OECD Food, Agriculture and Fisheries Papers No. 73

Innovation and the Experience with Agricultural Patents Since 1990

FOOD FOR THOUGHT

Douglas C. Lippoldt

OECD

OECD FOOD, AGRICULTURE AND FISHERIES PAPERS

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The publication of this document has been authorised by Ken Ash, Director of the Trade and Agriculture Directorate.

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Abstract

INNOVATION AND THE EXPERIENCE WITH AGRICULTURAL PATENTS SINCE 1990: FOOD FOR THOUGHT

By Doug Lippoldt, OECD

This report considers developments in agricultural patents since 1990 and their economic implications. It first provides an overview of the international framework for intellectual property protection and of the general trends in the stringency of protection in OECD countries. It then presents developments in the number of patents originating from OECD and other countries that are granted in Europe and the United States, for all fields and for agriculture and food technologies. These illustrate the leading role played by OECD countries in the provision of successful applications, although non-OECD countries increased their share of the total between 1990 and 2010. Finally, econometric analysis is used to assess the relationships between patenting and selected indicators of innovation and economic performance. The results points to favourable economic developments associated with the patent reforms in the recent decades.

Keywords: Agriculture, innovation, patents, intellectual property rights, intellectual property protection, performance

JEL classification: Q16, Q17, O34

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1.   Introduction

This report considers developments in agricultural patents for the period since 1990 and provides an illustration of the economic implications of these developments. Two dimensions make this timeframe particularly interesting for observers of these developments: 1) the past two decades have been a period of change in the international framework for protection of patents, and 2) the pace of technological change appears to have accelerated (e.g. Brynjolfsson and McAfee, 2012). Moreover, the topic is of strong policy relevance as policy-makers, including those of the G20 countries, continue to seek avenues for promotion of agricultural innovation and productivity.[1]

2.   Agricultural patents: The international framework for protection

New ideas embodied in intellectual property – such as patents – can contribute to technical progress with "disproportionate" impacts on economic growth (e.g. Jones, 2004; Warsh, 2006; Lippoldt, 2011). A single idea can be applied repeatedly in a non-rivalrous fashion, potentially yielding big returns on investment. As Jones (2004) notes, "Because of the non-rivalrous nature of ideas, output per person depends on the total stock of ideas in the economy instead of the per capita stock of ideas." Unlike a material resource, the same bit of intellectual property can be made available simultaneously and repeatedly on a non-exclusive basis to multiple users, generally at a low marginal cost.[2] Given the economic potential of ideas, policy makers may be particularly motivated to design policies with a view to boosting development of new intellectual property domestically and improving access to existing intellectual property from abroad.

Property rights are essential to the functioning of markets. As noted by Demsetz (1967, p. 347), "Property rights are an instrument of society and derive their significance from the fact that they help a man form those expectations which he can reasonably hold in his dealings with others. These expectations find expression in the laws, customs, and mores of a society. An owner expects the community to prevent others from interfering with his actions, provided that these actions are not prohibited in the specifications of his rights."

In light of the intangible nature of intellectual property, it can be challenging for the owners to assert their property rights and appropriate benefits from their innovations. In some cases, alternative approaches such as exploitation of first mover advantages in the market may provide means to reap returns on investment in innovation (e.g. Boldrin and Levine, 2007). But, in other cases, an absence of adequate protection could undermine incentives for development of some types of innovation. As Demsetz states (p. 359), "If a new idea is freely appropriable by all, if there exist communal rights to new ideas, incentives for developing such ideas will be lacking. The benefits derivable from these ideas will not be concentrated on their originators. If we extend some degree of private rights to the originators, these ideas will come forth at a more rapid pace."

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1.   For example, see the following reports: G20 Interagency Group (2012), pp. 33-36, and G20 Vice Ministers (2012), p. 9, point 14.ii.

2.   Maskus (2000, p. 28-29) provides a clear description of these characteristics noting that intellectual property, being based on information, has two traits of a public good: 1) a nonrivalrous aspect, meaning that one person's use of the intellectual property does not diminish another's use and 2) a non-excludable aspect meaning that it may not be possible by private means to prevent others from using the information without authorisation.

With respect to technological innovation, patents are a key form of intellectual property. Patents are exclusive rights granted to innovators upon approval of an application to national authorities with regard to inventions that are novel, useful and mark an innovative step over existing technology.[3] Internationally, reform efforts over the past two decades have promoted increased stringency in the protection of patent rights. These reforms were driven, in part, by a series of international agreements. The World Trade Organization's (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is perhaps the most well known of these international agreements. It entered into force in 1995 and provides a foundation for protection of intellectual property, establishing near-global minimum standards of protection as well as a mechanism to enforce these commitments via the WTO's Dispute Settlement Understanding. The agreement covers a broad range of intellectual property including patents.[4]

The TRIPS Agreement provides that patents shall be available – with a few exceptions – in all fields of technology for inventions that are new, non-obvious and useful. Of particular importance for agricultural innovation, one exception concerns plant varieties, which may be protected by patents or excluded and protected via a *sui generis* system[5] such as the one provided under the convention of the International Union for the Protection of New Varieties of Plants (UPOV), or by any combination of those two options. In addition, the TRIPS Agreement made clear that patents should be available for products and processes, provide at least 20 years protection, and ensure the owner's right to prohibit use by third parties without consent. In view of their economy-wide relevance to promotion of product and process innovation, the present assessment focuses on patents.[6]

The TRIPS Agreement references earlier international accords including the Paris Convention for the Protection of Industrial Property and operates in conjunction with some of them. In the area of patent protection, a key accord is the Patent Co-operation Treaty (PCT) of the World Intellectual Property Organisation (WIPO), which was last modified in 2001.[7]

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3.   As noted in OECD (2013, p. 10), the Oslo Manual provides a useful definition of innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (OECD and Eurostat, 2005). Patents are particularly important with respect to product and process innovation, though they may be relevant for other aspects of innovation in some cases.

4.   The TRIPS Agreement covers patents, plant variety protection, copyright and related rights, trademarks, undisclosed information (trade secrets), geographical indications, industrial designs and topographies of integrated circuits.

5.   In law, the term *sui generis* refers to a system that is "unique in its characteristics." Such systems may be tailored to the needs in each jurisdiction, employing various approaches for protection of plant varieties.

6.   Depending on availability of sufficient resources, further analyses could usefully focus on empirical assessment of innovation with respect to each of the other types of intellectual property. Currently, data constraints limit the possibility to undertake such assessments in some cases. For example, there is not a consistent international data set concerning plant variety protection in Europe (due to non-exclusive regional and national statistics and the risks of double counting of new varieties); thus, plant variety protection could not be taken into account for the present study. In a further example, trade secrets could not be covered due to the lack of comparable data: there are by definition no public data on undisclosed information (trade secrets) (Lippoldt and Schultz, 2014).

7.   For more information on the PCT, see: **http://www.wipo.int/pct/en/texts/articles/atoc.htm**. (NB, here and below all hyperlinks in this paper have been verified as being valid as of 1 February 2015.)

Among other objectives, the PCT provides a framework for international application, search, and preliminary evaluation of patent applications. Moreover, over the past two decades, there were a number of accessions to WTO and WIPO that further expanded the reach of the TRIPS Agreement and PCT. In addition, other international accords supplement the framework, including the International Treaty on Plant Genetic Resources for Food and Agriculture (FAO, 2009).[8] Finally, in some cases, national law and regional or bilateral accords provide for protection beyond the TRIPS-minimum standards such as with respect to remedies or administrative aspects of the system.[9]

Taken as a whole, the various reform efforts have led to a notable increase in protection for patents. One oft-cited indicator of the stringency of patent protection is the Patent Rights Index developed by Walter Park and colleagues at American University (Park, 2008). The index is based on laws on the books and considers stringency across five dimensions including: membership in relevant international treaties, patentability of different types of subject matter, restrictions on patent rights, enforcement provisions and duration of protection (Annex 1). Figure 1 presents the evolution of the stringency of protection during the period from 1960 to 2005; it highlights the notable increases in protection following the entry into force of the TRIPS Agreement.

The patent reform efforts get at the heart of a social bargain with innovators (Maskus, 2000 and 2012). In exchange for disclosing in some detail the nature of an innovation that meets the prescribed criteria, the innovator is granted market exclusivity for a specific period of time. This is intended to provide innovators with the ability to appropriate a share of the economic benefits from their innovations and to provide a mechanism to encourage the diffusion and use of the innovation. Stronger patent rights, for example, might encourage foreign rights holders to trade, invest directly or license intellectual property (Branstetter et al., 2006). The increased diffusion of innovative technology can play a central role in boosting output per worker and is an important determinant of income levels.[10]

At the same time, it should be kept in mind that firms may employ various intellectual property strategies when entering a market (e.g. Park and Lippoldt, 2008; Fosfuri et al., 2007; Lippoldt, 2011). They may rely on patents or other types of intellectual property rights, alternatively or in combination. These other rights concern protection of copyright and related rights, trademarks (including service marks), geographical indications, industrial designs, layout-designs (topographies) of integrated circuits, and undisclosed information including trade secrets. Firms may utilise strategies involving exclusive proprietary approaches, or they may employ open innovation models that can utilise intellectual property rights (IPRs) to prevent exclusive appropriation by innovators (in the latter case, the innovators may rely on sales of related services to appropriate benefits from the innovation, as happens with some types of software), or they may use a blended approach with some open and some exclusive

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8. The *International Treaty on Plant Genetic Resources for Food and Agriculture*, Food and Agriculture Organisation, Rome, is available on-line here: **ftp://ftp.fao.org/docrep/fao/011/i0510e/i0510e.pdf.**

9. The administration of the patent system also plays a potentially important role in terms of delivery of quality patents that provide an appropriate degree of protection (Dons and Louwaars, 2012). E.g., patents should be clearly defined with a scope in line with the nature of the invention and not overly broad.

10. For example, see WTO (2002) for a discussion and bibliographic references.

elements. In this firm-level strategic decision-making, patents are just one element in the mix and other factors may drive the decision-making.[11]

Figure 1. Patent Rights Index, 1960-2005

■ OECD Countries (n=30)　■ Others (n=92)
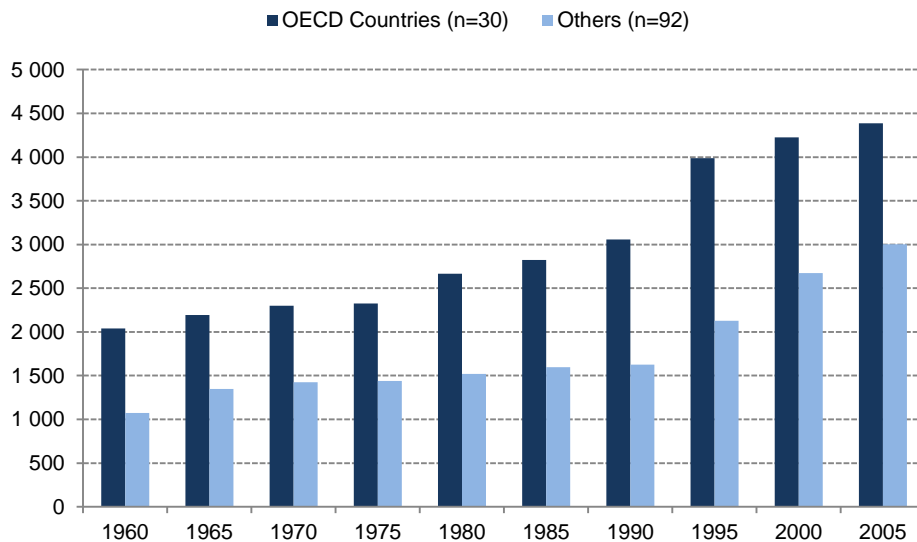
Notes: This figure refers to OECD countries that were members prior to 2005. The index is available at five-year intervals. It reflects the situation with respect to laws on the books as of the year shown in the chart.

Source: Park, W.G. and D. Lippoldt (2008), "Technology Transfer and the Economic Implications of the Strengthening of Intellectual Property Rights in Developing Countries", *Trade Policy Working Paper*, No. 62, OECD, Paris, available at: **http://dx.doi.org/10.1787/244764462745**.

The intellectual property reforms in recent decades have also attracted criticism. For example, Correa (2005) and others have challenged the legal and economic implications of strengthening IPRs including patents, alleging that the system of international IPR rules is imposing an undue burden on developing countries. Where patent standards are not well defined, some observers (e.g. Bessen, 2003) have pointed to possible impediments to innovation: "patent thickets" could arise as a consequence of multiple patent claims pertaining to various aspects of a given technology, blocking further innovation in that technology.[12] Lessig (1999) has challenged the privatisation of the so-called "intellectual commons" and the expanded scope of patentable innovation in the United States that now includes such areas as Internet business methods.[13] In view of such concerns, empirical assessments can play an important role in illuminating the experience with the performance of the IPR system in the real economy, highlighting the actual economic responses to IPR reforms.

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11. For example, market scale is a prime factor in locational decisions concerning investment and market entry (A.T. Kearney, 2007). Such considerations may take precedence over availability of effective IPR protection. However, in weak IPR environments firms may then need to take other precautions to maintain their competitiveness (such as holding back vulnerable technologies from such markets). Also see Kortum and Lerner (2000) for a discussion of trends in firm-level exploitation of technological opportunity.

12. For example, a multiplicity of poorly defined patent claims targeting various aspects of a given technology could increase legal complexity, fragment ownership leading to high licensing costs, or create uncertainty as to the scope of market exclusivity for existing inventions.

13. Further examples of such critiques can be found in Bessen and Meurer (2009) and Jaffe and Lerner (2007).

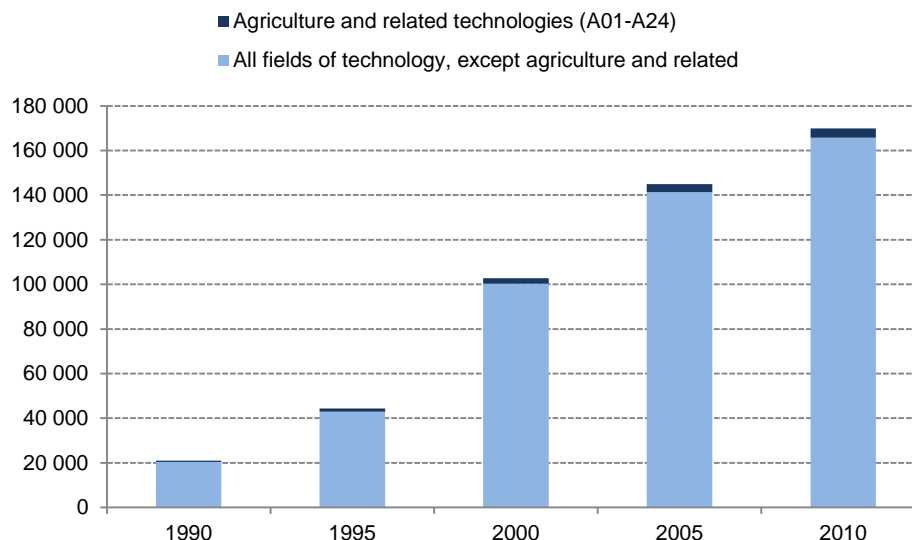## 3.   Agriculture and foodstuffs related patents

Recent OECD work has highlighted the role of IPRs – including patent rights – as an important factor influencing the performance of agricultural innovation systems (OECD, 2012a and 2012b; OECD, 2013). The empirical assessment presented below aims to shed light on the actual experience with patenting since 1990. It begins with a review of statistical indicators of patenting, including both applications and grants of patents. It then considers the relationship of these developments with other relevant indicators of economic performance and policy. **The overarching hypothesis is that the strengthening of patent protection during the period since 1990 increased incentives for innovation, technology transfer and technology diffusion and was associated with improved economic and innovation performance in agriculture.** This hypothesis can be tested using available indicators for the stringency of patent rights and indicators related to economic and innovation performance in agriculture, without directly measuring and testing the intervening incentives (e.g. such as price effects).

Statistical assessment

During the period since 1990, the world has experienced tremendous growth in the volumes of patents. Figure 2 highlights the increase in applications under WIPO's PCT, driven in part by the accelerating pace of innovation and increased recourse to the PCT by innovators (a filing via the PCT gives inventors global priority in their claim for up to 12 months). Agriculture and foodstuffs-related applications account for a relatively small fraction of the total.[14] Taking into account the core sections for these technologies in the *International Patent Classification* (IPC, sections A01-A24), agricultural and foodstuffs-related patent applications comprised 3% of the total PCT applications in 1990, a percentage that declined over the period to 2.4% in 2010.[15] In 2010, there were 3983 applications in these sections.[16]

The granting of a patent is intended to recognise technological progress in that the invention must clear a three-part test for novelty, utility and innovative step beyond existing technologies. Thus, for analysis of innovation, it is interesting to focus on patents actually granted (i.e. to focus on those inventions that have cleared the hurdle). As patents are granted at the national or regional level, applicants generally seek out patent offices in the largest markets. The European Patent Office (EPO) and the US Patent and Trademark Office (USPTO) are particularly important in this regard.

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14.   With respect to the analysis of patents presented here, agriculture and foodstuffs are each defined in line with the International Patent Classification. As used here, agriculture includes agriculture, forestry, animal husbandry, hunting, trapping and fishing. As used here, foodstuffs include foodstuffs and tobacco. Annex 2 presents a more detailed listing of the types of inventions classified in this paper as being under agriculture or foodstuffs.

15.   Details on the selection of patent categories in the present assessment are given in Annex 2. For more information on the IPC, see: **http://www.wipo.int/classifications/ipc/en/**.

16.   The leading technology sub-classes for these sections were: 1) biocides, e.g. as disinfectants, pesticides or herbicides; pest repellents or attractants; plant growth regulators; preservation of bodies of humans or animals or plants or parts thereof (1001 applications, 25% of the total for these sections); 2) foods, foodstuffs, or non-alcoholic beverages, not covered elsewhere; their preparation or treatment, e.g. cooking, modification of nutritive qualities, physical treatment; preservation of foods or foodstuffs, in general (689 applications, 17% of the total for these sections); and 3) animal husbandry; care of birds, fishes, insects; fishing; rearing or breeding animals, not otherwise provided for; new breeds of animals (362 applications, 9% of the total for these sections).

Figure 2. Patent Applications under the Patent Cooperation Treaty, 1990-2010

■ Agriculture and related technologies (A01-A24)

■ All fields of technology, except agriculture and related

*Source:* OECD Patent database, October 2013.

Figures 3 and 4 present the flows of patents granted by the EPO and USPTO, taking account the applicant's country of residence and the year the application was filed. The figures drop off in recent years in part because some patents filed in those years may remain in process. In each of these figures, Panel A presents the overall volumes of patents granted for all fields of technology. The figures confirm the leading role of OECD countries in provision of successful applications to these two patent offices, though non-OECD countries have increased their shares of the total. At the EPO, the non-OECD share rose from about 1% in 1990 to nearly 4% in 2010. At the USPTO, the non-OECD share rose even more substantially from about 2% in 1990 to nearly 17% in 2010.

Figures 3 and 4 highlight the experience for agriculture and in particular for *Agriculture; forestry; animal husbandry; hunting; trapping; fishing and foodstuffs*, classification A01, (Panels B) and *Foodstuffs; tobacco; related chemistry*, classification A21-24 and related, (Panels C). Overall, the combined patent grants for agriculture in these two areas during the period from 1990 to 2010 ranged between 4 and 5% of the total at the EPO and between 7% and 11% at the USPTO. In most years, the non-OECD countries' share of agriculture-related patents was smaller than their share for all classes of patents taken as a whole. In other words, OECD countries exhibited better performance in the share of patents granted in *Agriculture* and related technologies and *Foodstuffs* and related technologies than non-OECD countries (i.e. comparative advantage).

Among patents actually granted, not all are created equal. There is further variation in terms of the utility from one patent to the next. Variation in patent quality may further influence the economic consequences of the upsurge in patents being granted. Box 1 considers the issue of patent quality in agriculture and foodstuffs-related technologies and identifies a concern with respect to possible shortfalls in the relative performance in the sector.

Figure 3. Evolution of patents granted via the European Patent Office, by filing date
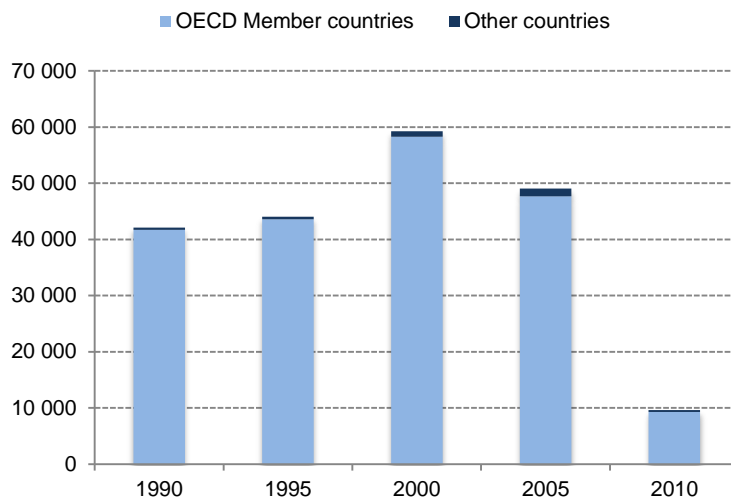
Panel A. Patents granted: All fields of technology

■ OECD Member countries   ■ Other countries

Panel B. Patents granted: Agriculture; forestry; animal husbandry; hunting; trapping; fishing (A01)

■ OECD Member countries   ■ Other countries

Panel C: Patents granted: Foodstuffs; tobacco; related chemistry (A21-24, C08B, C11-13)

■ OECD Member countries   ■ Other countries
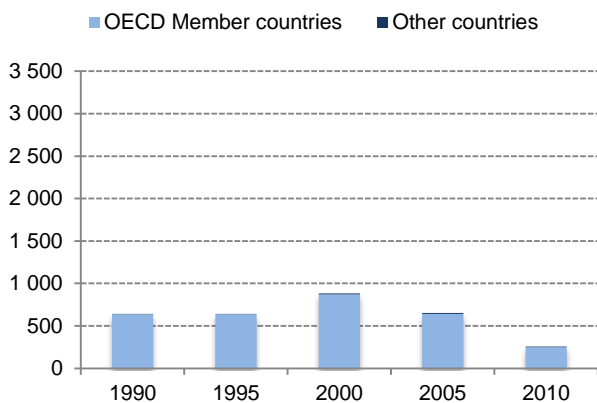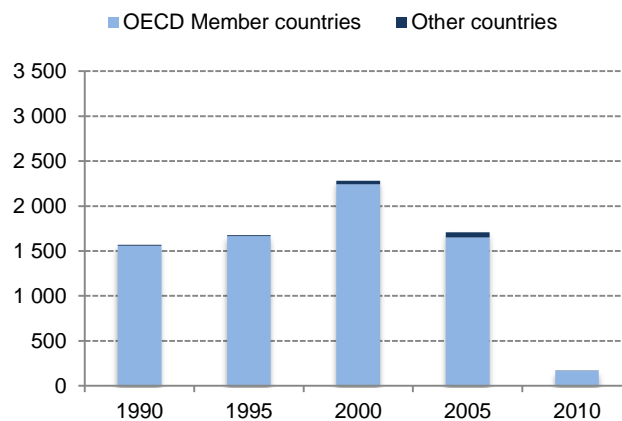
Note: For recent years, some patent applications may still be in process and are not included in these counts.

Source: OECD, Patent Database, October 2013.

Figure 4. Evolution of patents granted via the United States Patent and Trademark Office, by filing date
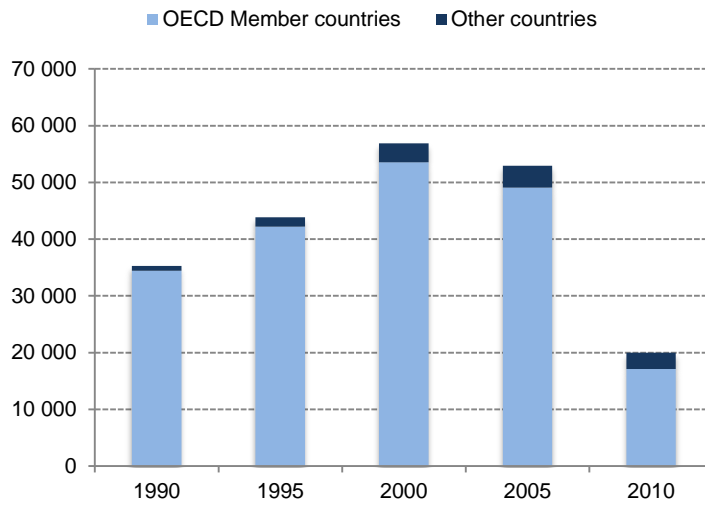
Panel A. Patents granted: All fields of technology

■ OECD Member countries ■ Other countries

Panel B. Patents granted: Agriculture; forestry; animal husbandry; hunting; trapping; fishing (A01)

■ OECD Member countries ■ Other countries

Panel C: Patents granted: Foodstuffs; tobacco; related chemistry (A21-24, C08B, C11-13)

■ OECD Member countries ■ Other countries
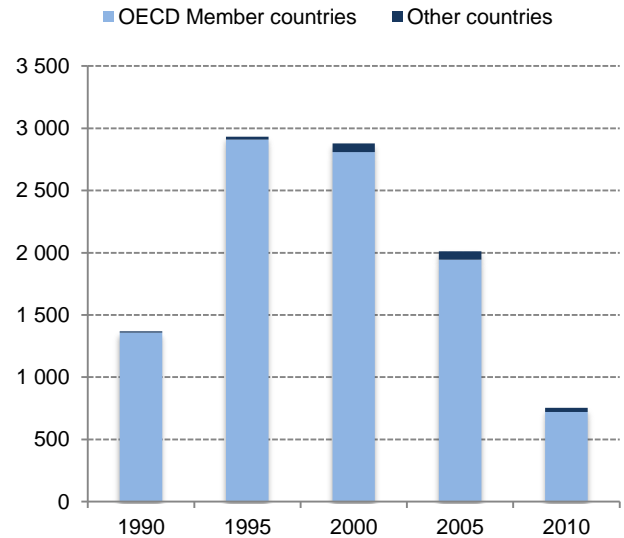
Note: For recent years, some patent applications may still be in process and are not included in these counts.

Source: OECD, Patent Database, October 2013.

Box 1. Assessment of Agricultural Patent Quality

Squicciarini *et al.* (2013) developed an experimental set of indicators of patent quality, drawing on information available from patent documents and calculated by aggregating the results for individual patents. The basic **composite index of patent quality** takes into account four elements: the number of forward citations (up to 5 years after publication), the patent family size (based on number of patent offices at which the patent has been granted), the number of claims made in the patent document, and the generalisation of the patent (based on the distribution of subsequent patent citations across IPC technology classes). These four aspects may matter economically because they reflect the potential breadth of utility of the innovation embodied in a patent and its relevance to further innovation. The scores for each of these elements are normalised and equally weighted to yield an index that can potentially range from 0 to 1. Most scores are clustered between 0 and 0.4. In order to help ensure the scores are representative, the version of the index discussed below only covers those countries with 10 or more patent grants in each year covered.

A review of the index of patent quality data reveals that by this measure:

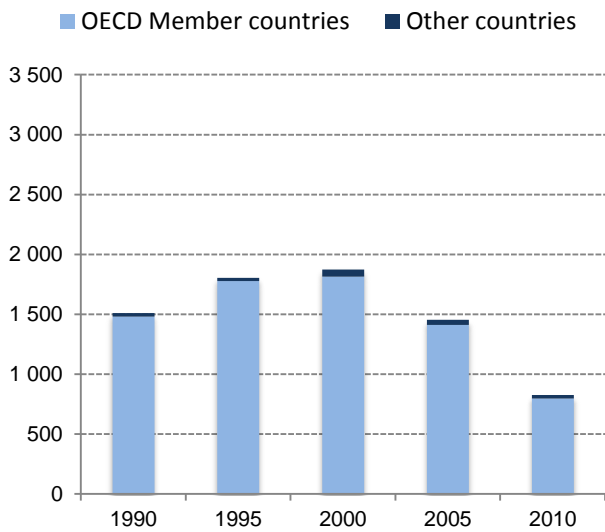- The average patent quality for *Agriculture and related technologies* and *Foodstuffs and related technologies* fell at the EPO. At USPTO, the score for *Agriculture and related technologies* increased slightly over the period, whereas for *Foodstuffs and related technologies* the average score fell.

- The average quality of agricultural patents tended to fall or remain below the averages for all technologies in recent decades (Box Figure 1). By the end of the period, the average patent quality scores in *Agriculture and related technologies* were about 7% below the overall score for all technologies at EPO and 10% below the overall score at USPTO. In the case of *Foodstuffs and related technologies*, the sector lagged the average by 10% at both EPO and USPTO.

While this result does not provide direct information on prices or other economic implications of patent quality in the sectors covered here, it does provide an indication that patents in these sectors may perform less well than those in other sectors on average in their scope, diffusion and take-up by other innovators. This patent quality issue may well have economic implications and therefore merits further exploration.

Box Figure 1. Agriculture and foodstuffs related technologies relative the average (1.0) for all technologies (n= countries covered)
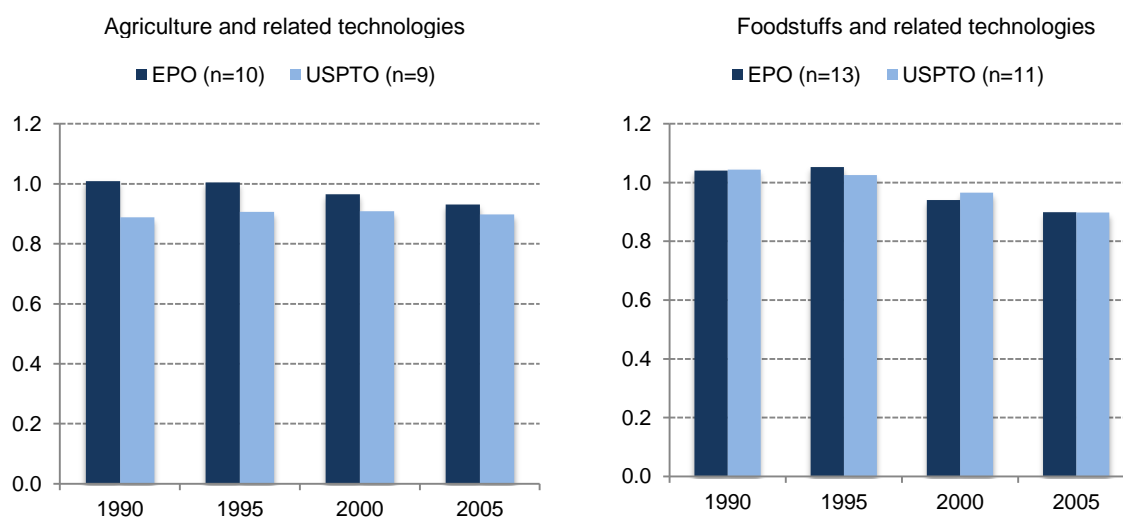
Source: Author's calculation based on OECD, Patent Database, October 2013.

The relationship of patenting to economic performance in agriculture

Romer (1990) highlights the importance of technological innovation in contributing to improved utilisation of specific pools of raw materials. This is an essential feature of sustainable economic performance. He also notes "technological change arises in large part because of intentional actions taken by people who respond to market incentives." In principle, patents can provide incentives for such innovation and its diffusion.

The following section attempts to assess the association of patented agricultural innovation with selected aspects of economic performance. The analytical method employed here with respect to agriculture is similar to the approach utilised in a number of earlier OECD studies that considered the relationship of IPR protection to international trade, investment and licensing. Drawing on these earlier studies, the present paper considers three areas where these earlier papers found positive relationships to patents. These include the association between newly patented inventions and productivity (e.g. Cavazos and Lippoldt, 2011), the association between the utilisation of the system for patent protection and access to foreign technological imports (e.g. Park and Lippoldt, 2005), and the relationship between the stringency of patent protection and the volume of newly patented innovation (e.g. Park and Lippoldt, 2008).

It is important to keep in mind that agriculture-related patents only provide a partial indication of innovation in the sector. They cover a portion of a specific type of innovation, which is technological invention.[17] Moreover, depending on the nature of the invention, innovators may choose to protect the underlying technological invention via patents or via other forms of intellectual property protection (e.g. plant variety protection, trademarks, or geographical indications) and trade secrets (business confidential information).[18] Alternatively, the inventors may forego such protection entirely.

It should be kept in mind that patents are issued nationally. Thus, they provide an indication of domestic innovation as well as innovation by foreign inventors wishing to protect their inventions in the nation (often in preparation for transfer of the technology to the market via trade or investment). In addition, it is worth noting that with patents there is public disclosure of the invention and some "leakage" in experience due to staff turnover and other forms of learning based on exposure to the invention. Such spillovers may lead others to undertake further incremental innovation or to innovate around the original technology. This can lead to indirect positive effects on economic performance that are stimulated by the original patented invention but not directly produced through the utilisation of the patented invention.[19]

In the first round of analysis, the underlying hypothesis is that availability of increased volumes of patented inventions may contribute to improvements in output performance. Thus, indicators of patent flows may be positively associated with improvements in output such as domestic value-added in exports, value-added per worker and yields per hectare. In the second

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17. There are other types of innovation (e.g. related to styling or marketing) for which patents may not be the most appropriate form of protection (e.g. there are cases where copyright or trademark may be more appropriate).

18. In addition, some patented inventions relevant to agriculture may be classified as having another primary sector of application (e.g. general purpose information technology) and may not be classified under agriculture.

19. See, for example, Coe, D.T., and E. Helpman (1993), "International R&D Spillovers," NBER Working Paper No. 4444 and Nadiri, M.I., and S. Kim (1996), "International R&D Spillovers, Trade and Productivity in Major OECD Countries", NBER Working Paper No. 5801; among other examples in the literature.

round of analysis, the underlying hypothesis is that availability of patent protection will have a positive effect on technology transfer from abroad via trade in agricultural equipment (i.e. if innovators seek patents in order to protect their inventions in a destination market, then they may be more likely to export their technology to the market). The improved technology may in turn have a productivity effect. In the third round of analysis, the stringency of available patent protection is considered. The hypothesis is that greater stringency of protection may be associated with relatively higher numbers of patent grants. In an environment, where patents are well protected, inventors may bring forth more inventions.[20]

The relationship between patenting and indicators of economic and innovation performance is assessed using a standard linear regression model, presented in Annex 3. The country coverage focused on a core sample of 35 countries from around the world (listed in Annex 3), reflecting considerable economic and geographic diversity. In most of the runs, at least some countries were dropped due to missing data.[21] Due in part to data limitations, the sample consists of data at five-year intervals beginning as early as 1990 for some series and ending with the 2010 observations for some series (Annex 4 provides information on the data sources).[22] The dataset consisted of an unbalanced panel, in that it was not possible to cover all countries in all time periods. The regression analysis employed pooled data and an ordinary least squares approach. Country fixed effects were included and help to address concerns with respect to some potential omitted variable issues.

As Park and Lippoldt (2008) have observed, IPR reforms in a given country generally roll out over a multi-year period and there is an advance signalling effect to domestic innovators and foreign rights holders prior to the actual change in the patent rights as measured by the index scores. Thus, the models presented here naturally include a degree of built-in lag with respect to patent rights. Similarly, the consideration of a patent application takes place over a period of years.[23] During this period, there may be a signalling effect for potential users, which may expedite subsequent adoption. Where the technology is foreign and already in use in another country, this experience may facilitate rapid adoption once patents are granted in further countries and those markets thereby opened to imports.

Table 1 illustrates the relationship of innovation to certain aspects of agricultural performance with respect to the subset of technological innovation that is captured by patent applications.[24] It presents the results for eight regression runs. These consider association of patents with economic performance in three contexts. They consider results for a broadly defined patent class and for a more narrowly defined patent class. They check the robustness of the associations.

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20. NB, this third round of analysis is based on patent grants. Granting a patent means that the application has successfully cleared the national review; this is a higher standard than simply using counts of patent applications. On the other hand, patent application data are more widely available for a greater number of countries and hence are used in most of the other analyses in this section of the paper.

21. In a few cases, additional countries were brought in, data permitting.

22. The choice of a five year interval was driven, in part, by data availability considerations.

23. The typical duration for consideration of an application is two years or more. For example, see the presentation "Patent backlogs, inventories, and pendency: An international framework", 23 November 2013, by Tony Clayton, UK IPO; Benjamin Mitra-Kahn, IP Australia; Nadiya Sultan, UK IPO; and Stuart Graham, USPTO, available here on the OECD web site: **http://www.oecd.org/site/stipatents/PSDM2013_7_2_Clayton_Mitra-Khan_Sultan_Graham.pdf**

24. As noted above, patents capture just a portion of technological innovation.

The first three runs highlight the relationship of the flows of patent applications to domestic value added in exports for agricultural products (i.e. embodied in foreign final demand for a country's agricultural products). The first run (1) considers the relationship for agriculture and foodstuffs patents as a group. The regression shows a relationship of weak statistical significance, whereby an increase of 1% in agricultural and foodstuff-related patent applications is associated with a 0.4% increase in domestic value added in agricultural exports, controlling for GDP per capita and agricultural foreign direct investment (FDI). The second run (2) considers the relationship of just agriculture patents to domestic value added in agricultural exports with the same controls. It shows a stronger relationship than the first run, with a larger coefficient for the patents variable and a stronger statistical significance. The third run (3) considers the relationship with agricultural patents lagged by one period as a test for endogeneity and controlling for GDP per capita. The relationship was positive and statistically significant.

A second set of regression runs in Table 1 considers the relationship of agricultural patent applications to agricultural value added per worker, controlling for GDP per capita. Here again the relationship of patent applications to the performance indicator was positive, but only weakly significant in run (4). In run (5), which incorporated the agricultural patent variable lagged by one period, the coefficient was still positive but not statistically significant.

A third set of regression runs in Table 1 highlights the relationship of patent applications to cereal crop yields, controlling for factors such as GDP per capita and the intensity of fertilizer usage.[25] In run (6), the variable for agricultural and foodstuffs patent applications is lagged by one period as a control for the possible problem of endogeneity.[26] The result is a positive and statistically significant coefficient for the patent application variable, highlight the favourable relationship to crop yields. In runs (7) and (8), the scope of patents considered is narrowed to cover just agricultural patent applications. In these runs, the only control is GDP per capita. Both run (7) and run (8), the coefficient for agricultural patent applications is positive and moderately significant. In run (8), the variable for agricultural patent applications was lagged by one period as a test for endogeneity.

Table 2 highlights a further set of illustrative relationships involving patents. Productivity can be driven by a complex set of factors that may influence the process of transforming inputs into outputs. Technological innovation is one factor that may influence this process.[27] Due to the complexity, it can be difficult to isolate the effects of incremental technological change on productivity (e.g. see Cavazos and Lippoldt, 2011). Thus, Table 2 considers the relationship of an important productivity input in agriculture, innovative agricultural

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25. A limitation of this analysis based on crop yields is that it does not take into account quality factors or environmental impacts.

26. For such models, independent variables are assumed to be unrelated to the error term. Statistical shortcomings that may lead to endogeneity issues in the model include measurement error, autocorrelation, simultaneity and omitted variables. A problem of endogeneity can arise if the independent variable is in fact determined by the dependent variable.

27. This observation goes back to Solow (1956), which delivered a major contribution to the theory of economic growth and provided a neoclassical elaboration that described the relationships of capital and labour to output, but with technology given as an exogenous factor. Romer (1990) led in subsequently developing a broader view that more accurately reflects important economic realities including technological change and accumulation of intangible assets (non-rival inputs), with a neoclassical model of growth with explicit provision for endogenous technological change.

equipment.[28] As was shown in the Figures, most patented agricultural innovation takes place in OECD countries (and, in fact, in just a small subset of OECD countries).[29] Thus, trade in agricultural equipment that embodies such patented innovation may be hypothesised to play a potentially important role in the economic performance of the sector.

In the first run (1) shown in Table 2, the positive and statistically significant coefficient indicates a favourable relationship of agricultural and foodstuffs patent applications to agricultural equipment imports. In this run, the patent variable was lagged by one period to test for endogeneity. In the second run in the table (2), the scope of patents was narrowed to consider just agricultural patent applications. Here again the coefficient was positive, though only weakly statistically significant. Taken together, these results may provide an indication that foreign rights holders respond positively to the availability of patent protection in a destination market, increasing their exports of agricultural equipment.[30] This in turn matters for growth in agricultural total factor productivity.

In run (3) of Table 2, the relationship of patent grants (agriculture and foodstuffs) via the US Patent and Trademark Office to subsequent agricultural total factor productivity is considered. The patent variable takes into account the inventor's country of residence. The coefficient for patent grants lacks statistical significance in run (3). The results for agricultural equipment imports, however, are positively associated (albeit with a weak statistical significance) with subsequent agricultural total factor productivity (TFP) growth[31]; and, we know from runs (1) and (2) in Table 2, that agricultural equipment imports are related to availability of patent protection.

Table 3 considers the importance of the patent rights framework (laws on the books) in an innovator's country of residence to the patent grant process at the EPO and USPTO. It examines the relationships separately for *Agricultural and related technologies* (A01) and *Foodstuffs and related technologies* (A21-A24). The strength of the patent rights framework in each country is considered based on the Patent Rights Index developed by Park (2008) et al., which is presented in Annex 1. In the case of the EPO patent grants for both technology fields, the Patent Rights Index is positive and significantly associated with the granting of EPO patents. This relationship is robust, with checks for endogeneity yielding similar results (i.e. with the patent index lagged by one period). Similar results were found for USPTO grants of patents for agricultural and related technologies. In the case of USPTO patent grants for Foodstuffs and related technologies, the coefficient was not statistically significant in

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28. Trade data use a different classification from patent data. While patent data are based on the IPR (Annex 2), the trade data employed in this paper are based on the Harmonised System. Agricultural equipment as defined here includes HS categories 8430-39.

29. In a concrete example using patent family data (taking into account ownership), King (2009) considers international technology diffusion with respect to agricultural biotechnology. He points out that the technology flows mostly between developed countries and that the technological diffusion through patent families is a significant predictor of international trade flows.

30. Since patents are issued on a national basis, innovators must apply in each country for each invention that they wish to protect. Thus, an uptick in patent applications by foreign innovators can signal that they wish to import their products into the economy concerned. The availability of such protection is one determinant of intellectual-property intensive imports. As most technological innovation takes place in just a small group of countries, such imports play an important role in technology transfer (Park and Lippoldt, 2008; Eaton and Kortum, 2002). Patent protection is associated positively with import volumes and not simply price effects (Lippoldt, 2011).

31. Agricultural TFP is simply the ratio of total output to total inputs in the sector. The present assessment considers growth in agricultural TFP over the subsequent 5-year period.

either specification (i.e. regardless as to whether the patent rights index was lagged or not).For the other cases, Table 3 highlights a generally positive relationship of the strength of patent rights protection to the development of technological inventions as recognised by two key patent offices. Thus, domestic and foreign innovators do appear to respond the availability of protection in their home countries, subsequently protecting their inventions in these two major markets.

4.   Conclusion

This report has provided an overview of the experience with agricultural patents in the years since 1990, an important time of patent reform around the world. The study demonstrates that much of the patented innovation in technologies related to agriculture and foodstuffs has taken place in OECD countries, though emerging and developing economies appear to be increasing their innovative activity in these areas. Generally, flows of patent applications and grants tend to be related to positive economic performance with respect to the indicators considered in the illustrative examples in this short paper. Moreover, the strength of patent protection in countries around the world tends to be associated with the granting of patents to their residents by the patent offices of the European Union and the United States. The stringency of available patent protection appears to provide a viable incentive to create and register agriculture and foodstuffs-related inventions that are novel, useful and mark an inventive step over existing technologies.

The methods employed in this paper highlight association and not causality; the results are valid for specific ranges and timeframes, and do not indicate whether further strengthening of patent rights would yield similar results. Moreover, they consider association between the variables presented and have not been adjusted to take into account some potentially important externalities such as environmental effects.[32] Nonetheless, the results point to favourable developments associated with the patent reforms in recent decades. Further research could contribute to confirmation and refinement of these findings. One area of potential economic importance in this regard is the issue of patent quality in agricultural and foodstuffs-related technologies and whether improvements in patent quality may play a role in boosting agricultural performance. Subject to availability of suitable internationally-comparable data, it would also be useful to extend the empirical analysis of agricultural innovation in order to examine the contribution of patents in relation to the contributions of other forms of intellectual property such as geographical indications or *sui generis* plant variety protection.

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32.   Environmental impacts could influence the net economic effects of technological innovation and diffusion. This influence might be positive or negative. Consequently, this issue could usefully be considered in follow on work in this area. OECD environmental-economic modelling provides an example of an initiative to take such factors into account: **http://www.oecd.org/env/indicators-modelling-outlooks/modelling.htm**.

Table 1. Illustrative relationships of domestic agricultural performance and patents, 1995 - 2010

All variables entered as natural logarithms	(1) Domestic value added embodied in foreign final demand: agriculture	(2) Domestic value added embodied in foreign final demand: agriculture	(3) Domestic value added embodied in foreign final demand: agriculture	(4) Agriculture Value Added Per Worker	(5) Agriculture Value Added Per Worker	(6) Cereal Crop Yields (kg per ha)	(7) Cereal Crop Yields (kg per ha)	(8) Cereal Crop Yields (kg per ha)
PCT Applications A01-A24	0.372767 *							
	0.185432							
PCT Applications A01-A24 (lagged 1 period)						0.068051 **		
						0.020522		
PCT Applications A01		0.423837 ***		0.073654 *			0.068389 **	
		0.088590		0.038220			0.033369	
PCT Applications A01 (lagged 1 period)			0.330403 **		0.048852			0.096559 **
			0.120412		0.052168			0.038838
GDP p/c constant USD	1.276893 *	-0.255363	-0.830798	0.898811 ***	0.805378 **	0.135277	0.292466 *	0.119049
	0.648374	0.582583	0.793415	0.186992	0.327926	0.174378	0.161400	0.252387
FDI in Agriculture	-0.021103	0.005440						
	0.061390	0.040643						
Fertiliser: Tonnes Per 1000 ha						0.220916 **		
						0.085907		
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Periods included	4	4	3	4	3	4	4	3
Years	1995-2010	1995-2010	2000-2010	1995-2010	2000-2010	1995-2010	1995-2010	2000-2010
Adjusted R2	0.934623	0.970983	0.921557	0.985186	0.990563	0.908654	0.898742	0.942436
Countries Covered	13	13	16	26	22	25	27	23
N	27	27	42	70	46	70	75	50

Note: Statistical significance is indicated in the tables as follows: *** $p < 0.01$; ** $0.01 < p < 0.05$; * $0.05 < p < 0.1$.

Table 2. Illustrative relationship of patents to productivity

	(1) Agricultural Equipment Imports (real USD); variables entered as natural logarithms	(2) Agricultural Equipment Imports (real USD); variables entered as natural logarithms	(3) Agricultural Total Factor Productivity (next 5 year's average growth)
PCT Applications A01-A24 (lagged 1 period)	0.073229 **		
	0.030299		
USPTO Patent Grants A01-A24 (Applicant's Country)			0.000265
			0.000225
PCT Applications A01		0.110892 *	
		0.061627	
GDP p/c constant USD	1.716150 ***	1.916241 ***	
	0.222120	0.298081	
Agricultural Equipment Imports (real USD)			0.000000011 *
			0.000000006
R&D Personnel as % of the Labour Force			6.326532 *
			3.029655
Literacy (PISA scores)			0.000363 **
			0.000164
Country Fixed Effects	Yes	Yes	Yes
Periods included	4	4	2
Years	1995-2010	1995-2010	2000-05
Adjusted R2	0.950155	0.955731	0.450548
Countries Covered	64	27	31
N	184	75	53

Table 3. Relationship of patent rights protection to patented innovation

All variables entered as natural logarithms	(1) EPO Patent Grants, Agriculture and related technologies, A01		(2) EPO Patent Grants, Foodstuffs and related technologies, A21-A24		(3) USPTO Patent Grants, Agriculture and related technologies, A01		(4) USPTO Patent Grants, Foodstuffs and related technologies, A21-A24	
Patent Rights Index Score (in inventor's home country)			1,11875	**	5,973267	**	0,26273	
			0,557693		1,839623		0.312944	
Patent Rights Index (lagged 1 period)	1.180995	**						
	0.497145							
GDP p/c constant USD	1.408951	**	0.632307		1.825112		2.152278	***
	0.656088		0.941022		1.180017		0.391700	
Trade Secrets Protection Index			1.310025	*	3.247318	**		
			0.763589		1.245244			
Business Expenditure on R&D (real USD)					-0.143889			
					0.185853			
Regulation Index (Fraser)	0.048294						-0.013597	
	0.464319						0.334050	
Country and Period Fixed Effects	Yes		Yes		Yes		Yes	
Periods included	5		5		5		5	
Years	1990-2010		1990-2010		1990-2010		1990-2010	
Adjusted R2	0.913105		0.921643		0.938082		0.934989	
Countries Covered	41		25		14		43	
N	134		97		34		160	

Annex 1.

Composition of the Patent Rights Index

1) Membership in International Treaties	Signatory	Not Signatory
-- Paris Convention and Revisions	1/5	0
-- Patent Cooperation Treaty	1/5	0
-- Protection of New Varieties (UPOV78 or 91)	1/5	0
-- Budapest Treaty (Microorganism Deposits)	1/5	0
-- Trade-Related Intellectual Property Rights (TRIPS)	1/5	0

2) Coverage	Available	Not Available
-- Patentability of pharmaceuticals	1/8	0
-- Patentability of chemicals	1/8	0
-- Patentability of food 1/8	0	
-- Patentability of surgical products	1/8	0
-- Patentability of microorganisms	1/8	0
-- Patentability of utility models	1/8	0
-- Patentability of software	1/8	0
-- Patentability of plant & animal varieties	1/8	0

3) Restrictions on Patent Rights	Does Not Exist	Exists
-- "Working" Requirements	1/3	0
-- Compulsory Licensing	1/3	0
-- Revocation of Patents	1/3	0

4) Enforcement	Available	Not Available
-- Preliminary Injunctions	1/3	0
-- Contributory Infringement	1/3	0
-- Burden-of-Proof Reversal	1/3	0

5) Duration of Protection	Full	Partial
	1	$0 < f < 1$

-- where f is the duration of protection as a *fraction* of 20 years from the date of application or 17 years from the date of grant (for grant-based patent systems).

Overall score for Patent Rights Index: sum of points under (1) – (5).

Note: The five key components are equal weighted, an approach that offered simplicity and proved to be robust in comparison to several alternatives. See Ginarte and Park (1997) and Park (2008) for details. The index was developed by Walter Park and colleagues at American University.

Source: Park, W.G. and D. Lippoldt (2008), "Technology Transfer and the Economic Implications of the Strengthening of Intellectual Property Rights in Developing Countries", *Trade Policy Working Paper*, No. 62, OECD, Paris, available at: **http://dx.doi.org/10.1787/244764462745**. .

Annex 2.

Relevant Sections of Data Classifications used here

I.   The International Patent Classification

The International Patent Classification (IPC) is maintained by WIPO. A search for the word "agriculture" in the IPC on-line publication (**http://web2.wipo.int/ipcpub/#refresh=page**, 22 November 2012) found 36 three and four digit classes and sub-classes with explicit references. The selection of IPC categories for the present analysis was based on this search for the keyword "agriculture", with some further adjustments to take into account only directly-related categories identified as such in the IPC manual. Via the OECD patent database, statistics are available according to IPC 4 digit codes: (**http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC**). The relevant sections are shown below.

1. Agriculture

A01 - Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing

A01B - Soil working in agriculture or forestry; parts, details, or accessories of agricultural machines or implements, in general

A01C - Planting; sowing; fertilising

A01D - Harvesting; mowing

A01F - Threshing; baling of straw, hay or the like; stationary apparatus or hand tools for forming or binding straw, hay or the like into bundles; cutting of straw, hay or the like; storing agricultural or horticultural produce

A01G - Horticulture; cultivation of vegetables, flowers, rice, fruit, vines, hops, or seaweed; forestry; watering

A01H - New plants or processes for obtaining them; plant reproduction by tissue culture techniques

A01J - Manufacture of dairy products

A01K - Animal husbandry; care of birds, fishes, insects; fishing; rearing or breeding animals, not otherwise provided for; new breeds of animals

A01L - Shoeing of animals

A01M - Catching, trapping or scaring of animals; apparatus for the destruction of noxious animals or noxious plants

A01N - Preservation of bodies of humans or animals or plants or parts thereof; biocides, e.g. as disinfectants, as pesticides or as herbicides; pest repellants or attractants; plant growth regulators

A01P - Biocidal, pest repellant, pest attractant or plant growth regulatory activity of chemical compounds or preparations

2. Foodstuffs; Tobacco

A21 - Baking; equipment for making or processing doughs; doughs for baking

A22 - Butchering; meat treatment; processing poultry or fish

A23 - Foods or foodstuffs; their treatment, not covered by other classes

Note, as indicated, certain calculations in this paper also take account of:

> C08b - Polysaccharides, derivatives thereof
>
> C11 - Animal or vegetable oils, fats, fatty substances or waxes
>
> C12 - Biochemistry, beer, spirits, wine, vinegar
>
> C13 - Sugar industry

A24 - Tobacco; cigars; cigarettes; smokers' requisites

3. Agriculture-related infrastructure and processes

A further category of agriculture-related infrastructure and processes was considered, but very little patent activity was identified and this was dropped from the assessment. The selected IPC classifications included the following, taken as a group: B21H 7/00, B21K 19/00, B62C, B65B 25/02, B66C 23/44, C09K 101/00, E02B 11/00, E04H 5/08, E04H 7/22, G06Q 50/02 (Other agriculture inputs & related: performing operations; transporting; chemistry; metallurgy; fixed constructions; physics).

II. The Harmonised System

Trade data are categorised here using the Harmonised System. They are not available using the IPC classification.

Agricultural equipment, as defined here includes:

HS Code 8430 Pile-drivers & extractors; snowplows & blowers; other moving, grading, leveling, scraping, extracting, boring machines for earth/minerals/ores;

HS Code 8431 Parts suitable for use solely or principally with the machinery of headings No. 84.25 to 84.30;

HS Code 8432 Agricultural, horticultural or forestry machinery for soil preparation or cultivation; lawn or sports-ground rollers;

HS Code 8433 Harvesting or threshing machinery; grass or hay mowers; machines for cleaning, sorting or grading eggs, fruit or other agricultural produce;

HS Code 8434 Milking, dairy machinery; parts thereof;

HS Code 8435 Presses, crushers & similar machinery used in the manufacture of wine, cider, fruit juices or similar beverages;

HS Code 8436 Other agricultural/horticultural/forestry/poultry or bee keeping machinery; parts thereof germination plant, poultry incubators and brooders;

HS Code 8437 Machines for cleaning/sorting/grading seed/grain/dried leguminous vegetable; machines for milling industry, working of cereals etc.; parts;

HS Code 8438 Other machinery for manufacture of food or drink (not animal or fixed vegetable fats or oils); parts thereof;

HS Code 8439 Machinery (not 8419) for making pulp (of fibrous cellulosic material), making or finishing paper/paperboard; parts thereof.

Annex 3.

The Basic Model

The core *model* for the analyses will be specified using a standard regression approach, as follows:

$$ln\ y_{it} = \alpha + \beta\ ln\ x_{it} + \gamma\ ln\ z_{it} + e_{it},$$

where

> *y* is the *dependent variable*, in most cases here defined as indicators of national aggregate or agriculture sector-specific economic or innovation performance.

> *x* is the independent variable, that is the national IPR policy variable of interest (i.e. the *Patent Rights Index score*, patent applications or patent grants)

> *z control variable(s)*, various factors that may influence economic performance.

and

> *e* the *error term*

> *ln* denotes the *natural logarithm*.

The subscripts refer to the values of y, x, and z for country *i* at time *t*, where i = 1, ,.., N and t = 1, ..., T. The symbols (α, β, γ) represent the *coefficients* indicating the association between an independent variables and the explanatory variable y, holding other factors constant. As both the dependent and independent variables are in log units, the parameter is equivalent to *percentage units* (e.g. if $\beta = 2$, a 1% increase in x is associated with a 2% increase in y, holding z constant).

The basic approach is similar to an earlier OECD study on technology transfer and IPRs by Park and Lippoldt (2008), though it is anticipated that ordinary least squares will be employed in the present study. Regressions may be run for panels of countries across time or as pooled regressions or as cross-sections of countries at specific points in time. The regression runs were handled as pooled assessments (unbalanced panels). A Durbin-Watson test revealed that use of fixed effects was appropriate.

Sample countries

The core sample included 35 countries: Argentina, Australia, Azerbaijan, Belarus, Bolivia, Brazil, Canada, Chile, China, Colombia, Dominican Republic, Ecuador, Israel[33], Japan, Jordan, Kenya, Korea, Kyrgyz Republic, Mexico, Moldova, Morocco, New Zealand, Nicaragua, Norway, Panama, Paraguay, Russian Federation, South Africa, Switzerland,

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33. Underlying statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Tunisia, Turkey, Ukraine, United States, Uruguay and Uzbekistan. The selection was driven in part by data availability and in part by an aim for economic and geographic diversity. In most of the analyses, at least some of the countries could not be covered due to lack of data. The data gaps varied depending on the issues under consideration. In a few of the analyses it was possible to include additional countries.

Annex 4.

Key Data Sources

Patent data

- **Patent data** in this paper are drawn from the *OECD Patent Database*. The series include patent applications under the PCT, EPO patent grants, and USPTO patent grants, extracted as necessary by field of technology and country. These data are available on-line to registered users at the following location: **http://stats.oecd.org/index.aspx?r=434824**.

- **Patent Rights Index** data are available from the paper, Park (2008), and correspondence with the author.

Other variables

- **Business expenditure in R&D, agriculture** (OECD R&D statistics on-line), available at: **http://stats.oecd.org/BrandedView.aspx?oecd_bv_id=strd-data-en&doi=data-00196-en**

- **Literacy data** (PISA), available at: OECD Programme for International Student Assessment, PISA database, various years, available on-line here: **http://www.oecd.org/pisa/**

- *World Development Indicators*, on-line edition, **http://data.worldbank.org/data-catalog/world-development-indicators** for various series including:

  – Agriculture value added per worker

  – Crop yields for cereals

  – GDP deflator (for use in calculations of constant value)

  – Population (for per capita calculations)

- Merchandise trade data: UN Comtrade Database: **http://comtrade.un.org/**

- Agricultural FDI: FAO Statistics on-line: **http://www.fao.org/statistics/en/**

- Business Regulation (Fraser): Fraser Institute, *Economic Freedom of the World* dataset, 2013, **http://www.freetheworld.com/release.html;** Chain-linked index: Business regulation (area 5)

- **Domestic value added in foreign final demand** (with respect to agricultural exports): data drawn from the OECD-WTO *Trade in Value Added* database; OECD-WTO, Measuring Trade in Value Added (TiVA), 10 June 2013 release of supplementary TiVA data, Value added in gross exports by source country *and* source industry, available here (as of 3 November 2013): **http://www.oecd.org/industry/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm**. The series used in the analysis for this paper is 01T05: Agriculture, hunting, forestry and fishing.

- **Fertiliser consumption** and **total factor productivity in agriculture**, data from: Fuglie (2012) and correspondence with the author.

- **Trade Secrets Protection Indicator** (TSPI), data from: Schultz and Lippoldt (2014) and subsequent updates.

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