: Agricultural Inputs and Their Effects in Economic Development. *Journal of Development Economics, 127*, 133-152. doi: https://doi.org/10.1016/j.jdeveco.2017.02.007

Naseem, A., Oehmke, J. F., & Schimmelpfennig, D. E. (2005). Does Plant Variety Intellectual Property Protection Improve Farm Productivity? Evidence from Cotton Varieties. *AgBioForum, 8*(2&3), 100-107. Retrieved from http://agbioforum.org/wp-content/uploads/2021/02/AgBioForum_8_23_100.pdf

OECD. (2018). *Concentration in Seed Markets: Potential Effects and Policy Responses*. OECD Publishing, Paris. doi: https://doi.org/10.1787/9789264308367-en

Phélinas, P., & Choumert, J. (2017). Is GM Soybean Cultivation in Argentina Sustainable? *World Development, 99*, 452-462. doi: https://doi.org/10.1016/j.worlddev.2017.05.033

Rositano, F., Pessah, S., Durand, P., & Laterra, P. (2022). Coupled Socio-Ecological Changes in Response to Soybean Expansion Along the 2001–2010 Decade in Argentina. *Anthropocene, 39*, 100343. doi: https://doi.org/10.1016/j.ancene.2022.100343

Smith, P. J., & Katovich, E. S. (2017). Are GMO Policies “Trade Related”? Empirical Analysis of Latin America. *Applied Economic Perspectives and Policy, 39*(2), 286-312. doi: https://doi.org/10.1093/aepp/ppw021

Srinivasan, C. S. (2004). Plant Variety Protection, Innovation, and Transferability: Some Empirical Evidence. *Applied Economic Perspectives and Policy, 26*(4), 445-471. doi: https://doi.org/10.1111/j.1467-9353.2004.00193.x

Tripp, R., Louwaars, N., & Eaton, D. (2007). Plant Variety Protection in Developing Countries. A Report From the Field. *Food Policy, 32*(3), 354-371. doi: https://doi.org/10.1016/j.foodpol.2006.09.003

UPOV. *International Convention for the Protection of New Varieties of Plants of December 2, 1961, as Revised at Geneva on November 10, 1972, on October 23, 1978, and on March 19, 1991* (UPOV Publication no: 221(E)). International Union for the Protection of New Varieties of Plants. Retrieved from https://www.upov.int/edocs/pubdocs/en/upov_pub_221.pdf

USDA. (2023, February). *USDA Agricultural Projections to 2032: Interagency Agricultural Projections Committee*. United States Department of Agriculture, Interagency Agricultural Projections Committee. Retrieved from https://www.usda.gov/sites/default/files/documents/USDA-Agricultural-Projections-to-2032.pdf

Varella, M. D., & Marinho, M. E. P. (2013). Contesting Monsanto's Patents on Life: Transnational Juridical Dialogue and the Influence of the European Court of Justice on Soybean-Exporting Countries. *Tulane Journal of Technology & Intellectual Property, 16*, 79-104. Retrieved from https://journals.tulane.edu/TIP/article/view/2633

Yan, J., Xue, Y., Quan, C., Wang, B., & Zhang, Y. (2023). Oligopoly in Grain Production and Consumption: An Empirical Study on Soybean International Trade in China. *Economic Research, 36*(2), 2142818. doi: https://doi.org/10.1080/1331677X.2022.2142818

Zhou, M., Sheldon, I., & Eum, J. (2018). The Role of Intellectual Property Rights in Seed Technology Transfer Through Trade: Evidence From U.S. Field Crop Seed Exports. *Agricultural Economics, 49*(4), 423-434. doi: https://doi.org/10.1111/agec.12426