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Necessity is the Mother, But Protection May Not Be the Father of Invention: The Limited Effect of Intellectual Property Regimes on Agricultural Innovation

A. Bryan Endres, University of Illinois at Urbana-Champaign
Carly E Giffin

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Necessity is the Mother, But Protection May Not Be the Father of Invention: The Limited Effect of Intellectual Property Regimes on Agricultural Innovation

A. Bryan Endres* & Carly E. Giffin**

Abstract

Standard innovation theory assumes that intellectual property protection is a prerequisite to the development of technological advances. Stretching back to the writing of the Constitution, a strong intellectual property system, comprised of both laws that establish intellectual property protection and a judicial or other adjudicative system to enforce the property right, has been considered necessary to stimulate innovation for the benefit of society. While not directly challenging this traditionally held belief, the authors used empirical data to test the assumption in the context of agriculture. This paper analyzed twenty years of agricultural production data from Argentina, Brazil, China, India, and the United States and their accompanying intellectual property systems. The authors sought to determine whether strong intellectual property laws, along with vigorous enforcement, would in fact correlate with greater innovation. The results of this empirical study were mixed. The authors’ analysis identified a statistically significant relationship between R & D expenditures — considered a proxy for innovation — and hectares planted, but found no significant relationship between R & D expenditures and crop yield. Subsequent analysis of applications for intellectual property protection and crop production yielded similar mixed results. Thus, the analysis reveals that some measures of innovation in the crops studied manage to thrive despite the absence of strong intellectual property regimes.

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* Associate Professor of Agricultural Law, University of Illinois. Department of Agricultural and Consumer Economics, and Director, University of Illinois European Union Center. This research was supported in part by the National Soybean Research Laboratory and USDA National Institute of Food and Agriculture, Hatch Project No. ILLU-470-309. Any opinions, findings, and conclusions or recommendations do not reflect the view of the funding agencies. The authors extend their appreciation for the valued research assistance of Muriel Lightborne, Kuang-Cheng Chang, Renata Oliveria, Martin Slavens, Dan Loshe and Devon Curtis. Also special thanks to Mojun Liu and Scott Main for assistance with statistical analysis.

** Postdoctoral Legal Research Associate, University of Illinois, Department of Agricultural and Consumer Economics. J.D. University of Illinois; B.A. Haverford College. Contact: carly.giffin@gmail.com.
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I. Introduction

Standard innovation theory assumes that intellectual property protection is a
necessary prerequisite to the development of technological advances. The theory states
that a profit maximizing private firm will not invest firm resources in research and
development activities unless a sufficient intellectual property rights regime is in place to
protect the innovation and enable the firm to earn a reasonable rate of return.¹ This

¹ Debra L. Blair, Intellectual Property Protection and its Impact on the U.S. Seed Industry, 4 DRAKE J. AGRIC. L., 297, 330-31 (1999) (discussing the value of intellectual property to seed development firms); Jay P. Kesan, Intellectual Property Protection and Agricultural Biotechnology: A Multidisciplinary Perspective, 44 AM. BEHAV. SCI. 464, 471 (2000) (noting that it is “critical to fashion IP regimes that adequately reward the inventor for his or her efforts and provide enough economic stability to promote investment in the inventive endeavors”). See also David Castle, Introduction, in The Role of Intellectual Property Rights in Biotechnology Innovation 1 (David Castle ed., 2009) (“Intellectual property rights (IPRs), particularly in the form of patent rights, are widely viewed as catalysts
theory stretches back to the intellectual property clause in Article 1, section 8, clause 8 of the U.S. Constitution. A strong intellectual property system, comprised of both the laws that establish intellectual property rights and a judicial or other adjudicative system to enforce the right, is believed to be one component that ensures an economically efficient allocation of research and development dollars to create innovation for the benefit of society. This paper does not challenge directly these assumptions, but rather seeks to empirically test the propositions within the context of agricultural production — specifically intellectual property protection for plant varieties.

The authors selected plant varieties as the subject of this empirical research due to the unique, and often controversial, mix of various intellectual property regimes related to plant varieties — plant patents, utility patents, plant variety protection certificates, and trade secrets. The authors determined that investigating a variety of plants and the accompanying intellectual property laws would provide the fullest background and

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2 U.S. CONST. ART I, §8, cl. 8. State Department papers and notes made at the Constitutional Convention suggest that James Madison suggested the inclusion of copyrights in the Constitution, believing the lack of protection for authors under the Articles of Federation. The Committee on Detail was responsible for the final wording as it appears in the Constitution. Karl Fenning, The Origin of the Patent and Copyright Clause, 11 J. PAT. OFF. SOC’y 438, 442 (1929).

perspective for the empirical data evaluated later in this paper. Within the history of intellectual property law, many of these protections for plants are quite new. For example, plant patents, the first form of intellectual property for plants in the United States, arose from the 1930 Plant Patent Act.\(^4\) It was another forty years before Congress passed the Plant Variety Protection Act of 1970 to protect sexually reproducing plants (i.e., reproduction via seeds).\(^5\) The Supreme Court did not settle the issues of whether utility patents could apply to plants until 1996.\(^6\)

From an international perspective, other nations have lagged behind the U.S. in establishing intellectual property protection for plants due to political and economic sensitivity of farmers.\(^7\) Specifically, the widespread opinion of many in developing countries (and some in the United States) is that plant varieties belong to the “heritage of mankind,” and free access to plant varieties (or at the very least the ability of farmers to save their own seed from season to season) is an essential element of agricultural production, especially subsistence farming, and a fundamental right of the farmer.\(^8\) Although these arguments are subsiding, many nations have only recently instituted intellectual property regimes for the protection of plant varieties — often as a result of country’s accession to the WTO/TRIPS agreement.\(^9\)

\(^7\) See infra Table 2, Part II.A.1 (listing the dates when each of the five countries adopted PVP protection).
\(^9\) India, for example, recently enacted its Plant Variety Act in 2001 to comply with Article 27.3(b) of TRIPS. Article 27.3(b) of TRIPS imposes on all countries the introduction of some form of intellectual property protection for plant varieties. Trade Related Aspects of Intellectual Property, Apr. 15, 1994, WTO [hereinafter TRIPS], available at http://www.wto.org/english/docs_e/legal_e/27-trips.pdf. Intellectual property requirements are also incorporated into articles 2.1 and 9.1. TRIPS, at articles 2.1 & 9.1. See also Dr. Philippe Cullet & Radhika Koluru, Plant Variety Protection and Farmers’ Rights: Towards a Broader Understanding, 24 DELHI L. REV. 41, 45 (2003).
We hypothesize that if some countries have lagged in the adoption of intellectual property rights for plant varieties, and if a robust intellectual property regime is a prerequisite to technological advancement and thus productivity improvement, there should be some correlation between the strength of an intellectual property regime for plant varieties and the jurisdiction’s agricultural production, especially in the post-adoption of plant-specific intellectual property protections era. To test this theory, this article examines intellectual property protection and plant innovation in the five major soybean producing nations: Argentina, Brazil, China, India, and the United States.\(^{10}\)

Soybeans were used as the leading indicator for selecting the country studies because soybeans, unlike hybrid crops such as maize, reproduce true-to-type. In other words, soybean seeds can be harvested, cleaned, saved for the following growing season and, when planted, produce an identical plant bearing multiple seed pods, thus facilitating the appropriation of technology by users and competitors. The authors extended their investigation into the four other major commodity crops of maize, wheat, rice and cotton because many of them do not reproduce true-to-type and saving seeds for planting the following season results in significant drops in yield and farm profitability. Accordingly, ceteris paribus, there is an inherent incentive for jurisdictions with significant soybean production to implement relatively more robust plant variety intellectual property regimes to stimulate innovation in this economically important crop. Thus, the authors selected the five largest soybean producing nations to explore the intersection between intellectual property rights and technological advancement.

\(^{10}\) United States Dep’t of Agric., Oilseeds: World Markets and Trade, tbl.04 (Mar. 2011), available at http://www.fas.usda.gov/oilseeds/circular/2011/March/oilseeds.pdf. In March of 2011, the production of soybeans in each of the top five producing countries was: United States – 100.47 million metric tons, Brazil – 73.50 million metric tons, China – 56.56 million metric tons, Argentina – 53.59 million metric tons, and India – 34.65 million metric tons. Id.
Contrary to the widely presumed link between intellectual property rights and innovation, the authors’ five-country regression analysis of data encompassing a twenty year period from 1985 to 2005, in most cases, failed to find a statistically significant correlation between intellectual property protection and agricultural innovation.\(^{11}\) The authors did find some significant correlations between soybean production variables and strength of enforcement, which will be discussed in Part V infra. Although the lack of a statistically significant correlation does not mean the underlying theory (i.e., intellectual property protection is essential for encouraging innovation and thereby agricultural production) is incorrect, it nonetheless implies that the presumed link between intellectual property rights and innovation may not be as direct as previously thought and warrants further empirical research. This is of particular importance in the agricultural context, where plant variety protection engenders complex issues of equity,\(^{12}\) subsistence farmers’ rights,\(^{13}\) and the government sanctioned monopolization by multi-national corporations of the basic building blocks of the human food supply.\(^{14}\)

One of the statistically significant correlations the authors did find illustrates much of the complexity of modern agricultural inputs. The authors found a statistically significant correlation between research and development (R&D) expenditure and hectares planted, but not crop yield. This finding might surprise farmers and others who thought that seed developers conduct extensive research to improve crop yield. Seed

\(^{11}\) See infra Part III.
\(^{14}\) For instance, Monsanto holds patents that are estimated to affect 98% of the United States soybean market and 79% of the United States corn market. *Update 1-DuPont Urges U.S. to Curb Monsanto Seed Monopoly*, REUTERS (Jan. 8, 2010), http://www.reuters.com/article/2010/01/08/monsanto-antitrust-idUSN087196620100108.
developers benefit most from hectares planted, as each additional hectare planted by a farmer means more seed purchased from the developer.\textsuperscript{15} Yield, on the other hand, provides a more direct benefit to the farmer as opposed to the seed developer, especially in regimes characterized by monopolistic seed distribution systems where. Yield improvements could benefit the seed developer by attracting customers, but this benefit assumes that customers have choice. A seed developer who is the only source of seed in the region need not worry about using higher yields to attract customers because the customers, due to a lack of competition, may not have alternative sources of seed.\textsuperscript{16}

Although our research suggests that the relationship between intellectual property protection, R&D and improvement in crop yield is not as strong as might be predicted, this nonetheless corresponds to our understanding of the profit maximizing firm.

To better understand the scope of the authors’ data and analysis, Part II of this article provides a brief background of both the relevant international intellectual property treaties relating to plant protection, as well as individual country-specific measures. Part III describes the collected data and empirical analysis. Specifically, the authors analyzed

\textsuperscript{15} Each additional hectare planted also means that some other organism has been displaced. Those organisms that have been displaced must either move or be reduced. In some cases, commodity crops expand to grow on land that had been used for livestock grazing forcing the livestock onto land that previous had been occupied by forests or other valuable organisms. \textsc{Tim Searchinger}, \textsc{Evaluating Biofuels: The Consequences of Using Land to Make Fuel, Brussels Forum Paper Series} (2009), available at http://209.200.80.89/brusselsforum/2009/docs/BF_Searchinger_Final.pdf. While it is beyond the scope of this article, it is worth remembering that increasing the number of hectares planted with commodity crops can have unexpected environmental consequences, such as depletion of forests and a resulting increase in carbon releases. \textit{Id.}

\textsuperscript{16} This is not a hypothetical situation, many countries are serviced by only one seed developer. The authors’ looked at the offices of operation for the top five seed developers and found that several countries were served by only one. Dupont (Pioneer) was the only company with offices in Jamaica, Barbados, Trinidad & Tobago, Estonia, Luxembourg, Angola, Zambia, and Cambodia. Monsanto was the only company with offices in Puerto Rico, Albania, Cyprus, Senegal, Sri Lanka, Kuwait, Oman, and the United Arab Emirates. Finally, Syngenta was the only company with offices in Cuba, Latvia, Moldova, Cameroon, Mozambique, Sudan, Turkmenistan, Iran, and the Syrian Arab Republic. \textit{Products, Services and Agronomy in Your Country, Pioneer}, http://www.pioneer.com/landing (last visited Feb. 2, 2012); \textit{Monsanto Global Locations, Monsanto}, http://www.monsanto.com/Pages/default.aspx (last visited Feb. 2, 2012); \textit{Syngenta Worldwide, Syngenta}, http://www.syngenta.com/global/corporate/en/Pages/home.aspx (last visited Feb. 2, 2012).
demographic, economic, and agronomic statistics for each of the five subject countries, along with a jurisdiction-specific assessment of intellectual property-related data such as the number of plant variety certificates, availability of utility patents, and private enforcement regimes for intellectual property right infringement. In Part IV, the authors summarize the research conclusions, explore possible alternative explanations, such as the use of contracts or restrictions on other members of the agricultural supply chain as a substitute for intellectual property protections in plant varieties, and analyze the implications for the broader intellectual property community. In addition, part IV explores the need for further empirical research, perhaps in other economic sectors, to probe the validity of the underlying assumption that robust intellectual property rights are an essential prerequisite to technological innovation.

II. The Legal Landscape: International Law and Country-Specific Implementation Measures

As a baseline for further comparative analysis of intellectual property regimes, this section first discusses the two fundamental international treaties related to intellectual property in plants: the International Union for the Protection of New Varieties of Plants (UPOV) and the Trade-Related Aspects of Intellectual Property Rights (TRIPS). Following the overview of the treaty-based rules, this section provides a brief background of each country’s implementation of TRIPS, UPOV, and other country-specific measures taken to protect intellectual property in plant varieties.
A. The International Intellectual Property Environment

This section first provides a background on the UPOV treaties as set forth by the International Convention for the Protection of New Varieties of Plants. Originally adopted in Paris in 1961, the parties subsequently revised the Convention in 1972, 1978, and 1991. Second, this section reviews the 1994 TRIPS agreement as set forth by the World Trade Organization (WTO).\(^{17}\) The WTO enacted TRIPS to relieve some of the tension different intellectual property regimes had placed on international trade.\(^{18}\) Although distinct treaties, both TRIPS and the UPOV Conventions may apply to a particular good. While TRIPS applies to all kinds of goods, the UPOV Conventions focus exclusively on intellectual property protection for new varieties of plants. A more detailed discussion of these agreements follows.

1. UPOV

The UPOV Conventions’ aim is to provide seed developers with a system that protects their unique intellectual property interests in an innovation capable of self-reproduction and thus appropriation by non-inventors. Headquartered in Geneva, and directed by a Secretary-General, whose position is held by the Director General of the World Intellectual Property Organization (WIPO),\(^ {19}\) UPOV’s mission is “[t]o provide and

\(^{17}\) Intellectual Property: Protection and Enforcement, WORLD TRADE ORG., http://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm7_e.htm (last visited Sept. 9, 2011).  See also Laurence R. Helfer, Regime Shifting: The TRIPS Agreement and New Dynamics of International Property Lawmaking, 29 YALE J. INT’L L. 1, 2-3 (2004) (noting that while the intent of TRIPS was to relieve tensions, it has created greater tension in developing countries where TRIPS may not fit their current situation).

\(^{18}\) Id.

\(^{19}\) Agreement Between the World Intellectual Property Organization and the International Union for the Protection of New Plant Varieties art. 4(1), Nov. 26, 1982, INF 8, available at http://www.upov.int/en/publications/pdf/inf_8.pdf.  The agreement’s preamble discusses the desire of each organization to continue working together and supporting each other’s work, while remaining independent
promote an effective system of plant variety protection, with the aim of encouraging the
development of new varieties of plants, for the benefit of society.”

To accomplish this mission, UPOV signatory countries must implement legislative provisions that provide seed developers Plant Variety Protection (PVP) certificates (also referred to as “breeders’ rights”). The underlying premise of UPOV is that offering seed developers’ protection for their new seed varieties will encourage the creation of new varieties in areas where a commercial market for such varieties exists. Without this incentive, innovation could decline and yields—an important measure of agricultural productivity—would stagnate.

UPOV assists member countries with implementing plant variety protection systems into their national legislation. Further, it promotes international harmonization among member countries’ laws by setting out general principles and minimum requirements for incorporation in each of its Member States’ national laws. Specifically, UPOV contributes to the harmonization of laws by detailing a set of rules for conducting tests for plant variety distinctness, uniformity, and stability (DUS Tests). These specific test guidelines (TGPs) apply to some 230 genera and species. Importantly, TGPs are not

entities. Id. at pmbl. In addition to the Secretary-General, UPOV governance consists of a Council composed of representatives of its Member States, each with one vote, and a Consultative Committee that reports to the Council. Id.


21 Id.

22 UPOV provides assistance by offering members model agreements and forms to make the adoption of a PVP system both easier and more compatible with the systems of other member nations. Int’l UNION FOR PROT. OF NEW VARIETIES OF PLANTS, INTERNATIONAL UNION FOR THE PROTECTION OF NEW VARIETIES OF PLANTS: WHAT IT IS, WHAT IT DOES 1 (July 8, 2011), available at http://www.upov.int/export/sites/upov/about/en/pdf/pub437.pdf [hereinafter WHAT IT IS].

23 Individual Test Guidelines Procedures (TGP) are first drafted by a Technical Working Party mainly composed of experts appointed by each Member State and then sent to the main international non-governmental organizations in plant breeding and to the seeds and plant industries for their comments. After receipt of the industry comments, the TGPs can be approved by the Technical Working Party of UPOV. These documents are progressively updated and extended to further genera and species. WHAT IT IS, supra note 22.
binding on members, but rather their objective is to provide a general guidance for the harmonized examination of DUS tests and plant protection laws more generally.

Despite its optional status, UPOV Member States tend to adopt the convention’s TGP protocols in order to achieve greater uniformity between domestic systems and those of their trading partners. As a further incentive toward harmonization, UPOV member States may enter into cooperative agreements for the examination of plant varieties whereby one member may either conduct tests on behalf of others or accept the test results provided by others in its examination process for granting a breeder’s right.24 These combined efforts minimize implementation costs for member states (an importance incentive for lesser developed countries) as well as for breeders seeking protection in multiple jurisdictions.

Since its inception in 1961, UPOV signatories have revised the Convention three times, November 10, 1972; October 23, 1978 (the ’78 Act); and March 19, 1991 (the ’91 Act). Currently, both the ‘78 Act and the ‘91 Act are in force and provide identical criteria for granting intellectual property rights to seed developers: novelty, distinctness, uniformity and stability. The most important provisions of both the ’78 Act and the ’91 Act, and where the two versions have substantial differences, are the scope of authorized exceptions to seed developer’s rights

The two noteworthy exceptions to the seed developer’s intellectual property rights are the “breeders’ exemption” and the “farmers’ exemption”. In the ‘78 Act, Article 15(3) carves out the breeder’s exemption from intellectual property protection,25 stating that the authorization of the plant variety certification holder is not required if the

24 Id.
25 Id.
protected variety is used by a plant breeder as an initial source for the creation of new varieties.\textsuperscript{26} For example, a breeder may use a PVP protected seed as a starting point to develop a distinct, new variety. A breeder, however, must obtain authorization from the PVP holder if the protected variety must be used each time the breeder seeks to reproduce the new variety.\textsuperscript{27} Article 5(1) of the '78 Act provides, by implication,\textsuperscript{28} the ability of a farmer to save seeds for personal uses, but not subsequent resale. Specifically, Article 5(1) states that the authorization of the PVP holder is not required if a farmer uses the propagating material of a protected variety for purposes other than its production for commercial marketing or its offering for sale. Thus, if a farmer does not intend to commercially explore the protected variety, he may use it on his own property for propagating purposes (i.e., saving seeds from harvest in year one for planting in year two).

Unlike the '78 Act, the '91 Act significantly restricted the availability of these exemptions\textsuperscript{29} and may explain why some UPOV signatories have elected to accede to the older, '78 Act, rather than the '91 Act.\textsuperscript{30} As noted above, the '78 Act reserves for farmers the right to save part of their harvest to provide seeds for planting in the following season. The '91 Act, on the other hand, provides national governments with the discretion to decide whether to permit seed saving.\textsuperscript{31} The '91 Act also significantly narrowed the

\begin{flushleft}
\textsuperscript{26} Id.
\textsuperscript{27} Id.
\textsuperscript{28} Id.
\textsuperscript{29} Id.
\textsuperscript{30} For example, Argentina, Brazil, and China have all acceded to the '78 Act rather than the '91 Act.
\end{flushleft}
In addition to the changes made to the farmers’ and breeder’s exemptions, the ’91 Act made several other significant addendums, including: (1) the extension of the protection for all genera and species;\(^{33}\) (2) the protection of Essentially Derived Varieties—EDV;\(^{34}\) (3) a greater scope of breeder’s rights;\(^{35}\) (4) an extended duration of protection;\(^{36}\) (5) the extension of the protection to marketed products;\(^{37}\) and (6) the possibility of protection under both a *sui generis* and patent system.\(^{38}\)

\(^{32}\) Id. See infra note 38.
\(^{33}\) The ’78 Convention provided for the progressive application of its dispositions to new botanical genera and species. The protection of at least 5 genera or species was the required number when a member State became party to the Convention, but it should encompass 10 genera or species in all within three years; 18 within six years and 24 within eight years. The ’91 Act, on the other hand, established the protection of at least 15 genera or species at the date the Member State is bound by the Convention and of all plant genera and species within 10 years of said date. Walker, *supra* note 31, at 29.
\(^{34}\) Under article 14(5)(b), a variety shall be deemed to be essentially derived from another variety (“the initial variety”) when (i) it is predominantly derived from the initial variety, or from a variety that is itself predominantly derived from the initial variety, while retaining the expression of the essential characteristics that result from the genotype or combination of genotypes of the initial variety, (ii) it is clearly distinguishable from the initial variety, and (iii) except for the differences which result from the act of derivation, it conforms to the initial variety in the expression of the essential characteristics that result from the genotype or combination of genotypes of the initial variety. *INT’L UNION FOR THE PROT. OF NEW VARIETIES OF PLANTS, EXPLANATORY NOTES ON ESSENTIALLY DERIVED VARIETIES UNDER THE 1991 ACT OF THE UPOV CONVENTION* 4 (Oct. 22, 2009), http://www.upov.int/en/publications/pdf/upov_exn_edv_1.pdf (last visited Sept. 20, 2011).
\(^{35}\) Both the ’78 Act and the ’91 Act allow the free access of a protected variety as an initial source for the creation of new varieties (research exemption), but under the latter, if the resulting new variety is an essentially derived variety, the holder of the PVP certificate of the initial variety has to provide prior authorization to any form of commercial use. Thus, the ’91 Act requires permission of the original breeder in more instances than the ’78 Act did, broadening the scope of breeders’ rights. Compare Article 5(3) of the 1978 UPOV Convention with Articles 15(1)(iii), 14 of the 1991 UPOV Convention.
\(^{36}\) The ’78 Act requires members to provide plants protection for a minimum of fifteen years and trees and vines protection for a minimum of eighteen years. The ’91 Act requires members to provide plants protection for a minimum of twenty years and trees and vines protection for a minimum of twenty-five years. Walker, *supra* note 31, at 29.
\(^{37}\) Under the ’91 Act, a breeder must obtain the permission of the original breeder before he can commercially market a new variety that is essentially derived from a protected variety. The ’78 Act allowed breeders to commercially market these new varieties without permission from the original breeder so long as the varieties were distinguishable. Id.
For ease of reference, the Table 1, below, compares many of the key differences between the '78 and the '91 versions of UPOV.

| Table 1: Distinctions Between the ’78 and ’91 UPOV Acts³⁹ |
|---------------------------------|-----------------|-----------------|
| UPOV Convention | 1978 | 1991 |
| Requirements | Distinct, Uniform, and Stable | Distinct, Uniform, Stable, and Novel⁴⁰ |
| Protects | Commercial use of reproductive material of the variety | All plant varieties and products including plants that are derived |
| Duration of Protection | Fifteen years from application date for most species; eighteen years for trees and vines | Twenty years from application date for most species; twenty-five years for trees and vines |
| Farmers’ Exemption | Yes. Seed saving allowed. | Optional. Governments given discretion to either allow or prohibit seed saving. |
| Breeders’ Exemption | Yes. Acts for breeding and development of other varieties are not prohibited | Optional. The decision to include an exemption is dependent on each members’ national legislation |
| Coverage | Member States to provide coverage to as many genera and species as possible. | All plant genera and species must be covered within ten years of adoption. |
| Additional Intellectual Property Protection | Does not allow a species eligible for protection under the Act to be patented. | Allows countries to permit both PVP and patent protection for the same plant varieties.⁴¹ |

As of 2011, sixty-nine countries are UPOV members. One is a party to the 1961/1972 Act,⁴² 23 signed onto the ’78 Act,⁴³ while 45 are signatories to the ’91 Act.⁴⁴

As of December 31, 1995, all incoming members must accede to the ’91 Act.⁴⁵

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³⁹ Walker, supra note 31, at 29.
⁴⁰ The ’91 Act explicitly requires that a plant variety be a new, novel variety in order to obtain PVP protection. ’91 Act at Chp. III, Art. 6. A variety is deemed novel if “at the date of filing of the application for a breeders’ right, propagating or harvested material of the variety has not been sold or otherwise disposed of to others, by or with the consent of the breeder, for purposes of exploitation of the variety (i) in the territory of the Contracting Party in which the application has been filed earlier than one year before that date and (ii) in a territory other than that of the Contracting Party in which the application has been filed earlier than four years or, in the case of trees or of vines, earlier than six years before the said date.” Id. at Chp. III, Art. 6(1).
⁴¹ Walker, supra note 31, at 29.
Table 2, below, briefly summarizes when each country subject to analysis in this article signed on to the various international intellectual property treaties. Most notably, India has not signed either version of UPOV. On the other hand, the United States is the only one of the five countries that has signed on to the ’91 Act. Originally an assessor to the ’78 Act the United States later signed the ’91 Act, updating its national implementing legislation accordingly.

<table>
<thead>
<tr>
<th>Country</th>
<th>WTO/TRIPS</th>
<th>UPOV ‘78</th>
<th>UPOV ‘91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>January 1, 1995</td>
<td>December 25, 1994</td>
<td>n/a</td>
</tr>
<tr>
<td>Brazil</td>
<td>January 1, 1995</td>
<td>May 23, 1999</td>
<td>n/a</td>
</tr>
<tr>
<td>China</td>
<td>December 11, 2001</td>
<td>April 23, 1999</td>
<td>n/a</td>
</tr>
<tr>
<td>India</td>
<td>January 1, 1995</td>
<td>Has not signed</td>
<td>Has not signed</td>
</tr>
</tbody>
</table>

The differences between the ’78 Act and the ’91 Act inform the balance of our discussion of the countries’ current intellectual property landscape. As described above, perhaps the most significant difference between the ’78 and ’91 Acts is the different level

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42 Belgium (Dec 5, 1976). *Id.*
43 Argentina (Dec 25, 1994), Bolivia (May 21, 1999), Brazil (May 23, 1999), Canada (Mar 4, 1991), Chile (Jan 5, 1996), China (Apr 23, 1999), Colombia (Sep 13, 1996), Ecuador (Aug 8, 1997), France (Oct 3, 1971), Ireland (Nov, 1981), Italy (Jul 1, 1997), Kenya (May 13, 1999), Mexico (Aug 9, 1997), New Zealand (Nov 8, 1981), Nicaragua (Sep 6, 2001), Norway (Sep 13, 1993), Panama (May 23, 1999), Paraguay (Feb 8, 1997), Portugal (Oct 14, 1995), Slovakia (Jan 1, 1993), South Africa (Nov 6, 1977), Trinidad and Tobago (Jan 30, 1998), and Uruguay (Nov 13, 1994). *Id.*
45 Article 37 (3) of the 1991 Act of the UPOV Convention.
of protection each affords to seed developers. More than just differentiating the two acts, however, the seed developer’s exceptions embody the main distinction between a *sui generis* system – such as the UPOV provides — and a utility patent system for protecting intellectual property rights in plants. Breeders’ and farmers’ exceptions granted in the UPOV allow for the free access to a protected variety without the authorization of the holder of a PVP certificate. In contrast, plants protected by a utility patent are afforded the same level of intellectual property protection as any other patented material. Accordingly, both breeders and farmers must obtain the permission of a patent holder under a patent intellectual property system. Utility patents, therefore, offer seed developers a level of protection not subject to farmers’ and breeders’ exemptions.

2. WTO and TRIPS

While UPOV protection is only available for plants, the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) applies to all kinds of inventions. At the close of the WTO’s 1994 Uruguay Round negotiations, the parties finalized an agreement establishing minimum standards for protection of intellectual property in WTO member countries. Notably, ratification of TRIPS is mandatory for

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46 A utility patent protects the way an article is used or works as compared to a design patent that protects merely the way an article looks. Compare 35 U.S.C. § 101 with 35 U.S.C. § 171 (distinguishing between utility and design patents). See also *A Guide to a Design Patent Application*, UNITED STATES PATENT & TRADEMARK OFFICE (Nov. 16, 2003), http://www.uspto.gov/web/offices/pac/design/definition.html.

47 UPOV does not grant PVP certificates. Rather, UPOV has the International Convention for the Protection of New Varieties of Plants (UPOV Convention) that can serve as a model for new member’s own PVP system. UPOV says that most countries base their systems off the UPOV Convention. UPOV REPORT, *supra* note 20, at 11.

WTO membership, an important demand that has led to the enactment of more robust intellectual property laws by countries seeking WTO membership.\(^49\)

The TRIPS agreement requires all WTO members to incorporate specific rules into their respective national intellectual property laws. With respect to plants, Article 27(3) of TRIPS requires protection of plant varieties “either by patents or by an effective *sui generis* system or by any combination thereof.”\(^{50}\) Accession and subsequent implementation into national law of the UPOV Convention satisfies the TRIPS requirements for a *sui generis* plant variety protection system.\(^{51}\) Each of the five countries subject to this research is a WTO member, and thus has an intellectual property system that meets the requirements of TRIPS.\(^{52}\)

3. Enforcement Regimes and the Special 301 Report

Due to international differences in intellectual property protection, the Office of the United States Trade Representative (USTR) annually releases the “Special 301 Report.” USTR prepares this document to serve as a review of the intellectual property protection and enforcement of forty trading partners of the US. In its report, the USTR evaluates each country’s intellectual property regime, detailing annual improvements, strength of enforcement, as well as areas of concern. The Special 301 Report classifies poor performing countries by placing them on either a Watch List or Priority Watch List,

\(^{49}\) Cullet & Koluru, *supra* note 9, at 45.

\(^{50}\) TRIPS, *supra* note 9.


the Priority Watch List reserved for those nations with more critical flaws in either their intellectual property protection or enforcement mechanisms. In the following section, we discuss in greater detail the intellectual property regimes for agricultural products in the respective countries analyzed in this article.

B. Country Specific Agricultural Production and Plant Intellectual Property Protection

1. Argentina

Argentina’s production in all five of the crops studied in this article has increased over the twenty year period of analysis. Soybean production, for instance, more than quintupled in the twenty year period. While maize and rice production roughly doubled, and wheat production increased forty-three percent. This steady increase in production provides a quantitative backdrop for the discussion of the Argentinean intellectual property system.

a. Argentina’s Intellectual Property Legal Regime

Enacted in 1935, Argentina’s first law to regulate seed varieties required registration of new varieties, but offered no legal protection for the breeders’ intellectual property rights. The “Law of Seeds” decree, passed by Argentina’s military government in 1973 and fully implemented in 1978, gave exclusive commercialization

53 Cotton production showed the smallest increase, going up less than one-hundred metric tons. It should be noted, however, that cotton production in Argentina peaked in the mid-nineties at about twice the current rate of production.

rights to inventors of new seed varieties. The Law of Seeds also established the National Seed Commission (CONASE), to advise and evaluate government policy.

In 1991, in response to political pressure from associations of seed producers and groups inside CONASE, the government issued Regulatory Decree 2183, which amended the Law of Seeds to bring it up to date with international standards. At this time, however, Argentina was not yet a member of UPOV or WTO/TRIPS. The Decree created the National Seed Service (SENASE) with responsibility for the implementation of the National Register for Seed Trading and Certification, the National Register of Cultivars and the National Register of Cultivar Ownership. SENASE also assumed responsibility for enforcement of laws and regulations regarding new seed varieties.

Later that same year, the National Seed Institute (INASE) replaced SENASE. The National Register of Cultivators Ownership, overseen by INASE, allocates property rights for plant varieties. Foreign breeders may file on their own behalf or through an authorized representative in Argentina. The granting of rights to foreign applicants is subject to reciprocity; the applicant’s country of origin must offer similar rights to Argentinean breeders. Plant varieties must meet the defined conditions of

55 Id. at 120. Article 22 of the Law of Seeds states that “The property right of a variety will be given for a period no less than 10 and no more than 20 years, according to the type of plant and the regulations,” and Article 37 of the Law of Seeds states that anyone who sells, reproduces, or markets seeds in a way that has not been authorized by the owner can be punished by a fine from $2,000 to $100,000. Law of Seeds, Law No. 20,247, Mar. 30, 1973, ch. VII, art. 22 & 37 [hereinafter 1973 Law of Seeds].
57 Kesan & Gallo, supra note 54, at 120.
61 Property rights last for a maximum of twenty years and shorter periods may be set for certain species. Decree 2183/91, Oct. 21, 1991, art. 37.
novelty, distinctness, uniformity, and stability.\textsuperscript{64} The novelty condition requires that the variety has not been “offered for sale or sold by the breeder or with his consent” within Argentina prior to the application date for ownership rights or in a state with which Argentina has a multilateral agreement “for a period greater than FOUR (4) years, or in the case of trees or vines, for a period greater than SIX (6) years.”\textsuperscript{65}

In addition to the Law of Seeds and implementing regulations for Decree 2183, current Argentinean law includes Norm 35/96, issued by INASE in 1996 (after its accession to the ’78 UPOV Act that contains both farmers’ and breeders’ rights). Norm 35/96 defines the scope of the relatively broad farmers’ privilege (e.g., seed saving) and breeders’ rights found in Article 27 of the Law of Seeds.\textsuperscript{66} The Law of Seeds’ breeders’ rights allow plant breeders to use a variety without authorization as a source in their work, but must secure authorization for the “repeated and/or systematic use of a variety as necessary means of producing commercial seed.”\textsuperscript{67} Thus, a plant breeder in Argentina can use a variety once to try to develop a new variety or for research, but not if that variety will be used regularly in the process for developing a seed for subsequent sale. Norm 35/96 did not alter these broad breeders’ rights.

The Law of Seeds’ farmers’ privilege also is quite broad. The Law of Seeds states that anyone who “holds back and sows seed for his own use” does not infringe on the owner’s property rights.\textsuperscript{68} Norm 35/96 does require that the seed be kept separate and identifiable\textsuperscript{69} and the source of the the saved seed must have been legally obtained.\textsuperscript{70} As

\begin{itemize}
\item[66] Norm 35/96, Feb. 1996.
\item[67] Decree 2183/91, Oct. 21, 1991, art. 43.
\item[68] 1973 Law of Seeds, supra note 55, at art. 27.
\item[69] Norm 35/96, Feb. 1996.
\end{itemize}
discussed above, the UPOV ’78 Act also contains some limits on the farmers’ privilege, and any inconsistencies that may arise between the UPOV and Argentinian law are resolved in favor of the ’78 Act.\textsuperscript{71}

\textit{b. Intellectual Property Enforcement in Argentina}

Although the existence of a system granting intellectual property rights is a necessary element of a functioning intellectual property regime, in a post-modern Hobbesian world there must be some form of enforcement mechanism accompanying this grant in order to prevent (or at provide least compensation for) infringement of the underlying property right.\textsuperscript{72} To that end, the Office of the United States Trade Representative (USTR) periodically publishes intellectual property enforcement Priority Watch List that analyses enforcement regimes of US trading partners. The USTR included Argentina on its most recent 2011 Priority Watch List,\textsuperscript{73} as well as lists published during the period of this study.\textsuperscript{74} The issues of concern to the USTR in 2005 also appeared on the 2011 list. Specifically, the USTR noted that the judicial system suffers from inefficiency, failing to adjudicate civil and criminal matters in a timely fashion or impose deterrent level sentences.\textsuperscript{75} From a procedural perspective, Argentina’s patent applications also remain

\textsuperscript{70} Norm 35/96, Feb. 1996, art. 1. (a)-(c), (e), (f); the ’78 Act dealt specifically curtailed farmers’ rights to sell any saved seed. UPOV Convention, Article 5(1) (1978).
\textsuperscript{73} 2011 SPECIAL 301 REPORT, supra note 1, at 27. The Special 301 Report does not have the force of law, but it does guide lawmakers on from both the United States and the countries it discusses. United States lawmakers will know whom to treat more cautiously, and lawmakers in the countries discussed know what changes would help raise their standing with the United States. This also serves as a warning to foreign direct investment, especially in products with extensive intellectual property value.
\textsuperscript{75} 2011 SPECIAL 301 REPORT, supra note 1, at 27; \textit{Id.}
backlogged. However, it recently has made steps towards addressing the patent backlog, and Argentina’s Attorney General issued new guidance on IP crimes. The USTR has praised Argentina for these positive steps. Serious problems, though, persist, and until Argentina addresses the issues with its judiciary, intellectual property enforcement in the country will remain weak, thereby undermining the protections afforded new seed developers under the law of seeds. In light of this report, the authors rank Argentina’s strength of enforcement of intellectual property protection as low due to the lack of patent coverage for plants as well as the leniency of penalties for intellectual property crimes during the period of study.

2. Brazil

During our period of investigation, Brazil’s agricultural production also increased for each of the five commodity crops, but the increases were more modest than those seen in Argentina. Soybean production again showed the largest increase, more than doubling. Maize production also showed an impressive increase—expanding by fifty-nine percent. Other commodity crops showed more modest increases.

a. Brazil’s Intellectual Property Legal Regime

Brazil has been a signatory to both TRIPS and the ’78 Act of the UPOV Convention since 1994 and 1999, respectively. The accession to both international agreements set the baseline standard for the further development of intellectual property laws for the protection of new varieties of plants in the country. Legislation protecting plant variety

76 Id.
77 Id. at 7.
78 Rice had the next greatest increase, of forty-six percent. Cotton production showed increased just twenty-eight percent, and wheat production increased a meager seven point eight percent.
intellectual property rights originated in 1945, when Brazil enacted its first Intellectual Property Code. Implementation of the Code, which expressly authorized the grant of patents to new varieties of plants, depended, however, on the subsequent passing of a regulation, which never occurred.

In 1991, when Brazil commenced discussions regarding a new Intellectual Property Code, the subject of plant protection resurfaced. Based on the prerogative established in the TRIPS agreement, Brazil excluded plants from patentability and instead established a \textit{sui generis} system for the protection of plant varieties. Although, since 1996, Brazil’s Intellectual Property Code has allowed patent protection to gene structures, genetically modified organisms, and \textit{processes} to obtain new plant varieties, it does not authorize patent protection for plants or part of plants. Rather, intellectual property protection for actual plant varieties in Brazil falls exclusively under the Brazilian Plant Variety Protection Law. The Brazilian Plant Variety Protection Law established a \textit{sui generis} system that follows, in large part, the dispositions of the ‘78 UPOV Act, although some provisions, such as the protection of essentially derived varieties, mirror the ‘91 Act. Brazilian law includes both the breeders’ and the farmers’ exemptions. Under Article 10(I)(II), a farmer does not infringe a seed developer’s right if

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79 Decreto No. 7903, de 27 de Agosto de 1945, Código de Propriedade Industrial (CPI).
80 \textit{Id.} at arts 3, 219.
82 Law No. 9,279, de 14 de Maio de 1996, Código de Propriedade Industrial (CPI).
83 CPI art. 18 (III) (“Não são patenteáveis: o todo ou parte dos seres vivos, exceto os microorganismos transgênicos que atendam aos três requisitos de patenteabilidade – novidade, atividade inventiva e aplicação industrial – previstos no art. 8º e que não sejam mera descoberta.”).
85 \textit{Id.}
he saves and sows seeds for his own use on his property, or if he uses or sells his harvested output as food or raw material, except for reproduction purposes.  

As for Brazil’s protection of farmers’ rights, item IV of Article 10 allows small farmers to donate or exchange seeds exclusively to and between other small farmers, but only if they are part of a government incentive program. The law states that a small farmer is someone who (1) employs no more than two full-time employees, with a third being permissible under certain circumstances; (2) owns no more than four “fiscal modules” of land; (3) derives 80% of his income from agriculture activities; and (4) lives on the property or nearby.

Despite the decade plus existence of a legal regime, Brazil, as of this writing, still lacks a satisfying infrastructure for the examination of PVP certificates. For example, national applicants generally perform their own DUS tests due to the lack of licensed authorities to perform the required procedures. Foreign applicants, however, must provide a DUS test performed by a foreign authority accepted by the Brazilian government. Thus, while Brazil has signed on to TRIPS and the ’78 Act, and

86 Id. at Art. 10(I)(II).
87 Id. at Art. 10(IV).
88 The 1978 Convention does not make such a difference between farmers. UPOV Convention, Article 5(1) (1978).
91 Memoranda from Renata Oliveria on the Brazilian Intellectual Property Regime to Bryan Endres (May 25, 2009) (on file with author).
92 Id. at art. 14(viii); Decree No. 2,366, de 15 de Novembro de 1997, art. 14. Article 14 specifies that the description of a new plant variety in Brazil must adequately describe indicators of distinctness, homogeneity, and stability or the applicant must have evidence of tests performed by a “competent agency.” Id.
implemented its own *sui generis* system, it has not achieved uniformity or ease of use for foreign applicants.

*b. Intellectual Property Enforcement in Brazil*

In contrast to Argentina, the USTR placed Brazil on the less cautionary\(^{93}\) Watch List in its 2011 intellectual property enforcement report.\(^{94}\) This is an upgrade from 2005 when USTR included Brazil on the Priority Watch List due to its high levels of piracy.\(^{95}\) In 2011, USTR expressed optimism in several steps Brazil has taken to increase its intellectual property protection. One positive improvement noted in the 2011 USTR report was that Brazil’s Federal Attorney General consolidated the authority to oversee patent applications in one entity, the National Industrial Property Institute.\(^{96}\) Brazil’s National Council to Combat Piracy has also increased enforcement actions, conducting major operations in early 2011.\(^{97}\) However, Brazil is only beginning to address its patent application backlog, and USTR continued its calls for stronger border enforcement and more deterrent legal sentences.\(^{98}\) The authors would appraise Brazil’s current intellectual property enforcement as medium in light of the 2011 USTR report. But the period of empirical study for this article concluded in 2005, during which time the USTR included Brazil on its Priority Watch List. Accordingly, for statistical purposes, the authors rank Brazil’s strength of enforcement of intellectual property protection as low.

\(^{93}\) Countries on the Watch List, as opposed to the Priority Watch List, are considered to have slightly stronger intellectual property enforcement mechanisms in place. *See generally* 2011 *SPECIAL 301 REPORT*, *supra* note 1.

\(^{94}\) *Id.* at 32.

\(^{95}\) 2005 *SPECIAL 301 REPORT*, *supra* note 79, at 26.

\(^{96}\) Previously, both the Brazilian sanitary regulatory agency (ANIVSA) and the National Industrial Property Institute had the authority to question patent applications. *Id.*

\(^{97}\) *Id.* It does not seem that any of these specific enforcement actions concerned plants or agriculture.

\(^{98}\) *Id.*
3. China

During the timeframe of this study, Chinese agricultural production exceeded Brazil’s, for each of the five commodity crops, with the exception of soybeans. Total production for all five crops also increased: maize production more than doubled, wheat production increase by nearly fourteen percent, rice production increased just over six percent, and soybean production showed a greater increase of nearly sixty percent. As in other countries, the increase in cotton production was the smallest by weight, but nonetheless represented a nearly thirty-eight percent increase.

a. China’s Intellectual Property Legal Regime

China became a member of the WTO on December 11, 2001, thereby binding itself to the intellectual property requirements embedded in TRIPS. China’s intellectual property laws, though, were in place long before of its accession to the WTO. China became a member of UPOV on April 23, 1999, adopting the ’78 Act. Administration of PVPs in China is divided into two branches. The State Forestry Administration implements China’s PVP laws with regard to forest products – such as forest trees, bamboo, woody plants and dry fruit trees. The Ministry of Agriculture administers PVPs for all other agricultural plants. In 1999, only 10 species were eligible for protection. As of 2005, 142 species are eligible.

101 Id. at 12.
102 Id. at 17.
China’s PVP protection includes a breeders’ exception. Companies and research institutes may freely use parent seeds of PVP protected varieties to develop new varieties; there is also no protection for novel genes. As a signatory to the ’78 UPOV Act, the PVP regime also includes an extensive farmers’ exception.

China’s patents laws were adopted by the National People’s Congress in 1984 and have since been amended three times, most recently in December of 2008. Much of the law is similar to patent law in the United States; one noticeable difference is the listing of specifically excluded subject matter. Article 25(4) states that while plant varieties are not patentable in China, processes for producing plants expressly are allowed: “For processes used in producing products referred to in items (4) of the preceding paragraph, patent right may be granted in accordance with the provisions of this Law.”

b. Intellectual Property Enforcement in China

USTR included China on its 2011 intellectual property enforcement Priority Watch List and provided a more detailed analysis of China’s enforcement than any other

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104 Id.

105 REGULATIONS OF THE PEOPLE’S REPUBLIC OF CHINA ON THE PROTECTION OF NEW VARIETIES OF PLANTS, 85 PVP GAZETTE, CH. II. ART. 10 (Oct. 1999), available at http://www.upov.int/upovlex/en/text.jsp?file_id=125966 (stating that a variety rights’ holder is not entitled to payment nor must the variety rights’ holder grant permission if the variety is for “. . . use[d] for propagating purposes by farmers, on their own holdings, of the propagating material of the protected variety harvested on their own holdings.” Id.


country on the list.\textsuperscript{108} In its 2005 report, USTR also devoted significantly more analysis to China, also including it on the Priority Watch List.\textsuperscript{109} This level of attention likely indicates nothing more than China’s greater importance to the United States as a trading partner and as a world economic force.\textsuperscript{110} USTR does devote some of its 2011 analysis to positive steps China has taken, such as more aggressively addressing the problem of counterfeit drugs\textsuperscript{111} and creating the “Program for Special Campaign on Combating IPR Infringement and Manufacture and Sales of Counterfeiting and Shoddy Commodities” (Special Campaign).\textsuperscript{112}

The bulk of USTR’s report on China, however, is decidedly cautionary. The USTR report details two instances in which the United States had to seek the help of the WTO to resolve intellectual property disputes with China.\textsuperscript{113} The USTR also expressed concerns about persistently high thresholds for criminal action in intellectual property cases,\textsuperscript{114} as well as the Chinese policy of requiring technology transfers as a condition for

\textsuperscript{108}USTR devotes eight and a half pages to discussing enforcement in China while devoting a single paragraph to most other countries. 2011 SPECIAL 301 REPORT, supra note 1, at 19.

\textsuperscript{109} 2005 SPECIAL 301 REPORT, supra note 79, at 22.

\textsuperscript{110} China’s importance to the United States and the world can be seen in the agriculture context simply by considering the yield information given at the beginning of this section. See id. at 21.

\textsuperscript{111} 2011 SPECIAL 301 REPORT, supra note 1, at 7 (Apr. 2011).

\textsuperscript{112} Id. at 19. However, critics note the Special Campaign is a temporary measure that was slated to end in March 2011 and extended by only three months to June 2011. Program for Special Campaign on Combating IPR Infringement and Manufacture and Sales of Counterfeiting and Shoddy Commodities, IPR IN CHINA (Nov. 11, 2010), http://www.chinaipr.gov.cn/newsarticle/news/government/201011/976869_1.html.

\textsuperscript{113} In 2007, China’s “regime for protecting and enforcing copyrights and trademarks on a wide range of products” was questioned. The WTO found for the United States. As of March 19, 2010 – one day before the agreed upon completion date – China announced it had implemented all the suggestions made by the WTO. “The United States continues to monitor China’s implementation. . .” 2011 SPECIAL 301 REPORT, supra note 1, at 16. The United States also availed itself of the WTO’s dispute resolution framework to address China’s distribution and marketing policies concerning a range of media. The WTO found for the United States on the majority of the measures. China has failed to make all the implementations within the agreed upon timeframe, and “[t]he United States is working closely with China to resolve the issues in this dispute. . .” Id.

\textsuperscript{114} The thresholds currently take the value of the goods at issue into consideration, a policy the United States urges China to stop. Id. at 21-22.
government benefits or preferences. While China has made attempts to improve its intellectual property system, many areas of concern to the USTR remain. In light of the above discussion, specifically the high threshold for criminal infringement, the authors consider China’s intellectual property enforcement to be low.

4. India

India, like Argentina, saw a marked rise in agricultural production during the twenty year period for which we have data. India’s soybean production was six times higher at the end of the period than it was at the beginning. Maize production doubled. Wheat production increased by fifty-eight percent, and rice production increased approximately forty-eight percent. Again, cotton production showed the most modest increase in weight, rising just under 5,000 metric tons over the twenty years, but this increase represented a doubling in production. In sum, the period of 1985-2005 witnessed impressive agricultural production gains in India.

a. India’s Intellectual Property Legal Regime

Perhaps the most notable aspect of India’s intellectual property regime is that India is the only country discussed in this article that has not signed either version of

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115 Chinese rules, regulations, and other documents “frequently” call for intellectual property to be owned, developed, or licensed – sometimes exclusively – in China. Id. at 23. In 2010, Chinese President Hu disavowed this policy, but it is not clear exactly how President Hu will ensure the practice no happens. Id. at 24.

116 See supra notes 111-12 and accompanying text.

117 Obviously, an increase in production can stem from either an planting an increased number of hectares or getting a higher yield from the same number of hectares. Our data shows that India increased both yield and hectares planted for all five crops, but for maize, wheat, rice, and cotton yield increase was far greater than the increase in hectares planted. Maize yield rose sixty-nine percent while its hectares increase only thirty-one percent. What yield rose thirty-nine percent while hectares increase twelve percent. Rice yield rose thirty-five percent while hectares increased a mere six percent, and cotton yield rose eighty-four percent while hectares rose only fifteen percent. Only soybeans say an increase in hectares planted that outstripped the increase in yield. Soybean hectares planted increased by nearly six-hundred percent while yield increased only forty percent.
UPOV, although it does have a *sui generis* intellectual property regime for plant varieties. In India, an application to register a plant variety may be made by “any person claiming to be the breeder of the variety.”118 Specific mention is made in the statute of “any farmers or group of farmers or community of farmers claiming to be the breeder of the variety” and “any university or publicly funded agricultural institution claiming to be the breeder of the variety.”119 The successor of a breeder, as well as those authorized by a breeder, may also apply to register a variety.120 Nationals of countries outside of India may also register a variety. However, if a “convention country” does not offer Indian nationals the same plant variety registration and protection rights as it offers its own nationals, then nationals from that country may not register varieties in India.121

Applications may be made for new varieties and extant varieties, which include farmers’ varieties.122 An extant variety is one that is available in India and either included under the Seeds Act as a farmers’ variety,123 a variety about which there is common knowledge, or a variety otherwise in the public domain.124 Applicants may only register those varieties which are of the genera and species specified in the Official Gazette,125 or essentially derived varieties.126

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118 PPV&FR Act 2001 § 16(1)(a).
119 PPV&FR Act 2001 § 16(1)(d), (f).
120 PPV&FR Act 2001 § 16(1)(b), (e).
121 PPV&FR Act 2001 §§ 31, 32. Under §31, the Central Government of India may declare a country with which it has a treaty, convention or arrangement to provide similar rights a “convention country” by giving notice in the Official Gazette. “Convention country” is further defined in § 1(f).
123 A farmers’ variety is one that “has been traditionally cultivated and evolved by the farmers in their fields” or “is a wild relative or land race or a variety about which the farmers possess the common knowledge.” PPV&FR Act 2001 § 2(l).
126 PPV&FR Act 2001 § 23. For a new variety to be registered, it must conform to the requirements of novelty, distinctiveness, uniformity, and stability. PPV&FR Act 2001 § 15(1). These are the same requirements as for the ’91 Act. The ’78 Act does not require novelty. Extant varieties, including farmers’
A successful applicant is issued a certificate of registration and holds an exclusive right to produce, sell, market, distribute, import, or export the variety.\footnote{PVP&FR Act 2001 § 28(1). The fee for registration as an agent or licensee is 10,000 IRP. PVP&FR Rules 2003 § 45, Second Schedule; about $227 USD.} The Central Government holds default rights as a breeder for extant varieties, unless it can be shown that an actual seed developer or another should hold the right. The rights of a seed developer who successfully registers an essentially derived variety are the essentially same as for other varieties, except that the breeder of the essentially derived variety must obtain authorization from the breeder of the initial variety before he or she can authorize the use of the essentially derived variety.\footnote{PVP&FR Act 2001 § 23(6). The breeder of an essentially derived variety cannot give permission to use his variety without first gaining the permission of the original breeder. For a full critique of breeders’ rights under Indian law see Biswajit Dhar & Sachin Chaturvedi, \textit{Introducing Plant Breeders’ Rights in India: A Critical Evaluation of the Proposed Legislation}, 1 J. of World Intellectual Prop. 245 (Mar. 1998).}

India’s 2001 registration statute, a PVP alternative, also contains a section on breeders’ rights.\footnote{PVP&FR Act 2001 § 30.} Registration of a variety does not prevent its use by other breeders “for conducting experiment or research” or “as an initial source of variety for the purpose of creating other varieties.” Permission is required, however, if “the repeated use of such variety as a parental line is necessary for commercial production of such other newly developed variety.”

The 2001 Act also contains a separate chapter dedicated to Farmers’ Rights.\footnote{PVP&FR Act 2001 §§ 39-46.} Farmers explicitly are permitted to register new varieties as breeders in addition to registering farmers’ varieties. With regard to varieties registered by others, a farmer may “save, use, sow, resow, exchange, share or sell” the seed but may not sell it as branded

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\end{itemize}
Thus, while India has not signed either the ’78 or ’91 version of UPOV, procedures are in place to protect the innovation and investment of seed developers.

b. Intellectual Property Enforcement in India

The USTR included India on both its 2005 and 2011 intellectual property enforcement Priority Watch List, and India’s legal system and overall IP enforcement remain weak. The United States has urged India to develop stronger protection for patents and more assertively address its patent application backlog. The United States also has suggested that India develop a more effective system for preventing unfair use and unauthorized disclosure of data relating to agricultural chemical products. India has taken some proactive steps, such as enrolling in a State Department funded training program for customs, police, and judicial officers that aims to stem intellectual property abuse. India also has developed a national intellectual property rights policy to help unify enforcement. These new measures are hopeful signs, but will not be effective unless India addresses underlying weaknesses in its criminal and judiciary systems. Following the lead of the USTR assessment, the authors classify the strength of India’s intellectual property enforcement regime as low.

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132 2005 SPECIAL 301 REPORT, supra note 79, at 27.
133 2011 SPECIAL 301 REPORT, supra note 1, at 28.
134 Id. The United States has suggested more efficient legal proceedings, stronger criminal enforcement, and deterrent level sentencing. Id. at 29.
135 Id.
136 This is also a problem with pharmaceutical chemicals. Id. at 28-29.
137 Id. at 9.
138 Id. at 28. The 2001 Act defines an act of infringement as selling, exporting, importing or producing a registered variety without the permission of the breeder or registered licensee or registered agent. PVP&FR Act 2001 § 64. The breeder may seek an injunction, to stop the wrongful use, and he may seek either damages or a share in the profits. PVP&FR Act 2001 § 66.
5. United States

Distinctively, the United States is the only country of the five studied in this article to show an actual decrease in production of one of the five commodity crops. Wheat production decreased by just over seven metric tons during the period at issue. This decrease is likely the result of increased prices for other commodities, pushing farmers to plant the more profitable crops. The other four crops, however, did show the expected increases. Maize production increased twenty five percent, and soybeans production increased nearly forty-nine percent. Cotton and rice production increases were more modest by weight but represented significant percentage increases, at nearly sixty-seven percent and sixty-five percent respectively. The United States more varied production history serves as an interesting background to the following analysis of its intellectual property system.

a. United States’ Intellectual Property Regime

The United States, the lone ’91 Act signatory, provides several methods by which an entity may claim it has a statutory right to intellectual property in plants and plant products. In 1930, Congress passed the Plant Patent Act of 1930 (PPA). The PPA provides plant patent protection for novel, asexually reproduced varieties. Under this act, seed saving and “brown bagging” remained a legal and common practice among framers.

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as the intellectual property protections afforded to asexually reproducing varieties did not cover seeds.\footnote{A. Bryan Endres & Peter D. Goldsmith, Alternative Business Strategies in Weak Intellectual Property Environments: A Law and Economics Analysis of the Agro-biotechnology Firm’s Strategic Dilemma, 14 J. INTELL. PROP. L. 237, 251 (2007).}

In 1970, Congress enacted an intellectual property regime for varieties reproduced by seed known as the Plant Variety Protection Act (PVPA).\footnote{Id.} The PVPA granted seed developers’ exclusive rights to commercialize new seed varieties.\footnote{Id.} As originally passed, the PVPA allowed farmers to save harvested seed and either sell or trade it to third parties. The 1994 amendments to the PVPA eliminated the statutory right of farmers to sell saved seed protected by a PVP Certificate. Farmers, however, could still save the seed for planting on their own farm.

Additionally, seed developers in the United States can obtain utility patents for plants provided that the patent application meets the general standards and requirements for patentability.\footnote{The requirements for patentability are laid out in 35 U.S.C. §§101-03.} Any living organism that is the product of human intervention potentially qualifies as a patentable composition of matter under United States’ law.\footnote{Diamond v. Chakrabarty, 447 U.S. 303 (1980).} As a result, plants subjected to human intervention such as breeding for a novel variety, are patentable subject matter. Moreover, in \textit{Ex parte Hibberd}, the United States extended patent protection—utility or plant patents—to plants produced by either sexual or asexual reproduction and to plant parts including seeds and tissue cultures.\footnote{Ex parte Hibberd, 227 USPQ 443 (Bd. Pat. App. & Int. 1985).} In 2001 the Supreme Court agreed with and extended \textit{Hibberd}. The Supreme Court held in \textit{JEM Ag Supply} that sexually reproducing plants were eligible for utility patents even if that same

\footnote{Id.}
plant was protected by the Plant Variety Protection Act (PVPA). In *JEM*, Pioneer Hi-Bred International (Pioneer) sued a seed distributor (JEM) for illegally reselling its patented corn seed. JEM responded by claiming that PPA and the PVPA offered exclusive protection for plant life, such as corn, and, therefore, corn could not be protected by a utility patent under 35 U. S. C. § 101. The Supreme Court disagreed, holding that plant life could be protected simultaneously by a utility patent and a PPA or a PVPA.

As an alternative to patent protection, seed developer in the United States can also keep the information as a trade secret, which has been used for decades to protect parental lines of hybrid corn. Most state trade secret laws protect information that: (1) has an independent economic value as a result of it not being generally known and not readily ascertainable by proper means; and (2) is subject to reasonable efforts to maintain its secrecy. Hybrid corn seed, for instance, traditionally has been an excellent candidate for trade secret protection.

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147 *J.E.M.*, supra note 6, at 128-29.
148 Id. at 129.
149 Id. at 144-46.
150 See UNIF. TRADE SECRETS ACT § 1.
151 Pioneer Hi-Bred Int’l v. Holden Found. Seeds, Inc., 35 F.3d 1226 (8th Cir. 1994), is the leading case regarding trade secret protection for plants. Hybrid corn seed is the result of the cross-pollination of pollen from two parent seeds resulting in a “hybrid” with enhanced characteristics. Pioneer Hi-bred Int’l v. Holden Found. Seeds, Inc., No. 81-60-E, 1987 WL 341211, at *46 n.5 (S.D. Iowa Oct. 30, 1987). Examination of the hybrid offspring does not reveal the genetic composition of the two parent seed lines. Id. at *2-3. Moreover, because the hybrid does not reproduce true-to-type, the same cross-pollination of the two parents must be performed each time to produce the hybrid variety. Id. As a result, hybrid corn seed breeders are able to keep the genetic composition of the parent lines secret when marketing their distinct hybrid seeds. Id. Recent advances in genomic sequencing, however, may limit the potential effectiveness of trade secret protection in the agricultural context as competitors could sequence the DNA and subsequently reverse engineer the plant—an accepted practice in the trade secret context.
Finally, corporations often use contracts, in the form of technology use agreements,\textsuperscript{152} to protect intellectual property. Restrictive licensing agreements have become common, especially for seeds.\textsuperscript{153} These agreements inform customers that each bag of seeds is for their personal, one time use, and that the saving of any seeds is prohibited.\textsuperscript{154} Licensing agreements offer seed developers another method of intellectual property protection.

\textit{b. Intellectual Property Enforcement in the United States}

The United States has the strongest intellectual property infringement enforcement of all the nations reviewed in this article. The strength of the United States’ enforcement is evident in the fact that United States serves as an enforcement watchdog for its trading partners.\textsuperscript{155} The United States also grants authority over many of its intellectual property cases to specialized court of appeals, thereby allowing for the development of an expertise and familiarity with intellectual property concepts and issues.\textsuperscript{156} Accordingly, the authors classify the intellectual property enforcement system in the United States as high.

\footnotesize
\textsuperscript{154} \textit{Id.}; see also 2008 Monsanto Technology/Stewardship Agreement, MONSANTO, available at http://www.monsanto.com/SiteCollectionDocuments/tug_sample.pdf (last visited Oct. 27, 2011). By signing the agreement, the farmer agrees not to 1) plant the purchased seed in more than one season, 2) sell the produced seed to anyone but a licensed Monsanto seed company, 3) save or clean any produced seed, or 4) transfer any Monsanto seed to another person or entity for planting. \textit{Id.}
\textsuperscript{155} See generally 2011 SPECIAL 301 REPORT, \textit{supra} note 1.
6. Country Summary

Although there are elements of similarity, each of the five countries discussed in this section employs a unique combination of laws and regulations to provide intellectual property protections to its seed developers and stimulate innovation. To aid in the understanding of the data analysis in Part III, below, Table 3 summarizes the preceding country specific description of intellectual property protections available in Argentina, Brazil, China, India and the United States.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Type of Plant Protection Provided</th>
<th>Strength of Plant Protection Provided</th>
<th>Type of Enforcement Mechanisms</th>
<th>Strength of Enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>Law of Seeds; UPOV '78; Norm 35.96; TRIPS; Decree 2183/91.(^{157})</td>
<td>Plant patents are unavailable leaving seed developers subject to the farmers’ and breeders’ exceptions in UPOV ’78.</td>
<td>Criminal and civil penalties available, but deterrent level sentences rarely given.</td>
<td>Low</td>
</tr>
<tr>
<td>Brazil</td>
<td>TRIPS; UPOV ’78; PVP under Law No. 9,456.</td>
<td>Plant patents are unavailable (patents are available for the process, but not the final plant), and the farmers’ and breeders’ exceptions are broader under Law No. 9,456 than under the model UPOV Conventions.</td>
<td>Criminal and civil penalties are available, and a recent overhaul to the entire IPR system provides a more uniform enforcement mechanism. However, legal sentences remain rather lax.</td>
<td>Low</td>
</tr>
<tr>
<td>China</td>
<td>TRIPS; UPOV ’78;</td>
<td>Patents not available for</td>
<td>Criminal and civil penalties</td>
<td>Low</td>
</tr>
</tbody>
</table>

\(^{157}\) The Decree does grant seed developers “property rights,” but these rights can still be abridged by farmers’ and breeders’ exceptions making them more akin to PVPs than patents. Decree 2183/91, art. 37.
<table>
<thead>
<tr>
<th>Country</th>
<th>Regulations/Acts</th>
<th>Protection Options</th>
<th>Penalties</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>Seeds Act; UPOV '78; PVP; TRIPS.</td>
<td>Patents not available for plants, and seed law is subject to both farmers’ and breeders’ exceptions.</td>
<td>Positive steps taken, but India’s legal system in regards to IP enforcement remains weak. Ineffective procedures for combating data disclosure in regards to agricultural chemicals.</td>
<td>Low</td>
</tr>
<tr>
<td>United States</td>
<td>PPA; PVPA; TRIPS; UPOV '91; Utility Patents; Trade Secrets; Contracts.</td>
<td>Utility patents available for plants which provide seed developers with a protection option that does not have the farmers’ and breeders’ exceptions.</td>
<td>Criminal and civil penalties available. Referral to Federal Circuit ensures judicial proceeding conducted by knowledgeable fact finder.</td>
<td>High</td>
</tr>
</tbody>
</table>

III. Methodology and Data Analysis

In the first phase of the research, we compiled two decades of data (1985 to 2005) on the agricultural production (including hectares planted, yield, and tons of crops)
harvested) and intellectual property regimes (e.g., existence of PVP or patent regimes, number of patents or PVPs issues) in the respective countries, as well as demographic and economic information. A series of research associates with a variety of nationalities compiled the data in an excel-based format from a variety of sources. The complete database and list of source documents is on file with the authors. After the database was assembled, we contracted with a statistician to conduct regression analysis on various comparisons that we hypothesized would demonstrate a correlation between different measures of innovation, production, and intellectual property protection. For the purposes of this article, we designated a statistically significant correlation to be one with an adjusted R-squared value of greater than 0.5 and a p-value of less than .0001.

Our analysis, which we describe below, is divided into three sections, which follow the different types of data collected.

As noted in the introduction, our regression analysis of data from 1985 to 2005, in most cases, failed to find a statistically significant correlation between intellectual property protection and agricultural innovation as measured by twenty-five separate crop-related variables. In the interest of brevity, we will not discuss all of our results. Rather, we highlight regression results in which we identified an interesting and statistically significant correlation and, perhaps more importantly for future investigations, several surprising results in which we expected to find, but ultimately could not demonstrate, a statistically significant correlation between intellectual property protection and agricultural innovation.

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158 For example, the database contains information about GDP, population, population of active workers, and prices paid each year for each commodity crop.
159 The crop-related variables include the following for each of the five crops: production cost, yield per hectare, total hectares planted and export quantity.
A. Research and Development Data

As a starting point in the statistical analysis, we explored the link between research and development (R&D) expenditure\(^\text{160}\) and agricultural production, with agricultural production serving as a proxy for innovation. Our regressions showed significant correlations between R&D expenditures\(^\text{161}\) and fifteen of the twenty-five crop variables we studied.\(^\text{162}\) The most significant correlations were between R&D expenditure and soybean production, soybean hectares planted, maize production, maize hectares planted, cotton production, cotton exports, and cotton hectares planted. Maize production and maize hectares planted also showed the best fit (with an adjusted R squared value nearing 0.7).\(^\text{163}\) Soybean hectares planted and cotton exports also displayed good fit. These finds are summarized in Table 4 below.

| Table 4: Significant Correlations Between R&D Expenditure and Crop Variables |
|-----------------------------|-------------------|-----------------|-------------------|-----------------|-----------------|
| Dependent Variables         | Coefficient of LS | Standard Error  | P-value of T-statistics | Root MSE | Adjusted R-square |

\(^\text{160}\) Traditionally, expenditures towards research and development (R&D) come from three main sources: public funding through the government, private funding through business, and higher education. NATIONAL PATTERNS OF R&D RESOURCES: 2008 DATA UPDATE, NATIONAL SCIENCE FOUNDATION TBL 1 (Mar. 2010), available at http://www.nsf.gov/statistics/nsf10314/pdf/nsf10314.pdf (showing that government, industry, and universities and colleges have been the leading funders since 1953). R&D expenditures from higher education have generally remained constant and minimal in each country for the years in our study. There have been, however, fluctuations between government and business expenditures in each country, with an increase in one corresponding almost exactly to a drop in the other (e.g., substituting a decline in government investment in R&D with increased business investment, and vice versa). As a general rule, in both the U.S. and China, business investment in R&D has exceeded government funding; in Argentina, Brazil, and India, the opposite is true.

\(^\text{161}\) To measure R&D expenditures, we used the overall R&D of the country to serve as a proxy for agricultural R&D. Agricultural-specific R&D data, although admittedly more accurate, were not available for all the countries in this study and thus the author’s selected aggregate R&D as the most appropriate proxy.

\(^\text{162}\) A significant correlation is generally shown when the p-value is below 0.05. However, variables with a p-value below 0.05 are not listed as significant when the coefficient is a negative number but the general trend in other variables shows a positive correlation. STATISTICS: METHODS AND APPLICATIONS; A COMPREHENSIVE FOR SCIENCE, INDUSTRY, AND DATA MINING 15 (Nov. 2005).

\(^\text{163}\) For the purposes of this paper, we considered an R squared value above 0.5 to show a good fit. A good fit in statistics indicates that the actual individual figures are close to those figures that would be predicted by the model created by the aggregate of all figures in the data set. Id. at 24.
<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Production</td>
<td>0.81635</td>
<td>0.18447</td>
<td>&lt;.001</td>
<td>0.74907</td>
<td>0.3172</td>
</tr>
<tr>
<td>Soybean Exports</td>
<td>1.79347</td>
<td>0.78531</td>
<td>0.0282</td>
<td>2.96833</td>
<td>0.0999</td>
</tr>
<tr>
<td>Soybean Ha</td>
<td>0.65993</td>
<td>0.09592</td>
<td>&lt;.0001</td>
<td>0.38948</td>
<td>0.5367 ***</td>
</tr>
<tr>
<td>Maize Production</td>
<td>1.59427</td>
<td>0.16559</td>
<td>&lt;.0001</td>
<td>0.67240</td>
<td>0.6963 ****</td>
</tr>
<tr>
<td>Maize Exports</td>
<td>1.85096</td>
<td>0.89837</td>
<td>0.0464</td>
<td>3.39569</td>
<td>0.0787</td>
</tr>
<tr>
<td>Maize Yield</td>
<td>0.38173</td>
<td>0.12218</td>
<td>0.0034</td>
<td>0.49613</td>
<td>0.1797</td>
</tr>
<tr>
<td>Maize Ha</td>
<td>1.20872</td>
<td>0.12453</td>
<td>&lt;.0001</td>
<td>0.50567</td>
<td>0.6997 ****</td>
</tr>
<tr>
<td>Wheat Production</td>
<td>0.61566</td>
<td>0.27458</td>
<td>0.0307</td>
<td>1.11496</td>
<td>0.0915</td>
</tr>
<tr>
<td>Wheat Ha</td>
<td>0.54086</td>
<td>0.22548</td>
<td>0.0213</td>
<td>0.91559</td>
<td>0.1062</td>
</tr>
<tr>
<td>Rice Exports</td>
<td>2.01038</td>
<td>0.85228</td>
<td>0.0237</td>
<td>3.22148</td>
<td>0.1072</td>
</tr>
<tr>
<td>Rice Yield</td>
<td>0.23020</td>
<td>0.08137</td>
<td>0.0073</td>
<td>0.33040</td>
<td>0.1490</td>
</tr>
<tr>
<td>Cotton Production</td>
<td>1.43447</td>
<td>0.24047</td>
<td>&lt;.0001</td>
<td>0.97645</td>
<td>0.4637*</td>
</tr>
<tr>
<td>Cotton Exports</td>
<td>2.28384</td>
<td>0.35166</td>
<td>&lt;.0001</td>
<td>1.42797</td>
<td>0.5073**</td>
</tr>
<tr>
<td>Cotton Yield</td>
<td>0.32851</td>
<td>0.13699</td>
<td>0.0214</td>
<td>0.55625</td>
<td>0.1062</td>
</tr>
<tr>
<td>Cotton Ha</td>
<td>1.10596</td>
<td>0.25725</td>
<td>&lt;.0001</td>
<td>1.04459</td>
<td>0.3041</td>
</tr>
</tbody>
</table>

An analysis of the aggregate country data for research and development shows that maize production has a strong correlation to R&D expenditures. This result is consistent with the predictions we made at the beginning of the article. Maize does not reproduce true-to-type and, therefore, seed from year one cannot be saved and planted in following years without a drop in yield. We predicted that this characteristic of maize would make intellectual property protection less important to maize innovation because maize’s reproductive method provides an inherent protection on infringement. Thus, as was supported by the regression, we expected that maize production would be

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164 For the purposes of this paper, we consider an adjusted R-squared value of >0.5 to represent a strong correlation. The adjusted R-squared for Maize production to R&D expenditures is 0.696.

significantly correlated to R&D expenditures regardless of other factors, including the different intellectual property regimes found in the five countries studied.

Conversely, soybeans do reproduce true-to-type and offer no inherent protection against infringement.166 Because of the differences in the reproduction methods of maize and soybeans, we expected that the two crops would respond differently to different inputs. To explore this hypothesis, we compared soybean production to R&D expenditures. In the aggregate, the data showed no correlation between soybean production and R&D expenditures.167 In other words, an increase in aggregate R&D did not correspond to an increase in soybean production. The lack of a correlation between soybean production and R&D expenditure in the aggregate, when such a correlation was found with maize, illustrates the fundamental difference between these two crops. Accordingly, we hypothesize that R&D expenditure, without adequate intellectual property protection, is not sufficient to induce innovation in soybeans because those innovations would not be sufficiently protected from competitors and farmers’ saving seed.168

When we explored soybean production and R&D expenditure at the individual country level, however, we found a strong positive correlation between Chinese soybean production and R&D expenditures.169 On the other hand, our data showed a strong, negative correlation between soybean production and R&D expenditure in Brazil.170 The other countries in our study did not have a statistically significant relationship between

167 Adjusted R-squared is 0.317.
168 When we explored this data at the individual country level, we found a strong positive correlation between
169 R-squared is 0.696. The authors’ are not certain why China shows this positive correlation.
170 R-squared is 0.671.
R&D expenditures and crop production. The negative correlation in Brazil during this time period could be due to a well-established, government soybean research and development program within that country,\textsuperscript{171} coupled with a history of appropriating (often without permission) agricultural technological advancements, such as improved plant genetics, from US-based seed companies operating in other South American countries, such as Argentina.\textsuperscript{172} Thus, in Brazil, privatized R&D may have been replaced by government and foreign R&D lowering the overall R&D expenditure within the country’s borders.

Total crop production, however, is only one measure of successful innovation in the agricultural context. Total production is a function of the amount of land under cultivation (measured in hectares in our database) and the yield per hectare. Innovations, such as improved heat, cold or drought tolerance can expand the total area under production by opening up new agricultural areas to a particular crop. Other (or complementary) R&D activities seek to improve crop yield on existing land under cultivation. Accordingly, we expected that an increase in R&D expenditures would result in an increase in crop yield. Moreover, we expected that in the absence of intellectual

\textsuperscript{171} For the past forty years, the Brazilian Agricultural Research Center (Empresa Brasileira de Pesquisa e Agropecuária, Embrapa) has been dedicated to creating new varieties of soybeans for the Cerrado region of Brazil (a savannah-like area that covers the Midwest and parts of six surrounding states). It is worth noting that the R&D data compiled is for the country as a whole, rather than R&D expenditures specifically related to agriculture, so the R&D in Brazil might simply be invested in other areas of innovation. Empresa Brasileira de Pesquisa e Agropecuária-Embrapa. \textit{Embrapa}, EMBRAPA (Apr. 25, 2008), http://www.embrapa.br/english. Embrapa’s research was necessary because the first soybean varieties imported from the United States and planted in southern Brazil, where the climate is subtropical to temperate, did not adapt to the lower latitudes of the Midwest. Due to Embrapa’s successful program of research and development, the Cerrado region became the second most important cropping area for Brazilian agriculture and accounts for 35.1% of the grains produced in the country. \textit{Id.}

property laws or enforcement, an increase in overall R&D expenditures would result in an increase in maize yield, but have minimal impact on soybean yield. 173

Our results, however, failed to find a statistically significant correlation between R&D expenditures and yield at the aggregate level. Figures one through five in Appendix A illustrate soybean and maize yield over time in each of the five countries. The data shows that soybean and maize yield is inconsistent, though generally increasing. This variability can be explained by the fact that yield is dependent on a multitude of factors, such as weather. Thus, yield may not be the best overall measurement of short run productivity. However, our examination of the data at the country level over a twenty-year period also was unable to identify a statistically significant correlation between R&D expenditures and crop yield.174 Accordingly, we are unable to demonstrate a statistically significant correlation between R&D and yield improvement.

An alternative analysis of the data is from the seed developer’s perspective. As a general proposition, a seed development firm will engage in R&D to increase profitability — often by attracting new customers. Accordingly, a seed developer may target R&D efforts at increasing the geographic range in which particular crops can be grown, as more hectares planted means more seed purchased by farmers. This new client base could include growers switching from lower value crop production, often grown on

173 The increase in maize would be expected because due to the fact that it does not produce viable seeds for planting in season two, intellectual property laws and enforcement are less necessary. See supra footnotes 167-68 and accompanying text for a more detailed discussion of maize and soybean reproduction.

174 As an exception to this conclusion, we did find a statistically significant correlation between R&D and maize in China and soybeans in Argentina. This is interesting because due to their different forms of reproduction, the authors hypothesized that a clear difference between the two crops would be shown by the data. Figures X and X in Appendix X illustrate soybean and maize yield over time in each of the five countries. We see that soybean and maize yield is inconsistent, though generally increasing. This variability can be explained by the fact that yield is dependent on a multitude of factors, such as weather. Thus, yield may not be the best overall measurement of short run productivity improvements.
marginal lands. Therefore, an increase in R&D expenditures could have a stronger association with an increase in hectares planted, as opposed to yield increases or total production.

Our statistical analysis supported this alternate hypothesis. In the aggregate, both soybean and maize hectares planted has a statistically significant correlation with R&D expenditures. However, when we disaggregated the data at the individual country level, we were unable to find a statistically significant correlation. We attribute this lack of a correlation to having too few observations points to achieve statistical significance. A future study will further explore these results.

At this point, we can conclude that R&D expenditures in general are not correlated to yield, however, we can demonstrate a statistically significant correlation between R&D and the amount of hectares planted — and thus the number of seeds sold by the firm doing the research.

B. Patent and PVP Data

Next, we evaluated the link between agricultural production, our measure of innovation, and utility patent and plant variety protection certificate (hereinafter referred to as a PVP certificate) data for each country. The utility patent and PVP data was used

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176 We did find a statistically significant correlation between China’s maize hectares planted and R&D if we instituted a two-year delay between R&D and hectares planted. We justified this result as current year R&D expenditures would be unlikely to result in current year increases in hectares planted as the innovation would be unlikely to reach the field level in the first year. Thus a two-year differential between the time of expenditure and impact in area cultivated seemed to be a reasonable assumption. However, even this deal did not result in a reliable correlation in the other countries analyzed in this study.
as proxy for the intellectual property regimes in each country. As intellectual property has long been considered necessary to maintaining and developing new technologies,\textsuperscript{177} we hypothesized that the data would show a correlation between intellectual property rights, crop production, and yield. Moreover, as some variation in intellectual property regimes exists among the countries subject to this study,\textsuperscript{178} we expected further analysis of the data to reveal evidence that the stronger the form of intellectual property (e.g., utility patent versus PVP certificate) and the more robust the enforcement regime, the stronger the positive correlation between crop yield and production would be — especially for those crops (e.g., soybeans) that require external protection against misappropriation.

First, we assumed that soybeans would benefit from a strong intellectual property regime because the nature of soybean genetics and reproduction (absent use of a genetic use restriction, commonly referred to as “Terminator” technology)\textsuperscript{179} allows farmers and competitors to appropriate innovations by simply replanting the harvested seed. Maize, on the other hand, due to its hybrid reproduction, benefits from built-in protection against genetic theft because farmers must buy new seed each year or suffer drastic reductions in yield. Secondly, we hypothesized that due to protections provided by utility patents \textit{vis a vis} PVP certificates,\textsuperscript{180} plant researchers would prefer patent protections.\textsuperscript{181} Therefore, we first analyzed the correlation between utility patents and crop productivity, followed by a discussion of PVP certificates.

\textsuperscript{177} \textit{See supra} note 1.
\textsuperscript{178} \textit{See supra} tbl. 3, page 36.
\textsuperscript{180} \textit{See supra} footnotes 46- 47 and accompanying text.
\textsuperscript{181} \textit{Id.}
1. **Utility Patents**

Due to the often significant time lag between patent filing and actual grant of a patent, we selected patent applications as a proxy for patents granted. Moreover, to account for the different sizes of the respective countries we studied, we normalized the number of patent applications by using patent applications per million of population. As Table 5, below, illustrates we found strong correlations between patent applications and soybean production, soybean yield, and soybean hectares planted.\(^{182}\) This is in-line with our expectations at the beginning of this research project.

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Coefficient of LS Estimate</th>
<th>Standard Error</th>
<th>P-value of T-statistics</th>
<th>Root MSE</th>
<th>Adjusted R-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Production</td>
<td>0.31843</td>
<td>0.03252</td>
<td>&lt;.0001</td>
<td>0.35508</td>
<td>0.6735****</td>
</tr>
<tr>
<td>Soybean Yield</td>
<td>0.11495</td>
<td>0.01214</td>
<td>&lt;.0001</td>
<td>0.13259</td>
<td>0.6583***</td>
</tr>
<tr>
<td>Soybean Ha</td>
<td>0.20272</td>
<td>0.02472</td>
<td>&lt;.0001</td>
<td>0.26991</td>
<td>0.5902**</td>
</tr>
<tr>
<td>Maize Production</td>
<td>0.16701</td>
<td>0.06787</td>
<td>0.0178</td>
<td>0.74111</td>
<td>0.0990</td>
</tr>
<tr>
<td>Maize Yield</td>
<td>0.12453</td>
<td>0.03832</td>
<td>0.0022</td>
<td>0.41838</td>
<td>0.1721</td>
</tr>
</tbody>
</table>

The data also indicated a significant correlation between maize production and yield and utility patent applications. Although not specifically predicted, this was unsurprising and may be the result of spillover effects arising from the benefit of increasing agricultural R&D generally, in light of newly formalized intellectual property protections for all plant species. Regardless of the underlying reason, the data

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\(^{182}\) When the authors refer to hectares planted, this is really a measure of the amount harvested each year because the area harvested is the area planted minus any loss due to events such as a freeze, drought or crop failure.
demonstrates a significant and strong correlation between utility patents and productivity (as measured by both yield and area planted) for both soybeans and maize.

2. **PVP Certificates**

As discussed above, WTO membership requires some form of intellectual property protection for plants and each country in our study, with the exception of India, provides PVP certificates in conformity with UPOV. As PVP certificates provide at least a baseline level of intellectual property protection for seed developers, we expected a positive correlation between PVP applications and soybean productivity, although perhaps with a lower coefficient than with utility patents. However, a linear regression of the number of plant variety protection applications per million population—a methodology similar to our regression for the number of patent applications per million—did not indicate statistically significant relationship between soybean productivity variables (e.g., yield, area planted, total production) and PVP applications.

This was a surprising result that warranted additional statistical analysis. We found that if we exclude data from Argentina (thereby restricting our analysis to Brazil, China and the United States), there is a strong, positive correlation between all soybean productivity variables and plant variety protection applications as shown in the table below.

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183 Argentina and Brazil do not provide patents, but are signatories of the ’78 Act and provide PVPs.

184 Soybean hectares planted had a coefficient of 0.56700, a p value of <.0001, and an adjusted R squared of 0.6837; soybean production had a coefficient of 0.74737, a p value of <.0001, and an adjusted R squared of 0.6786; soybean yield had a coefficient of 0.17946, a p value of <.0001, and an adjusted R squared of 0.4595 (which is just below the normal 0.5 threshold); and soybean exports had a coefficient of 2.13715, a p value of <.0001, and an adjusted R squared of 0.6813.

185 This positive correlation is found in China, Brazil, and the USA as India does not offer PVP protection. The USDA has provided some statistical evidence to support this assumption. See FERNANDEZ-CORNEJO, supra note 168, at 5.
Table 6: Correlation Between PVP Applications and Soybean Productivity Variables Excluding Argentina

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Coefficient of LS Estimate</th>
<th>Standard Error</th>
<th>P-value of T-statistics</th>
<th>Root MSE</th>
<th>Adjusted R-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Ha</td>
<td>0.56700</td>
<td>0.07642</td>
<td>&lt;.0001</td>
<td>0.27557</td>
<td>0.6837</td>
</tr>
<tr>
<td>Soybean Production</td>
<td>0.74737</td>
<td>0.10191</td>
<td>&lt;.0001</td>
<td>0.36748</td>
<td>0.6786</td>
</tr>
<tr>
<td>Soybean Yield</td>
<td>0.17946</td>
<td>0.03804</td>
<td>&lt;.0001</td>
<td>0.13718</td>
<td>0.4595</td>
</tr>
<tr>
<td>Soybean Exports</td>
<td>2.13715</td>
<td>0.30171</td>
<td>&lt;.0001</td>
<td>1.02963</td>
<td>0.6813</td>
</tr>
</tbody>
</table>

The strong correlation between the availability of patents and soybean and maize productivity, as well as the more modest correlation — once we remove Argentina from the data set — for PVP protection indicates that intellectual property protection may have a positive impact on crop productivity. However, as we stated above, the ability to secure intellectual property rights presents only one aspect of an overall intellectual property regime as there must be a functioning system to enforce these rights — either a strong moral/social code or a judicial enforcement regime. The following section discusses our analysis of enforcement regimes in the countries subject to this research.

C. Enforcement Regimes

The original postulate that this article set out to test was that intellectual property laws were a catalyst for invention. That is, that an inventor was more likely to invest their time and money to create a product if she was assured of some acknowledgement and monetary gain for her investment. However, as the article progressed, the authors realized that having intellectual property laws in place would not be enough to ensure an inventor received such a return. The mere existence of a law means nothing if that law is
not consistently enforced. Thus, the authors decided that the enforcement practices of each country must be studied in order to get a complete picture of the affect of intellectual property laws on invention.

As discussed above, we selected the USTR Special 301 Reports as a proxy to assess the relative strength of enforcement regimes for the countries in this study. The 301 Special Reports designated each country in this study, with the exception of the United States, as a member of the Priority Watch List. Our subsequent analysis resulted in a significant, positive correlation between the United States’ strong enforcement regime and soybean yield, soybean production, soybean exports, and soybean imports. These results intuitively follow from the difference between soybeans reproduction and the reproduction methods of the other plants. Soybeans reproduce true-to-type meaning that a saved seed will have the same vigor as a seed bought from the seed developer. In contrast, a saved maize or wheat seed loses some of its vigor, leading to loss in yields that farmers are typically unwilling to accept. Thus, the establishment and, especially, enforcement of an intellectual property regime is of greater necessity for soybeans as the seeds do not have a built in defense against patent infringement. Soybean developers are less willing to market and sell their newest and best seeds to countries in which their established intellectual property rights nonetheless

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186 See supra part II.A.3.
187 For the period which the data covered. In the newest 301 Report, Brazil was put on the less cautionary Watch List. 2011 SPECIAL 301 REPORT, supra note 1.
188 A significant correlation was also found between wheat and maize hectares planted.
189 See supra footnotes 167-68 and accompanying text.
190 Id.
will not be protected by an effective enforcement regime, leading to lower production numbers in those countries.\footnote{Our analysis also discovered a negative correlation between the United States and rice production and cotton imports. These figures are likely due to the fact that suitable land for rice production is limited in the United States. In fact, our data shows that the United States produced less rice than all countries except Argentina for every year studied. Thus, this figure may be more about geography than intellectual property enforcement. Conversely, the United States does grow a great deal of cotton, more than any other country except China during each of the twenty years studied. This level of production reduces the need for imports. The remaining sixteen crop variables showed no significant relationship with strength of enforcement.}

We must, however, temper these otherwise resounding conclusions justifying a robust intellectual property enforcement regime as a benefit to crop productivity with an acknowledgement that the unique nature of the United States utility patent system could provide an alternative mechanism to explain this correlation. Specifically, the United States utility patent system uniquely provides for two protection mechanisms for plants—a utility patent for the process used to develop the genetically improved seed (a relatively common feature among countries authorizing utility patents in the plant context) and a separate utility patent for the plant itself. The United States is the only country in our study that authorizes utility patents for the actual plant, as opposed to the process. As a result, our statistical analysis cannot distinguish with sufficient confidence whether our hypothesis that enforcement regimes provide an essential element to the underlying theory linking intellectual property protection with innovation in the plant context is correct or whether the productivity is a result of utility patents granted to both the development process and the plant. We hope in subsequent research we will be able to analyze the actual enforcement proceedings in each country to further explore this issue.
IV. Conclusion

As the authors stated at the outset, a profit maximizing firm will invest resources in research and development only if the firm is able to exercise some control over the resulting intellectual property that that it will achieve a return on investment. To that end, a strong intellectual property system, comprised of both laws that establish intellectual property rights and a system to enforce these rights, is a necessary prerequisite. In the research project we set out to empirically test these propositions within the context of plant varieties.

In light of the variations among plant-specific intellectual property regimes in major agricultural producers, we hypothesized that our statistical analysis would identify several powerful correlations between the strength of an intellectual property system, innovation and resulting productivity improvements. As described above, we identified a statistically significant correlation between R&D expenditures and hectares planted, but not crop yield. As we explained, this facially surprising result (i.e., no impact on yield) is nonetheless in accord with the firm’s motivation to increase customers via expanding into new areas as opposed to attempting to attract new customers in existing, non-competitive markets via increased yield. Improving varieties to withstand a broader range of agronomic environments may generate more customers and thus a greater return on investment.

With respect to the availability of utility patents, we found strong correlations between patent applications and soybean production, soybean yield, and soybean hectares planted. The data also indicated a significant correlation between utility patent applications and both maize production and yield. Our initial analysis of PVP
certificates, however, did not indicate statistical significance for soybean productivity variables (e.g., yield, area planted, total production). When we excluded Argentina from the analysis, however, we were able to demonstrate a strong, positive correlation between all soybean productivity variables and plant variety protection applications. This further supports the underlying theory that links innovation to intellectual property.

The final aspect of our analysis yielded results similarly consistent with our hypothesis. We found a significant, positive correlation between a strong intellectual property enforcement regime and crop productivity—especially for soybeans.

Although the results of our empirical study do, in some respects, comport with the underlying theory that intellectual property is a necessary precursor to innovation, significant uncertainty remains—especially with respect to crops other than soybeans.

While some measures of innovation in the agricultural crops studied managed to thrive in the absence of strong intellectual property regimes, other measures of innovation do seem to have crop specific links to intellectual property protection. At the outset, we assumed that twenty years of data would provide ample opportunities to verify correlations across multiple crops. But in light of the inability to provide statistically significant results in many cases for the major crops of rice, wheat, maize and cotton, we hope to revisit this project in 2015 with an additional ten years of data to inform the analysis. In the interim, we suggest that scholars and policymakers devote further consideration and empirical validation to linkages between innovation and intellectual property, as strength of this connection may be more nuanced and complex than previously considered.

192 Soybean hectares planted had a coefficient of 0.56700, a p value of <.0001, and an adjusted R squared of 0.6837; soybean production had a coefficient of 0.74737, a p value of <.0001, and an adjusted R squared of 0.6786; soybean yield had a coefficient of 0.17946, a p value of <.0001, and an adjusted R squared of 0.4595 (which is just below the normal 0.5 threshold); and soybean exports had a coefficient of 2.13715, a p value of <.0001, and an adjusted R squared of 0.6813.
Appendix A:

Crop Yield in Argentina, Brazil, China, India, and the United States from 1985-2005