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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[†]

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Standard innovation theory assumes that intellectual property protection is a prerequisite to the development of technological advances. A strong intellectual property system, composed 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, do in fact correlate

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with greater innovation. The results of this empirical study were mixed. The authors' analysis identified a statistically significant relationship between research and development (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 similarly mixed results. Thus, the analysis reveals that, based on some measures, innovation manages to thrive despite the absence of strong intellectual property regimes in some developing countries.

INTRODUCTION

Standard innovation theory assumes that intellectual property protection is a necessary prerequisite to the development of technological advances. The theory maintains 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 theory stretches

1. *See* 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, 1 (David Castle ed., 2009) ("Intellectual property rights (IPRs), particularly in the form of patent

back to the intellectual property clause in Article 1, Section 8, Clause 8 of the U.S. Constitution.[2] A strong intellectual property system, composed of both the laws that establish intellectual property rights and a judicial or other adjudicative system to enforce those rights, is believed to be one component that ensures an economically efficient allocation of research and development (R&D) dollars to create innovation for the benefit of society.[3] This paper does not challenge these assumptions directly, but rather seeks to test empirically 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 distinctive, and often controversial, mix of intellectual property regimes related to plant varieties, such as plant patents, utility patents, plant variety protection certificates, and trade secrets. Within the historical context of intellectual

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rights, are widely viewed as catalysts for innovation . . . ."); Ove Granstrand, *Innovation and Intellectual Property Rights*, *in* The Oxford Handbook of Innovation 266, 280 (Jan Fagerber et al. eds., 2005) ("IPRs, particularly patents, play several important roles in innovation systems—to encourage innovation and investment in innovation, and to encourage dissemination (diffusion) of information about the principles and sources of innovation throughout the economy."); Richard S. Gruner, *Better Living Through Software: Promoting Information Processing Advances Through Patent Incentives*, 74 St. John's L. Rev. 977, 981 (2000) ("Patent incentives help to promote greater numbers and diversity of technological discoveries . . . ."); Robert M. Meeks, *Metaphors of Infringement and Equivalence: The Solution of Our Problems*, 2 J. Intell. Prop. L. 279 (1994) ("Patents help encourage efforts in unconventional directions, protecting them from the crush of the status quo and ensuring technological diversity."); Stephen Smith, *Intellectual Property Protection for Plant Varieties in the 21st Century*, 48 Crop Sci. 1277, 1277 (2008) ("Intellectual property protection must be strengthened on a global basis . . . to increase genetic diversity."). *Cf.* Ronald Kirk, Office of the U. S. Trade Representative, 2011 Special 301 Report, at 5 (Apr. 2011), *available at* http://www.ustr.gov/webfm_send/2841 (noting that a lack of effective intellectual property protection undermines "U.S. comparative advantages in innovation and creativity") [hereinafter 2011 Special 301 Report].

2. U.S. Const. art. I, § 8, cl. 8.

3. Sharmila Vishwasrao, *Intellectual Property Rights and the Mode of Technology Transfer*, 44 J. Dev. Econ. 381, 381-82 (1994) (reporting a high correlation between stronger intellectual property regimes and innovation); *Cf.* Edwin L.-C. Lai, *International Intellectual Property Rights Protection and the Rate of Product Innovation*, 55 J. Dev. Econ. 133, 147 (1998) (finding that stronger intellectual property protections in "South" (less developed countries) fosters innovation if foreign direct investment is the primary channel of production transfer, but such protections have the opposite effect if imitation is the primary channel of production transfer).

property law, many of the available protections for plants are quite new. For example, Congress did not establish plant patents, the first form of intellectual property for plants in the United States, until it passed the Plant Patent Act of 1930.[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] The still-evolving nature of plant protection in some nations makes this an area where comparisons among different countries can provide insight into the effects of the protections afforded.

From an international perspective, other nations have lagged behind the United States in establishing intellectual property protection for plants[7] due to the political and economic sensitivity of farmers. Specifically, the widespread opinion of many farmers 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 the country's accession to the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).[9]

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4. Plant Patent Act of 1930, 35 U.S.C. §§ 161–164 (2006).

5. Plant Variety Protection Act of 1970, 7 U.S.C. §§ 2321–2582 (2006).

6. *J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred Int'l*, 534 U.S. 124, 145-46 (2001).

7. *See infra* Table 2, Part II.A.1 (listing the dates when each of the five countries adopted Plant Variety Protection (PVP). For a description of PVPs, see International Union for the Protection of New Plant Varieties (UPOV), *What is Plant Variety Protection?*, http://www.upov.int/overview/en/protection.html (last visited Oct. 20 2011).

8. *See* J.P. Kesan & A.A. Gallo, *Insecure Property Rights and Plant Varieties: The Effects on the Market for Seeds and on Farmers in Argentina, in* Agricultural Biotechnology and Intellectual Property: Seeds of Change 216 (Jay P. Kesan ed., 2007); Pratibha Brahmi, et. al., The Protection of Plant Varieties and Farmers' Rights Act of India, 86 Current Sci. 3 (Feb. 2004), *available at* http://assets.wwfindia.org/downloads/the_protection_of_plant_varieties_and_farmers_rights.pdf (noting that, until concerns about biodiversity were raised by the Convention on Biological Diversity, which came into force in 1993, plant genetic material was broadly considered to be the "heritage of mankind.").

9. India, for example, recently enacted its Plant Variety Act in 2001 to comply with Article 27.3(b) of TRIPS. The Protection of Plant Varieties and Farmers' Rights Act, 2001, No. 53, Acts of Parliament, 2001 (India). Article

The authors realized that the different levels of protection afforded by different countries offered a research opportunity. We hypothesized that 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]

The authors chose to analyze the five leading soybean-producing countries because soybeans, unlike hybrid crops such as maize, reproduce true-to-type. Plants that reproduce true-to-type generate seeds that maintain vigor from season to season. For example, soybean seeds can be harvested, cleaned, saved for the following growing season and, when planted, produce an identical plant bearing multiple seed pods, thereby facilitating the appropriation of technology by users and competitors. Plants that do not reproduce true-to-type produce seeds that when planted in a subsequent season result in a weaker plant with significantly lower yield and, therefore, profitability. In contrast to soybeans, second-generation maize seed is so much weaker when planted in a subsequent season that farmers typically do not bother to plant saved corn seed. This second season weakness gives maize an inherent protection against appropriation. The authors did not extend their investigation into maize and the three other major

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27.3(b) of TRIPS imposes on all countries the introduction of some form of intellectual property protection for plant varieties. Marrakesh Agreement Establishing the World Trade Organization, Annex 1C: Agreement on Trade Related Aspects of Intellectual Property, art. 27.3(b), Apr. 15, 1994, 1869 U.N.T.S. 299 [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. *Id.* at arts. 2.1 & 9.1. *See also* Philippe Cullet & Radhika Koluru, *Plant Variety Protection and Farmers' Rights: Towards a Broader Understanding*, 24 Delhi L. Rev. 41, 45 (2003) (explaining different rationales for India's move towards plant variety protection).

10. 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. USDA, Circular Series FOP 03-11, Oilseeds: World Markets and Trade, tbl.04 (Mar. 2011), *available at* http://www.fas.usda.gov/oilseeds/circular/2011/March/oilseeds.pdf.

commodity crops—wheat, rice and cotton—because many of these crops do not reproduce true-to-type and saving seeds for planting the following season results in significant drops in yield and farm profitability. A study of just those plants that do not produce true-to-type would have been significantly confounded because any effect observed could be caused either by differences in intellectual property regimes or by mere unprofitability of appropriating those crops. In light of the biological traits of soybeans (i.e., true-to-type reproduction), where other factors are equal, there is an incentive for jurisdictions with significant soybean production to implement relatively robust plant variety intellectual property regimes to stimulate innovation in this economically important crop. Thus, the authors chose to explore the intersection between intellectual property rights and technological advancement by studying the five largest soybean-producing nations.

Contrary to the widely assumed 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] Although the lack of a statistically significant correlation does not disprove standard innovation theory, it nonetheless implies that the presumed link between intellectual property rights and plant innovation may not be as direct as previously thought and warrants further empirical research. This is of particular importance in the agricultural context, in which plant variety protection engenders complex issues of equity,[12] subsistence farmers' rights,[13] and government-sanctioned monopolization by multi-national corporations of the basic building blocks of the human food supply.[14]

One statistically significant correlation the authors did find illustrates the complexity of modern agricultural inputs. The

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11. *See infra* Part III.

12. A. Bryan Endres, *State Authorized Seed Saving: Political Pressures and Constitutional Restraints*, 9 Drake J. Agric. L. 323, 326-9 (2004).

13. As a concession to this sensitivity, UPOV does specifically exempt subsistence farming from breeders' rights. Rolf Jördens, *Benefits of Plant Variety Protection*, WIPO Mag., June 2010, at 20-21, *available at* http://www.wipo.int/wipo_magazine/en/2010/03/article_0007.html.

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. Cary Gillam, *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.

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 think that seed developers conduct extensive research to improve crop yield. Seed developers benefit most from hectares planted, as each additional hectare planted by a farmer means more seed purchased from the developer.[15] Yield, on the other hand, provides a more direct benefit to the farmer as opposed to the seed developer. This contrast is especially stark in countries that have monopolistic seed distribution systems where any seed purchased is likely purchased from one of the agricultural giants that spent the R&D dollars. While yield improvements could benefit the seed developer by attracting customers, 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.[16] Our research, therefore, suggests that the relationship between

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15. Each additional hectare planted also means that some other organism has been displaced. Displaced organism populations must either relocate, more efficiently use remaining space, or be reduced. Tim Searchinger, German Marshal Fund of the United States, Evaluating Biofuels: The Consequences of Using Land to Make Fuel 5 (2009), *available at* http://rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Further%20Reading/Brussels%20Forum%20Paper%20-%20Searchinger%20%282009%29.pdf. In some cases, commodity crops expand to grow on land that had been used for livestock grazing, forcing the livestock onto land that previously had been occupied by forests or other valuable organisms. *Id.* at 12. 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. *Id.* at 8.

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. *Products, Services and Agronomy in Your Country*, Pioneer, http://www.pioneer.com/landing (last visited Feb. 2, 2012); *Monsanto Global Locations*, Monsanto, http://www.monsanto.com/Pages/default.aspx (last visited Feb. 2, 2012); *Syngenta Worldwide*, Syngenta, http://www.syngenta.com/global/corporate/en/Pages/home.aspx (last visited Feb. 2, 2012).

intellectual property protection, R&D, and improvement in crop yield is not as strong as might be predicted. This finding corresponds to our understanding of profit-maximizing impulses: seed developers spending R&D dollars should be most concerned with what makes *them* profit (i.e., increased acres planted associated with increased seed sales), not what makes their customers profit (increased yield).

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 and individual country-specific measures. Part III describes the collected data and empirical analysis. Specifically, the authors analyze demographic, economic, and agronomic statistics for each of the five subject countries and assess jurisdiction-specific 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 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, possibly in other economic sectors, to probe the validity of the underlying assumption that robust intellectual property rights are an essential prerequisite to technological innovation.

I. THE LEGAL LANDSCAPE: INTERNATIONAL LAW AND COUNTRY-SPECIFIC IMPLEMENTATION MEASURES

As a baseline for further comparative analysis of intellectual property regimes, this part first discusses the two fundamental international treaties related to intellectual property in plants: the International Convention for the Protection of New Varieties of Plants (UPOV Convention) and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Following the overview of the treaty-based rules, this part then provides a brief background of each country's implementation of TRIPS, the UPOV Convention, 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 UPOV Convention was subsequently revised in 1972, 1978, and 1991. Second, this section reviews the 1994 TRIPS Agreement as an annex to the World Trade Organization (WTO) Agreement.[17] The purpose of TRIPS is to relieve some of the tension different intellectual property regimes had placed on international trade.[18] A more detailed discussion of these agreements follows.

1. UPOV

The International Union for the Protection of New Varieties of Plants (UPOV) was formed 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—a position which is currently held by the Director General of the World Intellectual Property Organization (WIPO)[19]—UPOV's mission is "[t]o provide and 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."[20] To accomplish this mission, UPOV signatory countries must implement legislative provisions that provide Plant Variety Protection (PVP) certificates (also referred to as "breeders' rights") to seed developers. The underlying premise of the UPOV

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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 Intellectual 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. Helfer, *supra* note 17, at 2-3.

19. Agreement Between the World Intellectual Property Organization and the International Union for the Protection of New Varieties of Plants art. 4(1), Nov. 26, 1982, UPOV/INF 8, *available at* http://www.upov.int/edocs/infdocs/en/upov_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 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.

20. Int'l Union for the Prot. of New Varieties of Plants, UPOV Report on the Impact of Plant Variety Protection 11 (2005) [hereinafter UPOV Report], *available at* http://www.upov.int/about/en/pdf/353_upov_report.pdf.

Convention 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.[21] Without this incentive, innovation could decline and, as a result, yields—an important measure of agricultural productivity—could stagnate.

UPOV assists member countries with implementing plant variety protection systems into their national legislation.[22] Additionally, UPOV promotes international harmonization among member countries' laws by setting out general principles and minimum requirements for incorporation into each of its member states' national laws. Specifically, UPOV contributes to the harmonization of laws by detailing a set of rules for determining plant variety distinctness, uniformity, and stability (DUS Tests). These specific test guidelines (TGPs) apply to some 230 genera and species.[23] Though TGPs are not binding on members, they provide general guidance for the harmonized examination of DUS tests and plant protection laws more generally.

Despite TGPs' optional status, UPOV member states tend to adopt the TGP protocols in order to achieve greater uniformity among each country's domestic system 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. Under these agreements one member may either conduct tests on behalf of other UPOV members or accept the test results provided by other members in

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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 the Prot. of New Varieties of Plants, Publication No. 437(EN), International Union for the Protection of New Varieties of Plants: What It Is, What It Does 2 (Dec. 5, 2012 ed.) [hereinafter What It Is], *available at* http://www.upov.int/export/sites/upov/about/en/pdf/pub437.pdf.

23. What It Is, *supra* note 22, at 2. Individual TGPs are first drafted by a Technical Working Party, mainly composed of experts appointed by Member States, and are 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 Committee of UPOV. These documents are progressively updated and extended to further genera and species. Int'l Union for the Prot. of New Varieties of Plants, General Introduction to the Examination of Distinctness, Uniformity and Stability and the Development of Harmonized Descriptions of New Varieties of Plants 5 (Apr. 19, 2002), *available at* http://www.upov.int/export/sites/upov/publications/en/tg_rom/pdf/tg_1_3.pdf.

its examination process for granting a breeder's right.[24] These combined efforts minimize implementation costs for member states (an important incentive for less developed countries) as well as for breeders seeking protection in multiple jurisdictions.

Since UPOV's adoption in 1961, UPOV Convention signatories have revised the Convention on three occasions: November 10, 1972; October 23, 1978 (the '78 Act); [25] and March 19, 1991 (the '91 Act).[26] Currently, both the '78 Act and the '91 Act are in force. New signatories must adopt the '91 Act, but the '78 Act remains in force for previous signatories. Both Acts provide identical criteria for granting intellectual property rights to seed developers: novelty, distinctness, uniformity and stability. The most important provisions of both the '78 and '91 Acts, and where the two Acts diverge most drastically, relate to the scope of authorized exceptions to seed developers' rights.

Two noteworthy exceptions to seed developers' intellectual property rights are the "breeders' exemption" and the "farmers' exemption." In the '78 Act, article 5(3) creates the breeders' exemption from intellectual property protection, stating that the authorization of the plant variety certification holder is not required if the protected variety is used by a plant breeder as an initial source for the creation of new varieties.[27] For example, a breeder may use a PVP-protected seed as a starting point to develop a distinct, new variety. A breeder must, however, obtain authorization from the PVP holder if the protected variety must be used each time the breeder seeks to reproduce the new variety.[28] Article 5(1) of the '78 Act provides, by implication,[29] 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.[30] Thus, if a farmer does not intend to commercially exploit the protected variety, he

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24. *Id.*

25. International Convention for the Protection of New Varieties of Plants, Oct. 23, 1978, 33 U.S.T. 2703, 1861 U.N.T.S. 281 [hereinafter UPOV 1978 Act].

26. International Convention for the Protection of New Varieties of Plants, Mar. 19, 1991, S. Treaty Doc. No. 104-17 (1995), *available at* http://www.upov.int/en/publications/conventions/1991/act1991.htm [hereinafter UPOV 1991 Act].

27. UPOV 1978 Act, *supra* note 25, at art. 5.

28. *Id.*

29. *Id.*

30. *Id.*

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 restricts the availability of these exemptions.[31] This restriction may explain why some UPOV signatories have elected to remain a party to the older '78 Act while declining to adopt the '91 Act.[32] 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, grants national governments discretion to decide whether to permit seed saving.[33] The '91 Act also significantly narrows the breeders' exemption by requiring researchers and other seed developers to obtain permission from the PVP holder.[34]

In addition to the changes made to the farmers' and breeders' exemptions, the '91 Act contains several significant addendums, including: (1) the extension of the protection to all genera and species;[35] (2) the protection of Essentially Derived Varieties (EDVs);[36] (3) a greater scope of breeders' rights;[37] (4) an extended

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31. Simon Walker, Environmental Policy and Law Paper No. 41, *The TRIPS Agreement, Sustainable Development and the Public Interest: Discussion Paper*, IUCN Envtl. L. Ctr., 2001, at 29, *available at* http://data.iucn.org/dbtw-wpd/edocs/EPLP-041.pdf.

32. For example, Argentina, Brazil, and China have all acceded to the '78 Act rather than the '91 Act.

33. Walker, *supra* note 31, at 29.

34. *Id. See infra* note 39.

35. The '78 Act provided for the progressive application of its provisions to new botanical genera and species. The protection of at least five genera or species was required when a Member State became a party to the Convention, but it should encompass ten genera or species in all within three years, eighteen within six years and twenty-four within eight years. The '91 Act, on the other hand, established the protection of at least fifteen genera or species at the date the Member State is bound by the Convention and of all plant genera and species within ten years of said date. Walker, *supra* note 31, at 29.

36. 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).

37. Both the '78 Act and the '91 Act allow free access to a protected variety to serve as an initial source for the creation of new varieties under the

duration of protection;[38] (5) the extension of the protection to marketed products;[39] and (6) the possibility of protection under both a *sui generis* and a patent system.[40]

For ease of reference, Table 1, below, sets out many of the key differences between the '78 and the '91 Acts of UPOV.

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research exemption. However, under the '91 Act, 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 does the '78 Act, broadening the scope of breeders' rights. *Compare* UPOV 1978 Act, *supra* note 25, at art. 5(3), *with* UPOV 1991 Act, *supra* note 28, at arts. 14, 15(1)(iii).

38. 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.

39. 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.*

40. *Id. J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred Int'l, Inc.*, 534 U.S. 124 (2001), affirmed the use of both PVPs and patents in the United States.

Table 1: Distinctions Between the '78 and '91 UPOV Acts		
UPOV Convention	1978	1991
Requirements	Distinct, Uniform, and Stable	Distinct, Uniform, Stable, and Novel
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
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 ember's 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.[43]

As of 2011, sixty-nine countries are UPOV members. One is a party to the 1961/1972 Act, [41] twenty-three signed onto the '78 Act, [42] and forty-five are signatories to the '91 Act.[43] As of December 31, 1995, all incoming members must accede to the '91 Act.[44]

41. Belgium (Dec 5, 1976). *UPOV Lex, Convention Notifications*, UPOV, http://www.upov.int/upovlex/en/notifications.jsp (last visited Jan. 2, 2013).

42. 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). *See id.*

43. Albania (Oct 15, 2005), Australia (Mar 1, 1989), Austria (Jul 14, 1994), Azerbaijan (Dec 9, 2004), Belarus (Jan 5, 2003), Bulgaria (Apr 24, 1998), Croatia (Sep 1, 2001), Czech Republic (Jan 1, 1993), Denmark (Oct 6, 1968), Estonia (Sep 24, 2000), European Community (Jul 29, 2005), Finland (Apr 16, 1993), Germany (Aug 10, 1968), Hungary (Apr 16, 1983), Israel (Dec 12, 1979), Japan (Sep 3, 1982), Jordan (Oct 24, 2004), Kyrgyzstan (Jun 26, 2000), Latvia (Aug 30, 2002), Lithuania (Dec 10, 2003), Netherlands (Aug 10, 1968), Poland (Nov 11, 1989),

Table 2, below, briefly summarizes when each country subject to analysis in this article signed on to the relevant 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 the '91 Act. Originally a party to the '78 Act, the United States later signed the '91 Act, updating its national implementing legislation accordingly.

Table 2: Dates of Countries Joining Certain IP-Related Agreements
*See discussion above for UPOV signing history of the United States

Country	WTO/TRIPS	UPOC '78 Act	UPOV '91 Act
Argentina	January 1, 1995	December 25, 1994	n/a
Brazil	January 1, 1995	May 23, 1999	n/a
China	December 11, 2001	April 23, 1999	n/a
India	January 1, 1995	Has not signed.	Has not signed.
United States	January 1, 1995	November 8, 1981	February 22, 1999

The differences between the '78 Act and the '91 Act inform the balance of our discussion of the countries' current intellectual property landscapes. As described above, perhaps the most significant difference between the '78 and '91 Acts is the level 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 plant-focused *sui generis* system—such as the UPOV Convention provides—and adopting a general utility patent system[45] for protecting intellectual property rights in plants. Breeders' and farmers' exemptions granted in the UPOV Conventions, prior to '91, allow for free access to a protected variety without the authorization of the holder

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Republic of Korea (Jan 7, 2002), Republic of Moldova (Oct 28, 1998), Romania (Mar 16, 2001), Russian Federation (Apr 24, 1998), Singapore (Jul 30, 2004), Slovenia (Jul 29, 1999), Spain (May 18, 1980), Sweden (Dec 17, 1971), Switzerland (Jul 10, 1977), Tunisia (Aug 31, 2003), Ukraine (Nov 3, 1995), United Kingdom (Aug 10, 1968), United States of America (Nov 8, 1981), Uzbekistan (Nov 14, 2004), Iceland (May 3, 2006), Morocco (October 8, 2006), Viet Nam (December 24, 2006), Dominican Republic (June 16, 2007), Turkey (November 18, 2007), Georgia (November 29, 2008), Costa Rica (January 12, 2009), Oman (Nov. 22, 2009), and The Former Yugoslav Republic of Macedonia (May 4, 2011). *See id.*

44. 1991 UPOV Act, *supra* note 26, at art. 37(3).

45. 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 (2006), *with* 35 U.S.C. § 171 (2006) (distinguishing between utility and design patents). *See also* U. S. Patent & Trademark Office, A Guide to Filing a Design Patent Application (Nov. 16, 2003), *available at* http://www.uspto.gov/web/offices/pac/design/definition.html.

of a PVP certificate.[46] In contrast, plants protected by a utility patent are afforded the same level of intellectual property protection as any other patented material and are not subject to farmers' and breeders' exemptions. Accordingly, both breeders and farmers must obtain the permission of a patent holder under a patent intellectual property system for actions they could have taken without permission under UPOV.

2. WTO and TRIPS

Unlike UPOV, which is available only 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 to the negotiation finalized an agreement establishing minimum standards for protection of intellectual property in WTO member countries.[47] Notably, ratification of TRIPS is mandatory for WTO membership, an important demand that has led countries seeking WTO membership to enact more robust intellectual property laws than previously in force.[48]

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."[49] Accession to the UPOV Convention, along with implementation of the Convention into national law, satisfies the TRIPS requirements for a *sui generis* plant variety protection system.[50] Each of the five countries subject to this research is a WTO member, and thus has

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46. UPOV does not grant PVP certificates. Rather, the UPOV Convention 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.

47. TRIPS, *supra* note 9.

48. Cullet & Koluru, *supra* note 9, at 45.

49. TRIPS, *supra* note 9, at art. 27(3).

50. *UPOV Press Release No. 30: The 1991 Act of the International Convention for Protection of New Varieties of Plants (The UPOV Convention) Enters into Force*, Int'l Union for the Prot. of New Varieties of Plants (Apr. 21, 1998), http://www.upov.int/news/en/pressroom/30.html. The way each of the five countries in our study has implemented the requirements of the TRIPS agreement is explored further later in this paper. *See infra* Part II.B.

an intellectual property system that meets the requirements of TRIPS.[51]

3. Enforcement Regimes and the Special 301 Report

In response to international differences in intellectual property protection, the Office of the United States Trade Representative (USTR) annually releases the "Special 301 Report" to serve as a review of the intellectual property protection and enforcement of forty trading partners of the United States. In its report, the USTR evaluates each country's intellectual property regime, detailing its annual improvements, strength of enforcement, and areas of concern. The Special 301 Report places poor performing countries on either a Watch List or a Priority Watch List. The Priority Watch List is reserved for those nations with more critical flaws in either their intellectual property protection or enforcement mechanisms than countries on the Watch List. In the following section, we will discuss in greater detail the intellectual property regimes for agricultural products in the respective countries analyzed in this article as well as their corresponding production statistics for the relevant period.

B. Country Specific Agricultural Production and Plant Intellectual Property Protection

1. Argentina

Argentina's production of all five of the crops studied in this article increased over the twenty-year period of analysis. Soybean production more than quintupled in the twenty-year period, while maize and rice production roughly doubled, and wheat production increased forty-three percent.[52] This steady increase in production provides a quantitative backdrop for the discussion of the Argentinean intellectual property system.

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51. World Trade Org., *Understanding the WTO: The Organization, Members and Observers*, http://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm (last visited Sept. 20, 2011).

52. 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. Production data was sourced through the FAOSTAT database of the Food and Agricultural Organization of the United Nations, http://faostat.fao.org/. A copy of the original data is on file with the authors.

a. Argentina's Intellectual Property Legal Regime

Enacted in 1935, Argentina's first law regulating seed varieties required registration of new varieties, but offered no legal protection for the breeders' intellectual property rights.[53] The "Law of Seeds" decree, passed by Argentina's military government in 1973 and fully implemented in 1978, gave exclusive commercialization rights to inventors of new seed varieties.[54] However, the Law of Seeds farmers' privilege 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 variety owner's property rights.[55] Such seeds must be kept separate and identifiable[56] and the source of the saved seed must have been legally obtained.[57] The Law of Seeds also established the National Seed Commission (CONASE) to advise and evaluate government policy.[58]

In 1991, in response to political pressure from associations of seed producers and groups inside CONASE,[59] the government issued Regulatory Decree 2183, which amended the Law of Seeds to bring it up to date with international standards. At the time of the amendment Argentina was not yet a member of UPOV or WTO/TRIPS.[60] Regulatory Decree 2183 created the National Seed Service (SENASE) and imbued it 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

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53. J.P. Kesan & A.A. Gallo, *Property Rights and Incentives to Invest in Seed Varieties: Governmental Regulations in Argentina*, 8 J. Agrobiotechnology Mgmt. & Econ. 118, 119 (2005), *available at* http://www.agbioforum.org/v8n23/v8n23a08-kesan.pdf.

54. *Id.* at 120. Article 22 of the Law of Seeds states that "[t]he 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 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 No. 20247, Mar. 30, 1973, ch. VII, arts. 22 & 37, [22.648] B.O. 2 (Arg.) [hereinafter 1973 Law of Seeds].

55. 1973 Law of Seeds, *supra* note 57, at art. 27.

56. Res. 35/96, Feb. 28, 1996, art. 1(f), [28.354] B.O. 23 (Arg.).

57. Res. 35/96, Feb. 28, 1996, art. 1(a)-(c), (e), (f). The UPOV '78 Act specifically curtailed farmers' rights to sell any saved seed. UPOV 1978 Act, *supra* note 25, art. (5)(1).

58. 1973 Law of Seeds, *supra* note 57, at ch. II, arts. 4-8.

59. Kesan & Gallo, *supra* note 56, at 120.

60. Argentina joined the UPOV Convention in December 1994 and the WTO a month later in January 1995.

new seed varieties.[61] Later that same year, the National Seed Institute (INASE) replaced SENASE.[62]

The National Register of Cultivators Ownership, overseen by INASE, allocates property rights[63] for plant varieties.[64] 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.[65] Plant varieties must meet the defined conditions of novelty, distinctness, uniformity, and stability.[66] 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."[67]

Argentinean law now also includes Resolución 35/96, issued by INASE in 1996 (after Agentina's accession to the '78 UPOV Act, which contains both farmers' and breeders' rights). Resolución 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.[68] The Law of Seeds allows plant breeders to use a variety without authorization as a source in their work, but requires them to secure authorization for the "repeated and/or systematic use of a variety as necessary means of producing commercial seed."[69] 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 of developing a seed for subsequent sale. Resolución 35/96 does not alter these broad

61. Law No. 2183/91, Oct. 21, 1991, arts. 5-7, [LI-D] A.D.L.A. 4013 (Arg.).

62. Law No. 2817, Dec. 30, 1991, art. 2, [27.363] B.O. 3 (Arg.).

63. Property rights last for a maximum of twenty years and shorter periods may be set for certain species. Law No. 2183/91, Oct. 21, 1991, art. 37.

64. 1973 Law of Seeds, *supra* note 57, at arts. 19-30, chs. VI-VII, arts. 26-40.

65. *Id.* at art. 26.

66. Law No. 2183/91, Oct. 21, 1991, art. 26. These requirements are identical to the requirements under the '91 Act. UPOV 1991 Act, *supra*, note 26. The'78 Act does not require novelty. UPOV 1978 Act, *supra*, note 25.

67. Law No. 2183/91, Oct. 21, 1991, art. 26.

68. Res. 35/96, Feb. 28 1996.

69. Law No. 2183/91, Oct. 21, 1991, art. 43.

breeders' rights. Any inconsistencies that may arise between the UPOV and Argentinian law are resolved in favor of the '78 Act.[70]

b. Intellectual Property Enforcement in Argentina

Although a system granting intellectual property rights is a necessary element of a functioning intellectual property regime, there must be some enforcement mechanism accompanying this grant in order to prevent (or at least provide compensation for) infringement of the underlying property right.[71] To that end, the Office of the United States Trade Representative (USTR) periodically publishes an intellectual property enforcement Priority Watch List that analyzes the enforcement regimes of U.S. trading partners. The USTR included Argentina on its most recent 2011 Priority Watch List,[72] as well as lists published during the period of this study.[73] The issues of concern to the USTR in their 2005 report—covering the time period analyzed in this article—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.[74] From a procedural perspective, Argentina's patent applications also remain backlogged. However, Argentina has recently made steps towards addressing the patent backlog, and Argentina's Attorney General issued new guidance on IP crimes.[75] The USTR has praised Argentina for these positive steps.[76] However, serious problems persist and until Argentina addresses

70. Kesan & Gallo, *supra* note 56, at 120.

71. 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 (2007).

72. 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 from both the United States and the countries it discusses. United States lawmakers know who 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.

73. Office of the U. S. Trade Representative, 2005 Special 301 Report 26, *available at* http://www.ustr.gov/archive/assets/Document_Library/Reports_Publications/2005/2005_Special_301/asset_upload_file195_7636.pdf [hereinafter 2005 Special 301 Report].

74. 2011 Special 301 Report, *supra* note 1, at 27.

75. *Id.*

76. *Id.* at 7.

the inefficiency of 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 the lack of patent coverage for plants as well as the leniency of penalties for intellectual property crimes during the period of study, the authors rank Argentina's strength of enforcement of intellectual property protection as low.

2. Brazil

During our period of investigation, Brazil's agricultural production for each of the five commodity crops increased, though the increases were lower than those seen in Argentina. Soybean production again showed the largest increase, more than doubling. Maize production also showed an impressive increase of fifty-nine percent. Other commodity crops showed more modest increases.[77]

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 Brazil's further development of intellectual property laws for the protection of new varieties of plants in the country. Legislation protecting plant variety intellectual property rights originated in 1945, when Brazil enacted its first intellectual property code.[78] However, implementation of the code, which expressly authorized the grant of patents to new varieties of plants,[79] depended on the subsequent passing of a regulation, which never occurred.[80]

In 1991, when Brazil commenced discussions regarding a new intellectual property code, the subject of plant protection resurged. Based on the prerogative established in the TRIPS agreement,

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77. Rice had the next greatest increase, at forty-six percent. Cotton production showed increased just twenty-eight percent, and wheat production increased a meager 7.8 percent. *See supra* note 55.

78. Decreto No. 7903, de 27 de Agosto de 1945, Código de Propriedade Industrial (C.P.I.), Diário Oficial da União [D.O.U] de 29.09.1945 (Braz.).

79. *Id.* at arts. 3, 219.

80. Memorandum from Renata Oliveria on the Brazilian Intellectual Property Regime to Bryan Endres (May 25, 2009) (on file with author); *see also* Antonella Carminatti, *Development of Industrial Property Laws*, http://www.cbsg.com.br/pdf_publicacoes/development_industrial_laws.pdf (last visited Jan. 26, 2012).

Brazil excluded plants from patentability and instead established a *sui generis* system for the protection of plant varieties. Though Brazil's intellectual property code[81] has allowed patent protection for gene structures, genetically modified organisms, and *processes* to obtain new plant varieties since 1996, it does not authorize patent protection for plants or part of plants.[82] Rather, intellectual property protection for actual plant varieties in Brazil falls exclusively under the Brazilian Plant Variety Protection Law.[83] The Brazilian Plant Variety Protection Law established a *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.[84] Brazilian law includes both the breeders' and the farmers' exemptions. Under article 10(I)(II) of the Brazilian Plant Variety Protection Law, a farmer does not infringe a seed developer's right if 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.[85]

Brazil's protection of farmers' rights also allows small farmers to donate or exchange seeds exclusively with other small farmers, but only if they are part of a government incentive program.[86] The law defines a small farmer[87] as 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;[88] (3) derives 80% of his income from agriculture activities; and (4) lives on the property or nearby.[89]

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81. Lei No. 9.279, de 14 de Maio de 1996, Código de Propriedade Industrial (C.P.I.), Diário Oficial da União [D.O.U] de 15.05.1996 (Braz.).

82. *Id.* at 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.").

83. Lei No. 9.456, de 25 de Abril de 1997, Diário Oficial da União [D.O.U] de 28.04.1997 (Braz.).

84. *Id.*

85. *Id.* at art. 10(I)(II).

86. *Id.* at art. 10(IV).

87. The 1978 Convention does not make such a difference between farmers. 1978 UPOV Act, *supra* note 25, at art. 5(1).

88. A fiscal module is "a land unit established by the National Institute of Colonization and

Agrarian Reform (INCRA) mainly for rural real estate taxation according to Federal Decree No 8.485/1980." Jose Heder Benatti & Luly Rodrigues da Cunha Fischer, Land Use Regulations in the State of Para, Brazil: An Overview of Its Guidelines 13, *available at*

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[90] due to the lack of licensed authorities to perform the required procedures.[91] Foreign applicants, however, must provide a DUS test performed by a foreign authority accepted by the Brazilian government.[92] Thus, while Brazil has signed on to TRIPS and the '78 Act—and 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

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http://siteresources.worldbank.org/EXTARD/Resources/336681-1236436879081/5893311-1271205116054/BenattiPaperGOV4.pdf.

89. Lei No. 9.456, de 25 de Abril de 1997, Diário Oficial da União [D.O.U] de 28.04.1997 (Braz.).

90. DUS tests are conducted to show that a variety is distinct, uniform, and stable. *Test Guidelines*, Int'l Union for the Prot. of New Varieties of Plants, http://www.upov.int/en/publications/tg_rom/introduction.html (last visited Oct. 25, 2012).

91. Memorandum from Renata Oliveria on the Brazilian Intellectual Property Regime to Bryan Endres (May 25, 2009) (on file with author).

92. Lei No. 9.456, de 25 de Abril de 1997, at art. 14(viii). 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. See generally* Decreto No. 2.366, de 5 de Novembro de 1997, art. 14, Diário Oficial da União [D.O.U.], de 6.11.1997 (listing requirements to establish precedence of plant variety protection).

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 76, at 26.

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 during the time of this study as low.

3. China

During the timeframe of this study, China's agricultural production exceeded Brazil's for each of the commodity crops studied except soybeans. Total production for all five crops also increased: maize production more than doubled, wheat production increased by nearly fourteen percent, rice production increased by 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,[99] thereby binding itself to the intellectual property requirements embedded in TRIPS. China's intellectual property laws, though, were in place long before its accession to the WTO Agreement.[100] China became a member of UPOV on April 23,

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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.*

99. *Protocols of Accession for New Members Since 1995, Including Commitments in Goods and Services*, WTO (July 23, 2008), http://www.wto.org/english/thewto_e/acc_e/completeacc_e.htm#list.

100. China passed its PVP law in 1997. *See* Bonwoo Koo et al., *The Economics of Generating and Maintaining Plant Variety Rights in China* 2 (Int'l Food Policy Research Inst., EPTD Discussion Paper No. 100, 2003), *available at* http://www.ifpri.org/sites/default/files/publications/eptdp100.pdf.

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.[101] The Ministry of Agriculture administers PVPs for all other agricultural plants. In 1999, only ten species were eligible for protection.[102] As of 2005, 142 species were eligible.[103]

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 patent protection for novel genes.[104] As China is a signatory to the '78 UPOV Act, the PVP regime also includes an extensive farmers' exception.[105]

China's patent 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, but one noticeable difference is the listing of specifically excluded subject matter.[106] Article 25(4) makes plant varieties not patentable in China, while expressly allowing patents on processes for producing plants: "For processes used in producing products referred to in items (4) of the preceding

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101. *Id.* at 12.

102. *Id.* at 17.

103. USDA Foreign Agric. Serv., GAIN Report No. CH5048, China, Peoples Republic of Planting Seeds: New Plant Variety Protection List Updated 3 (Jun. 20, 2005) [hereinafter USDA Report], *available at* http://www.fas.usda.gov/gainfiles/200506/146130055.pdf. It appears that China has not added any new species since 2005. The Information Network of China Plant Varieties Protection website has not been updated since 2005, nor does it list any additional species. *Brief Introduction of China Plant Varieties Protection,* The Info. Network of China Plant Varieties Prot., http://www.cnpvp.com/english/National%20List%20of%20Protected%20Plants.htm (last visited Jan. 24, 2011).

104. USDA Report, *supra* note 106, at 3.

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 ". . . use[d] for propagating purposes by farmers, on their own holdings, of the propagating material of the protected variety harvested on their own holdings.").

106. Gregory C. Ellis, *Intellectual Property Rights and the Public Sector: Why Compulsory Licensing of Protected Technologies Critical for Food Security Might Just Work in China*, 16 Pac. Rim L. & Pol'y J. 699, 711 (2007).

paragraph, patent right may be granted in accordance with the provisions of this Law."[107]

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 country on the list.[108] In its 2005 report, USTR also devoted significantly more analysis to China than to any other country, also including it on the Priority Watch List.[109] This level of attention likely indicates China's greater importance to the United States as a trading partner and as a global economic force.[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[111] and creating the Program for Special Campaign on Combating IPR Infringement and Manufacture and Sales of Counterfeiting and Shoddy Commodities (Special Campaign).[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.[113] The USTR also

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107. Patent Law of the People's Republic of China (promulgated by the State Intell. Prop. Office of the P.R.C., effective Aug. 25, 2000) 2000 China Law LEXIS 2159 (China Law 2000), at * 11, art. 25, *available at* http://english.sipo.gov.cn/laws/lawsregulations/201101/t20110119_566244.html.

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.

109. 2005 Special 301 Report, *supra* note 76, at 22.

110. China's importance to the United States and the world can be seen in the agriculture context simply by considering the production information given at the beginning of this section. *See id.* at 21.

111. 2011 Special 301 Report, *supra* note 1, at 7.

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.

113. In 2007, China's "regime for protecting and enforcing copyrights and trademarks on a wide range of products" was questioned. 2011 Special 301 Report, *supra* note 1, at 16. The WTO found for the United States. *Id.* 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. . ." *Id.* The United States also availed itself of the WTO's dispute resolution framework to address

expressed concerns about persistently high thresholds for criminal action in intellectual property cases,[114] as well as the Chinese policy of requiring technology transfers as a condition for government benefits or preferences.[115] While China has made attempts to improve its intellectual property system,[116] 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 at the end of the period was six times as high as it was at the beginning. Maize production doubled. Wheat production increased by fifty-eight percent, and rice production increased by 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.[117]

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 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.*

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.

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 longer happens. *Id.* at 24.

116. *See supra* notes 115-16 and accompanying text.

117. Obviously, an increase in production can stem from either 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 increased increase only thirty-one percent. Wheat yield rose thirty-nine percent while hectares increased 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 saw an increase in hectares planted that outstripped the increase in yield.

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 UPOV Convention, 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 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 is included under the Seeds Act as a farmers' variety, or classified as a variety about which there is common knowledge, or otherwise in the public domain.[123] Applicants may register only those varieties that are of the genera

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Soybean hectares planted increased by nearly six hundred percent while yield increased only forty percent. *See supra* note 55.

118. The Protection of Plant Varieties and Farmers' Rights Act, 2001, No. 53, Acts of Parliament, §16(1)(a), 2001 (India).

119. *Id.* § 16(1)(d), (f).

120. *Id.* § 16(1)(b), (e).

121. *Id.* §§ 31-32. Under section 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 section 2(f). *Id.*

122. *Id.* § 14. Farmers' varieties are those varieties which have been cultivated by a farmer, rather than a seed developer, by cross breeding on his or her own property. *Id* § 2(l) (a farmer's variety is either 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.").

123. *Id.* § 2(j).

and species specified in the Official Gazette,[124] or essentially derived varieties.[125]

A successful applicant is issued a certificate of registration and holds an exclusive right to produce, sell, market, distribute, import, or export the variety.[126] 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 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 she can authorize the use of the essentially derived variety.[127]

India's 2001 registration statute, a PVP alternative, also contains a section on breeders' rights.[128] Registration of a variety does not prevent its use by other breeders "for conducting experiments or research" or "as an initial source of variety for the purpose of creating other varieties."[129] 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."[130]

The 2001 Act also contains a separate chapter dedicated to farmers' rights.[131] Farmers are explicitly 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 seed.[132] Thus, while India has not signed either the

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124. *Id.* § 29(2).

125. *Id.* § 23. For a new variety to be registered, it must conform to the requirements of novelty, distinctiveness, uniformity, and stability. *Id.* § 15(1). These are the same requirements as for the '91 Act. The '78 Act does not require novelty. Extant varieties, including farmers' varieties, need not be novel but must conform to the remaining three requirements. *Id.* § 15(2).

126. *Id.* § 28(1). The fee for registration as an agent or licensee is 10,000 IRP (about $227 USD). The Protection of Plant Varieties and Farmers' Rights Rules, 2003, r. 45, second sched., Gazette of India, section 3(i) (Sept. 12, 2003).

127. The Protection of Plant Varieties and Farmers' Rights Act § 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, *Introducing Plant Breeders' Rights in India: A Critical Evaluation of the Proposed Legislation*, 1 J. World Intell. Prop. 245 (1998).

128. The Protection of Plant Varieties and Farmers' Rights Act § 30.

129. *Id.*

130. *Id.*

131. *Id.* §§ 39-46.

132. *Id.* § 39(1)(iv).

'78 or '91 Act of UPOV, procedures are in place to protect the innovation and investment of seed developers. Patent protection for plants is not available in India.

b. Intellectual Property Enforcement in India

The USTR included India on both its 2005[133] and 2011[134] intellectual property enforcement Priority Watch Lists, and India's legal system and overall IP enforcement remain weak.[135] The United States has urged India to develop stronger protection for patents and to address its patent application backlog more assertively.[136] The United States has also suggested that India develop a more effective system for preventing unfair use and unauthorized disclosure of data relating to agricultural chemical products.[137] 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.[138] India has also developed a national intellectual property rights policy to help unify enforcement.[139] These new measures are positive 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.

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

133. 2005 Special 301 Report, *supra* note 74, at 27.

134. 2011 Special 301 Report, *supra* note 1, at 28.

135. *Id.* The United States has suggested more efficient legal proceedings, stronger criminal enforcement, and deterrent level sentencing. *Id.* at 29.

136. *Id.*

137. This is also a problem with pharmaceutical chemicals. *Id.* at 28-29.

138. *Id.* at 9.

139. *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. The Protection of Plant Varieties and Farmers' Rights Act § 64. The breeder may seek an injunction to stop the wrongful use and he may seek either damages or a share in the profits. *Id.* § 66.

commodities, pushing farmers to plant the more profitable crops.[140] The other four crops, however, did show the expected increases. Maize production increased by twenty-five percent, and soybean production increased by 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 Legal 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 legislation, seed saving and "brown bagging" remained a legal and common practice among farmers, as the intellectual property protections afforded to asexually reproducing varieties did not cover seeds.[141]

In 1970, Congress enacted the Plant Variety Protection Act (PVPA), an intellectual property regime for varieties reproduced by seed.[142] The PVPA granted seed developers exclusive rights to commercialize new seed varieties.[143] 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.[144] Any

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140. William Neuman, *Amber Waves to Ivory Balls*, N.Y. Times, Mar. 28, 2011, at B1 (noting that rising cotton prices could force out less profitable crops, such as wheat); *About Illinois Wheat*, Ill. Wheat Ass'n., http://www.illinoiswheat.org/about-illinois-wheat.html (last visited Dec. 28, 2011) (arguing that post World War II demand for corn and soybeans has caused these crops to replace wheat on many Illinois farms).

141. Endres & Goldsmith, *supra* note 72, at 251.

142. *Id.*

143. *Id.* at 252.

144. The requirements for patentability are laid out in 35 U.S.C. §§ 101-03.

living organism that is the product of human intervention potentially qualifies as a patentable composition of matter under U.S. law.[145] As a result, plants subjected to human intervention, such as breeding for a novel variety, are patentable subject matter. Moreover, in *Ex parte Hibberd*, the U. S. Board of Patent Appeals and Interferences 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.[146] In 2001 the Supreme Court upheld and extended *Hibberd* in *J.E.M. Ag Supply,* holding that sexually reproducing plants–even those protected by the Plant Variety Protection Act (PVPA)–are eligible for utility patents.[147] In *J.E.M.*, Pioneer Hi-Bred International (Pioneer) sued a seed distributor (J.E.M.) for illegally reselling its patented corn seed.[148] J.E.M. responded by claiming that the 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.[149] The Supreme Court disagreed, holding that plant life could be protected simultaneously by a utility patent and a PPA or a PVPA.[150]

As an alternative to patent protection, seed developers in the United States can also protect the information as a trade secret, unlike the other nations reviewed in this article. Trade secrets have 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 its not being generally known and not readily ascertainable by proper means; and (2) is subject to reasonable efforts to maintain its secrecy.[151] Hybrid corn seed, for instance, traditionally has been an excellent candidate for trade secret protection.[152]

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145. *Diamond v. Chakrabarty*, 447 U.S. 303, 310 (1980).

146. *Ex parte* Hibberd, 227 U.S.P.Q. (BNA) 443, 444 (B.P.A.I. 1985).

147. *J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred Int'l*, 534 U.S. 124, 127, 144-45 (2001). The PVPA applies to sexually reproducing plants. Jorge Fernandez-Cornejo, USDA, Agric. Info. Bulletin No. 786, The Seed Industry in U.S. Agriculture: An Exploration of Data and Information on Crop Seed Markets, Regulation, Industry Structure, and Research and Development 26 (2004).

148. *J.E.M.,* 534 U.S. at 128-29.

149. *Id.* at 129.

150. *Id.* at 144-46.

151. *See* Unif. Trade Secrets Act § 1 (amended 1985), 14 U.L.A. 437 (1990).

152. *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

Finally, corporations often use contracts, in the form of technology use agreements,[153] to protect intellectual property. Restrictive licensing agreements have become common, especially for seeds.[154] 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.[155] Licensing agreements offer seed developers another method of intellectual property protection.

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.[156] The United States also grants authority over many of its intellectual property cases to federal courts,[157] thereby allowing for the development of expertise and familiarity with

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seeds resulting in a "hybrid" with enhanced characteristics. *Pioneer Hi-Bred Int'l v. Holden Found. Seeds, Inc.*, Civ. 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.

153. *See 2008 Monsanto Technology/Stewardship Agreement*, Monsanto, http://www.monsanto.com/SiteCollectionDocuments/tug_sample.pdf (last visited Sept. 20, 2011).

154. *See generally* A. Bryan Endres, *State Authorized Seed Saving: Political Pressures and Constitutional Restraints*, 9 Drake J. Agric. L., 323, 337 (2004) (discussing the use of technology licensing agreements and tags attached to individual bags of seed).

155. *See id.* (describing the technology use agreement used by Monsanto, the patent holder for Roundup Ready® soybeans); *see also* Monsanto, *supra* note 156. By signing the Monsanto technology use 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. *Id.*

156. *See generally* 2011 Special 301 Report 2011, *supra* note 1.

157. *See Court Jurisdiction*, United States Court of Appeals for the Federal Circuit, http://www.cafc.uscourts.gov/the-court/court-jurisdiction.html (last visited Sept. 14, 2011).

intellectual property concepts and issues. Accordingly, the authors classify the intellectual property enforcement system in the United States as the highest of those reviewed in this paper.

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 3: Chart Summarizing Protection and Enforcement Mechanisms in Each Country

Country	Type of Plant Protection Provided	Strength of Plant Protection	Enforcement Mechanisms	Strength of Enforcement
Argentina	Law of Seeds; UPOV '78; Resolución 35/96; TRIPS; Decree 2183/91.[161]	Plant patents are unavailable leaving seed developers subject to the farmers' and breeders' exceptions in UPOV '78.	Criminal and civil penalties available, but deterrent level sentences rarely given.	Low
Brazil	TRIPS; UPOV '78; PVP under Law No. 9,456.	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.	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.	Low
China	TRIPS; UPOV '78; PVP.	Patents not available for plants themselves (patents are available for the transformation process, but not the final plant). Thus, seed developer's innovations are subject to the farmers' and breeders' exceptions.	Criminal and civil penalties are available. Threshold for criminal action is, however, quite high.	Low
India	Seeds Act; UPOV '78; PVP; TRIPS.	Patents not available for plants, and seed law is subject to both farmers' and breeders' exceptions.	Positive steps taken, but India's legal system in regards to IP enforcement remains weak.	Low
United States	PPA; PVPA; TRIPS; UPOV '91; Utility Patents; Trade Secrets; Contracts.	Utility patents available for plants which provide seed developers with a protection option that does not have the farmers' and breeders' exceptions.	Civil penalties available. Referral to Federal Circuit ensures judicial proceeding conducted by knowledgeable judiciary.	High

II. 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 issued) in the respective countries, as well as demographic and economic information.[158] A series of research associates from different countries 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 worked 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.[159] 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. Importantly for future investigations, in several instances we expected to find statistically significant correlation between intellectual property protection and agricultural innovation but ultimately could not demonstrate such results.

A. Research and Development Data

As a starting point in the statistical analysis, we explored the link between R&D expenditure[160] and agricultural production with

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.

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. *See* Nat'l Sci. Found., NSF 10-314, National Patterns of R&D Resources: 2008 Data Update, 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.

agricultural production serving as a proxy for innovation.[161] Our regressions showed significant correlations between R&D expenditures[162] and fifteen of the twenty-five crop variables we studied. [163] The most significant correlations the authors found 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).[164] Soybean hectares planted and cotton exports also displayed good fit. These findings are summarized in Table 4 below.

Table 4: Significant Correlations Between R&D Expenditure and Crop Variables

Dependent Variables	Coefficient of LS Estimate	Standard Error	P-Value of T-Statistics	Root MSE	Adjusted R-Square
Soybean Production	0.81635	0.18447	<.0001	0.74907	0.3172

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 United States and China, business investment in R&D has exceeded government funding. In Argentina, Brazil, and India, the opposite is true. *Id.*

161. In the view of the authors, total agricultural production serves as a proxy for innovation in light of the competitive world market for these commodity crops, as well as the opportunity cost for land. Without some form of innovation, these land resources would be put to a higher and better use. The authors do acknowledge, however, that this is an imperfect representation of innovation, but it is the best representative factor for which reliable public data is available.

162. 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 authors selected aggregate R&D as the most appropriate proxy.

163. 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. Thomas Hill & Pawel Lewicki, Statistics: Methods and Applications 5-6 (1st ed. 2006).

164. 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.

Soybean Exports	1.79347	0.78531	0.0282	2.96833	0.0999
Soybean Ha	0.65993	0.09592	<.0001	0.38948	0.5367
Maize Production	1.59427	0.16559	<.0001	0.6724	0.6963
Maize Exports	1.85096	0.89837	0.0464	3.39569	0.0787
Maize Yield	0.38173	0.12218	0.0034	0.49613	0.1797
Maize Ha	1.20872	0.12453	<.0001	0.50567	0.6997
Wheat Production	0.61566	0.27458	0.0307	1.11496	0.0915
Wheat Ha	0.54086	0.22548	0.0213	0.91559	0.1062
Rice Exports	2.01038	0.85228	0.0237	3.22148	0.1072
Rice Yield	0.2302	0.08137	0.0073	0.3304	0.149
Cotton Production	1.43447	0.24047	<.0001	0.97645	0.4637
Cotton Exports	2.28384	0.35166	<.0001	1.42797	0.5073
Cotton Yield	0.32851	0.13699	0.0214	0.55625	0.1062
Cotton Ha	1.10596	0.25725	<.0001	1.04459	0.3041

An analysis of the aggregate country data for research and development shows that maize production has a strong correlation to R&D expenditures.[165] 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.[166] 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 against infringement. Thus, as was supported by the regression, we expected that maize production would be 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.[167] Because of the differences in the reproduction methods of maize and soybeans,

165. 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.

166. *See* Endres & Goldsmith, *supra* note 74, at 253. *See also* Jim Waltrip, *Hybridization: A Phenomenon That Feeds Us Well*, Ed Hume Seeds, http://www.humeseeds.com/hybrdlvr.htm (last visited Mar. 28, 2012).

167. *See* Fernandez-Cornejo, *supra* note 150, at 18.

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.[168] 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. As soybeans do not have the built-in biological protection to discourage seed saving, as compared to maize, it follows that seed developers in countries without strong IP protection have a disincentive to devote significant R&D resources for soybeans. Thus, the correlation is not found.

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 R&D expenditures[171] and crop production. The negative correlation in Brazil during this time period could be due to a well-established government soybean R&D program within that country,[172] coupled with a history of appropriating (often without permission)

168. Adjusted R-squared is 0.317.

169. R-squared is 0.696. The authors are not certain why China shows this positive correlation.

170. R-squared is 0.671.

171. R&D expenditures considered came from government and private sector investors.

172. 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 Brazil's 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. *Welcome to 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. *Id.*

agricultural technological advancements such as improved plant genetics from U.S.-based seed companies operating in other South American countries, including Argentina.[173] Thus, in Brazil, privatized R&D may have been replaced by government and foreign R&D, lowering 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 property laws or enforcement, an increase in overall R&D expenditures would likely result in an increase in maize yield as it has an inherent protection from appropriation, but would have minimal impact on soybean yield.[174]

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 across years, 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 measure of short-run productivity. However, our examination of the data at the country level over a twenty-year period also failed to identify a statistically significant correlation between R&D expenditures and

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173. *See* Endres & Goldsmith, *supra* note 74, at 248; Randy Schnepf, Cong. Research Serv., RS21558, Genetically Engineered Soybeans: Acceptance and Intellectual Property Rights Issues in South America 4 (2003) (noting that Brazilian farmers, during the period of this study, purchased a significant amounts of imported seeds on the black market).

174. The increase in maize would be expected because it does not produce viable seeds for planting in season two, and thus intellectual property laws and enforcement regimes are less necessary from a seed developer's perspective. *See* Endres & Goldsmith *supra* note 74, at 247 (discussing maize and soybean reproduction).

crop yield.[175] Accordingly, we are unable to demonstrate a statistically significant correlation between R&D and yield improvement.

This data can also be analyzed 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. In non-competitive markets—often the case in developing nations such as Brazil, Argentina, or China—increasing yield may not attract significant quantities of new customers as farmers in non-competitive markets will already purchase the available seed. Rather, a seed developer may target R&D efforts at increasing the geographic range in which particular crops can be grown, as more hectares planted across a wider range means more seed purchased by farmers. This new client base could include growers switching from lower value crop production, often grown on marginal lands.[176] 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 have 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.[177] We attribute this lack of a correlation to having too

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175. 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 the authors hypothesized that a clear difference between the two crops would be shown by the data due to the plants' different forms of reproduction. The figures in Appendix A 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.

176. For example, from 1995 to 2010 soybean production in South Dakota went up 82,320,000 bushels while flaxseed production in South Dakota – a lower value commodity crop – decreased 176,000 bushels. *See South Dakota*, USDA Nat'l Agric. Statistics Service, http://www.nass.usda.gov/Statistics_by_State/South_Dakota/Publications/County_Estimates/index.asp (last visited Sept. 19, 2011).

177. 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 because 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

few observation points to achieve statistical significance. A future study will explore these results further.

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 number 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 (PVP certificate) data for each country. The utility patent and PVP data was used as a proxy for the strength of intellectual property regimes in each country. As intellectual property regimes have long been considered necessary to maintaining and developing new technologies,[178] 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,[179] 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 that require external protection against misappropriation (e.g., soybeans).

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)[180] 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

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in area cultivated seemed to be a reasonable assumption. However, even this adjustment did not result in a reliable correlation in the other countries analyzed in this study.

178. *See supra* note 1.

179. *See supra* Table 3, p. 36.

180. Samantha M. Ohlgart, *The Terminator Gene: Intellectual Property Rights vs. the Farmer's Common Law Right to Save Seed*, 7 Drake J. Agric. L., 473, 474 (2002) (defining terminator genes as those that do not allow seed to germinate, a condition which effectively precludes seed saving),

suffer drastic reductions in yield. Second, we hypothesized that due to protections provided by utility patents *vis-à-vis* PVP certificates,[181] plant researchers would prefer patent protections.[182] Therefore, we first analyze the correlation between utility patents and crop productivity, followed by a discussion of PVP certificates.

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 illustrates we found strong correlations between patent applications and soybean production, soybean yield, and soybean hectares planted.[183] This is in line with our expectations at the beginning of this research project.

Table 5: Significant Correlations with Patent Applications Per Million

Dependent Variables	Coefficient of LS Estimate	Standard Error	P-Value of T-Statistics	Root MSE	Adjusted R-Square
Soybean Production	0.31843	0.03252	<.0001	0.35508	0.6735
Soybean Yield	0.11495	0.01214	<.0001	0.13259	0.6583
Soybean Ha	0.20272	0.02472	<.0001	0.26991	0.5902
Maize Production	0.116701	0.06787	0.0178	0.74111	0.099
Maize Yield	0.12453	0.03832	0.0022	0.41838	0.1721

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 generally increasing agricultural R&D generally in light of newly formalized intellectual property protections for all plant species. Regardless of the underlying reason, the data demonstrate a significant and strong

181. *See supra* notes 46- 47 and accompanying text.

182. *See supra* notes 46- 47 and accompanying text.

183. 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.

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.[184] 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 a 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[185] (thereby restricting our analysis to Brazil, China and the United States), there is a strong, positive correlation between all soybean productivity variables[186] and plant variety protection applications as shown in the table below.[187]

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

185. The results excluding Argentina are reported to show interesting and significant patterns in the other countries. Furthermore, Argentina, unlike Brazil, China and the United States has taken a more restrictive approach to genetic engineering in an effort to preserve market access in those countries with significant opposition to genetically modified agricultural products. Our analysis does not allow us to offer a critique of Argentinian genetic engineering policy, but may provide a basis for further investigation.

186. 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.

187. This positive correlation is found in China, Brazil, and the USA—all countries with PVP protection. The USDA has provided some statistical evidence to support this assumption. *See* Fernandez-Cornejo, *supra* note 150, at 5.

Table 6: Correlation Between PVP Applications and Soybean Productivity Variables Excluding Argentina					
Dependent Variables	Coefficient of LS Estimate	Standard Error	P-Value of T-Statistics	Root MSE	Adjusted R-Square
Soybean Ha	0.567	0.07642	<.0001	0.27557	0.6837
Soybean Production	0.74737	0.10191	<.0001	0.36748	0.6786
Soybean Yield	0.17946	0.03804	<.0001	0.13718	0.4595
Soybean Exports	2.13715	0.30171	<.0001	1.02963	0.6813

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 intellectual property regime. There must also be in place a functioning system to enforce these rights, whether it be a strong moral, social code, or 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 are a catalyst for invention—that is, that an inventor is likely to invest her time and money to create a product if she is 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 is not 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 effect 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.[188] The 301 Special Reports designated each country in this study, with the exception of the

188. *See supra* Part II.A.3.

United States, as a member of the Priority Watch List.[189] Our subsequent statistical analysis resulted in a significant, positive correlation between the United States' strong enforcement regime and soybean yield, soybean production, soybean exports, and soybean imports.[190] This strong correlation was not found in the other countries. These results intuitively follow from the difference between soybean 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.[191] 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.[192] Thus, the establishment and enforcement of an intellectual property regime is of greater necessity for soybeans than for maize, as soybean 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 will not be protected by an effective enforcement regime, because an ineffective enforcement regime leads to lower production numbers.[193]

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 explanation for 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

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189. The 301 Special Reports made these designations 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.

190. A significant correlation was also found between wheat and maize hectares planted.

191. *See* Fernandez-Cornejo, *supra* note 150, at 18-20.

192. *Id. See also* Endres & Goldsmith, *supra* note 74, at 247.

193. 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 show 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.

relatively common feature among countries authorizing utility patents in the plant context) as well as 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 about enforcement regimes is correct or whether the productivity is a result of the fact that utility patents are 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.

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 such that it will realize a return on investment. To that end, a strong intellectual property system, comprising both laws that establish intellectual property rights and a system to enforce these rights, has always been considered 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 powerful correlations would exist 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 by 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[194] and plant variety protection applications. This further supports the underlying theory that links innovation to intellectual property.

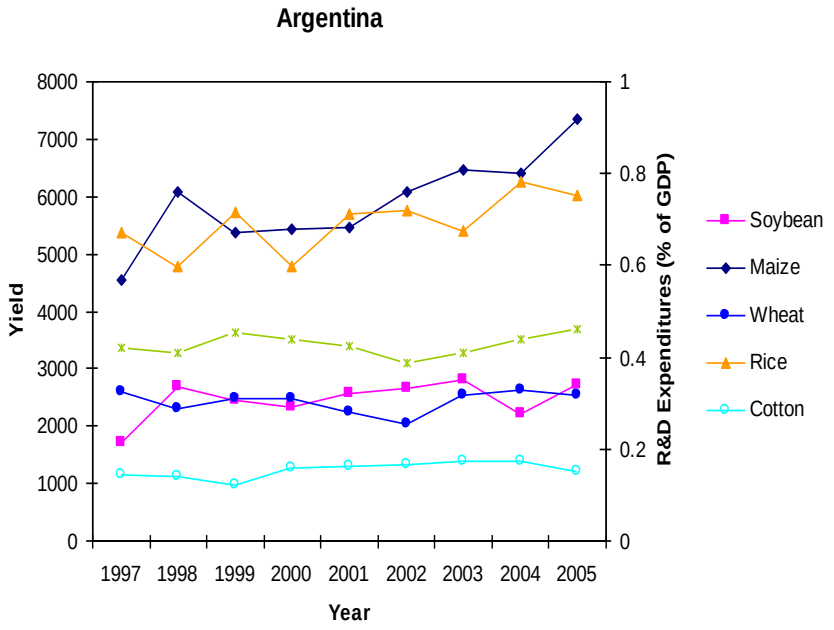
The final aspect of our analysis yielded results similarly consistent with our hypothesis. We found a significant, positive correlation between strong intellectual property enforcement regime and crop productivity, especially for soybeans.

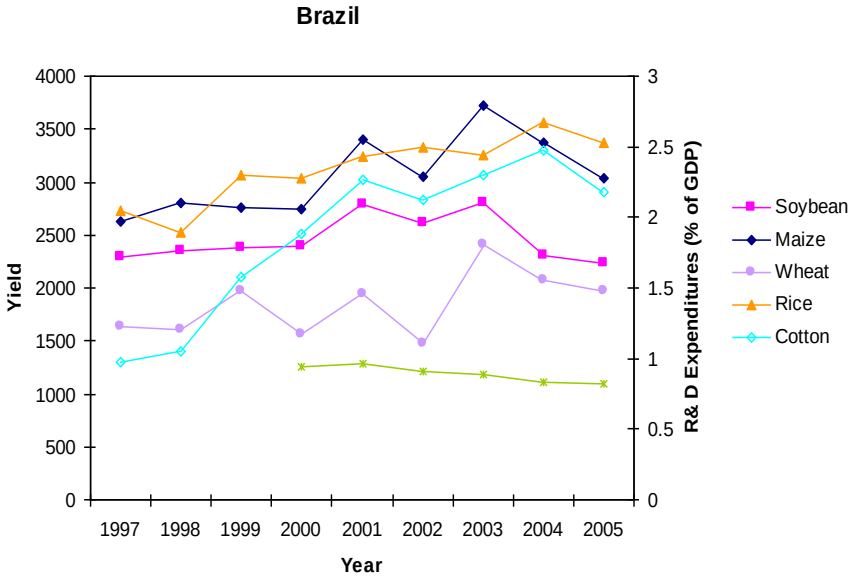
Although the results of our empirical study do in some respects comport with the underlying theory that intellectual property is a necessary precursor to innovation, significant uncertainty remains, especially with respect to crops other than soybeans. While some measures of innovation in the agricultural 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 opportunity 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 the strength of these relationships may be more nuanced and complex than previously considered.

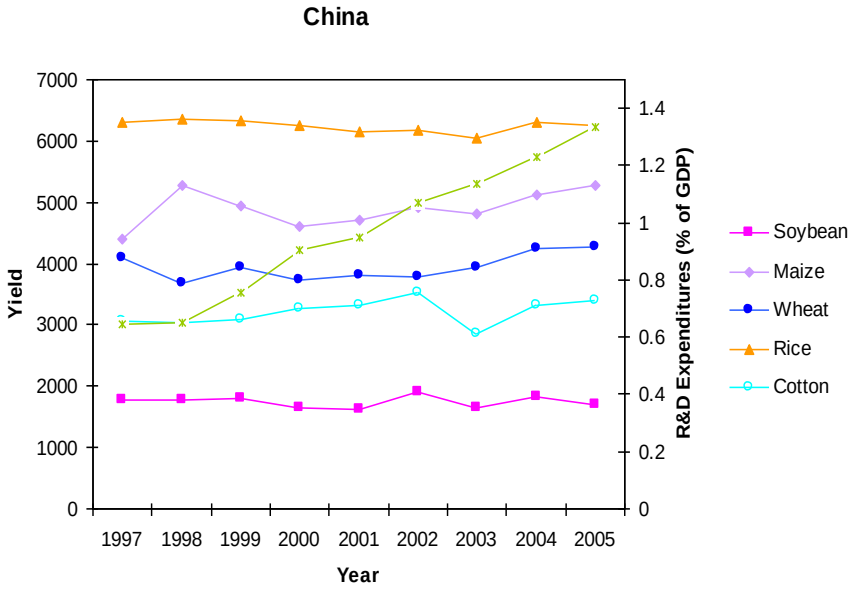
194. Soybean hectares planted had a coefficient of 0.56700, a p value of <.0001, and an adjusted R squared of 0.6837; soybean production had a coefficient of 0.74737, a p value of <.0001, and an adjusted R squared of 0.6786; soybean yield had a coefficient of 0.17946, a p value of <.0001, and an adjusted 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.

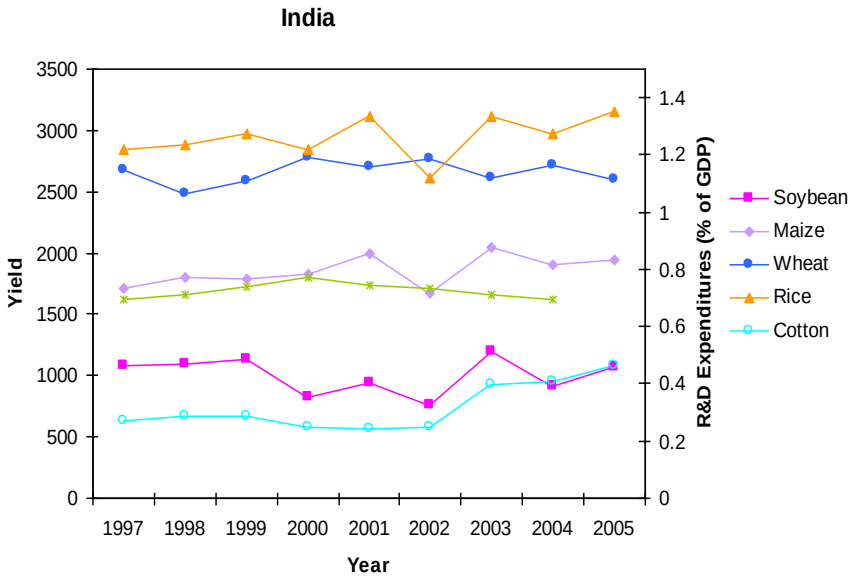
Appendix A:

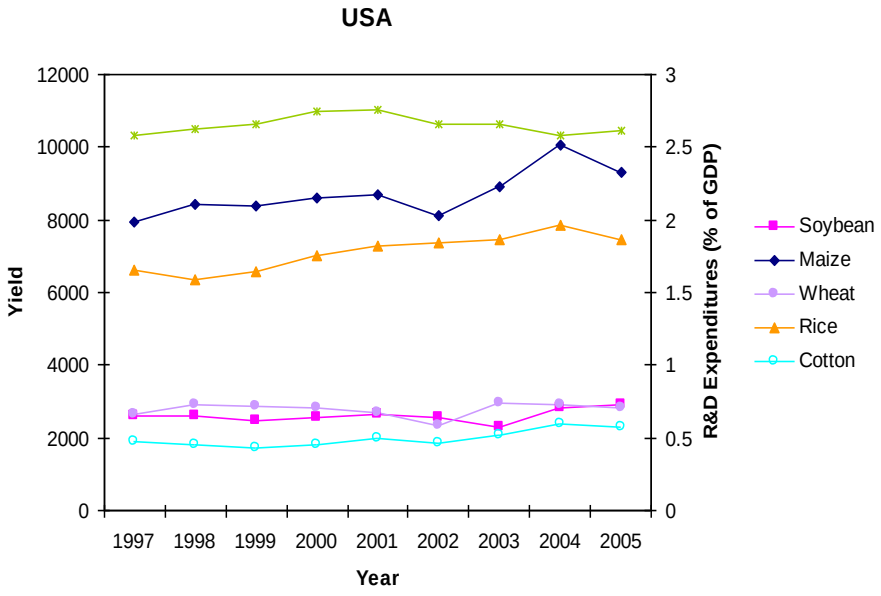
Crop Yield in Argentina, Brazil, China, India, and the United States from 1985-2005






China
Yield
R&D Expenditures (% of GDP)
Year
Soybean
Maize
Wheat
Rice
Cotton
7000
6000
5000
4000
3000
2000
1000
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1997
1998
1999
2000
2001
2002
2003
2004
2005


India
Yield
R&D Expenditures (% of GDP)
Year
Soybean
Maize
Wheat
Rice
Cotton
3500
3000
2500
2000
1500
1000
500
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1997
1998
1999
2000
2001
2002
2003
2004
2005


USA
Yield
R&D Expenditures (% of GDP)
Year
12000
10000
8000
6000
4000
2000
0
3
2.5
2
1.5
1
0.5
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
Soybean
Maize
Wheat
Rice
Cotton