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International Patent Behavior of Nine Major Agricultural Biotechnology Firms

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This paper examines the international patent behavior of nine major firms for seven patent authorities: Australia, Brazil, Canada, China, the European Patent Office (EPO), Japan, and South Africa. The patent sample is based on firms having an initial US patent application; this provides an indication of the amount of technology transfer that occurs from the United States to other countries. Using patent data, the research examines the correlation of firms' patent application decisions based on crop and invention types, the differences in the patent grant rates among the patent authorities, and firms' decisions to pursue patent renewals. The analysis uses empirical evidence to justify possible reasons for the lack of observing much technology transfer from the United States to other countries. Australia, Canada, and the EPO are most likely to receive patent applications. Corn and soybean and gene and method inventions are most likely to be applied for abroad. Approval rates are generally low and vary among patent offices.

Key words: corn, international patents, rice, soybean, technology transfer, wheat.

Introduction

In 1980, the United States Supreme Court ruled[1] that isolated genes and genetically modified plant varieties were patentable. Following this ruling, other countries have changed their patent laws in similar, although not always identical, ways. Changing the patent laws increased the incentives of for-profit firms to engage in agricultural biotechnology research. The combination of stronger intellectual property rights and the increased involvement of for-profit firms in innovation has the potential to both harm and benefit future innovation. On the one hand, countries adopting new technology could experience an increase in development costs if technology must first be licensed from for-profit firms.[2] On the other hand, strong intellectual property rights may be necessary to encourage technology transfer among countries and provide incentives for further development of technology.[3] However, within this debate, it is unclear how often firms transfer technology to other countries using patents.

This paper analyzes the international patent behavior of nine major agbiotech firms: Asgrow, Calgene, Dekalb, DuPont, Merck, Monsanto, Mycogen, Novartis, and Pioneer HiBred. The sample includes firms' patent decisions for the years 1990–2000 for seven patent authorities: Australia, Brazil, Canada, China, the European Patent Office (EPO),[4] Japan, and South Africa. Patent applications relate to any of four crops: corn, soybean, wheat, and rice.

This paper provides a descriptive analysis of the patent behavior and grant outcomes of patent applications from nine firms. Examining firms' patent behavior provides inferences into firms' beliefs about both the profitability[5] of their technology and the enforceability of their intellectual property rights in countries other than the United States. The descriptive statistics[6] provide information on where firms choose to patent after

1. *Specifically, Diamond v. Chakrabarty (1980).*
2. *An alternative to patents would be to have technology funded, developed, and owned by nonprofits. Nonprofits may be more likely to share technology at lower costs. The reader may refer to Scotchmer (2002) for a theoretical analysis of the impact of intellectual property treaties among countries. Several authors discuss the need for more nonprofit involvement. For example, see Alston (2004). Butler and Marion (1985) provide an analysis of the US plant variety protection law on innovation and also discuss the role of nonprofits.*
3. *That is, country-specific factors (e.g., availability of development facilities) exist that need to be overcome before some types of technology can be implemented effectively in a particular country (Sunding & Zilberman, 2001).*
4. *The European Patent Office is a regional office. Firms may designate any number of contracting states when applying through the EPO. If the patent is issued, the patent will be enforceable throughout all of the designated states, provided that the patent owner continues to pay national fees in the designated states. For ease of exposition, the author sometimes refers to Europe as a single country.*

filing an initial patent application in the United States. By focusing on firms' subsequent patent decisions, this research provides an indication of the amount of technology transferability[7] that occurs from the United States to other countries as confined by the firms' beliefs and the patent laws in the various countries.

This research reports the correlation among firms' decisions on where to apply and the correlation among patent authorities' decisions to issue the patents for the seven patent authorities. Finally, it examines information on firms' decisions to abandon patent applications for the patent authorities that receive the most applications: Australia, Canada, and the European Patent Office.

The data shows that the nine firms most often apply for patents in Australia, Canada, and the European Patent Office. Correlations of patent applications among these three patent offices are quite high. That is, firms will apply for patents in all three offices. Different crops receive more international attention than others. Both wheat and rice tend to be applied for as much in other countries as in the United States. Meanwhile, corn and soybeans only tend to be applied for at a fraction of what is applied for in the United States. Gene and method inventions are also more likely to be applied for internationally than variety inventions. Finally, countries differ in their grant rates of patent applications. Some of these differences, however, may be explained by firms' decisions to abandon their patent applications early.

International Patents in Agricultural Biotechnology

A patent allows the owner to prevent others from making, using, selling, or importing the invention. A patent owner must apply for a patent in every country in which s/he wishes to protect the invention. After applying for an initial patent in any particular country, firms have up to one year to file in any other country.[8] The ability to patent particular types of inventions varies across countries.

In this paper, three types of inventions are considered. Similarly to Graff, Rausser, and Small (2003), inventions are divided into three main categories: methods, genes, and varieties. *Method inventions* refer to process technology (methods of manufacture, plant breeding, or genetic engineering technology). *Gene inventions* refer to biological information (mainly isolated genes or proteins, but also includes unicellular microorganisms such as bacteria). *Variety inventions* refer to specific plant varieties (e.g., corn, soybean, wheat, and rice plant varieties).

All countries included in the sample allow for method patents. All patent authorities as of 2000 allowed for gene patents. However, three patent authorities changed their patent laws regarding gene patents during the sample time period: China began allowing for gene patents in 1994; Brazil began allowing for gene patents in 1997; and the European Patent Office began allowing for variety patents in 1999. Finally, only Australia, Japan, and the United States allow for variety patents.

The nine firms included in the study patent the most internationally.[9] Most are headquartered in the United States, although several are multinational or are subsidiaries of multinational firms. Specifically, only Novartis is based outside of the United States (in Switzerland). Throughout the sample time period, the industry underwent much consolidation. When examining firm behavior in this paper, patents are assigned to the patent assignee, even though the firm may have been acquired by another firm during the sample time period.

This paper considers only inventions where firms applied for an initial patent in the United States. Using the US as the originating country from which to measure firms' desire to transfer technology to other countries seems appropriate[10] for several reasons. First, with the exception of Novartis, all of the firms included in the study are based in the United States. It is well known that most firms choose to patent in their home countries first. Second, firms are likely to target the US market first for profitability reasons. The United States grows the greatest amount of genetically modified crops as

5. *Profits include the size of the market for the invention and costs. Costs include patent costs and may also include costs of development (e.g., development costs for creating a new product and costs of regulatory approvals).*
6. *For a statistical model of the behavior of these nine firms, see Chan (2005).*
7. *Patent applications are only one measurement of technology transfer. Others, of course, could include a measure of foreign direct investment and foreign portfolio investment.*
8. *As specified by the Paris Convention.*
9. *As determined by the data sources used in this study.*
10. *It would be interesting to examine patent applications that originated from outside the United States. However, a study including years prior to 2000 would necessarily exclude the United States, because it did not begin publishing failed patent applications until after 2000.*

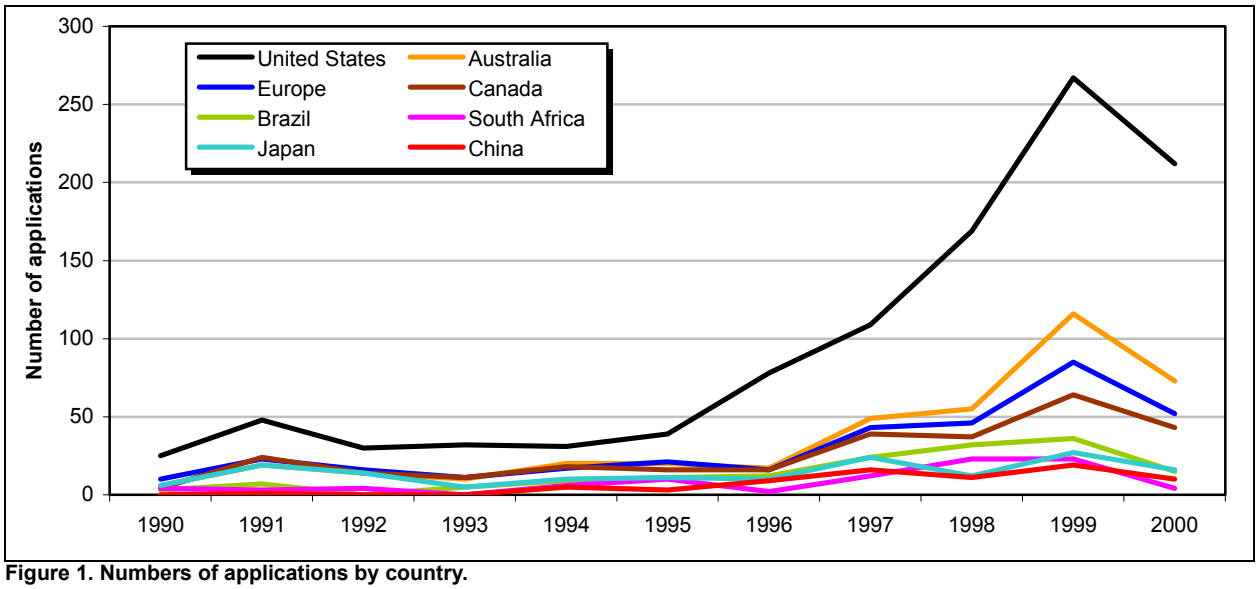

Figure 1. Numbers of applications by country.

Note. The sample size is 1,040 inventions. The dropoff in 2000 is due to data truncation. Numbers obtained by author calculations using data from Derwent (2002). The year refers to the year of application, except for in the United States, where the year of application is one year prior.

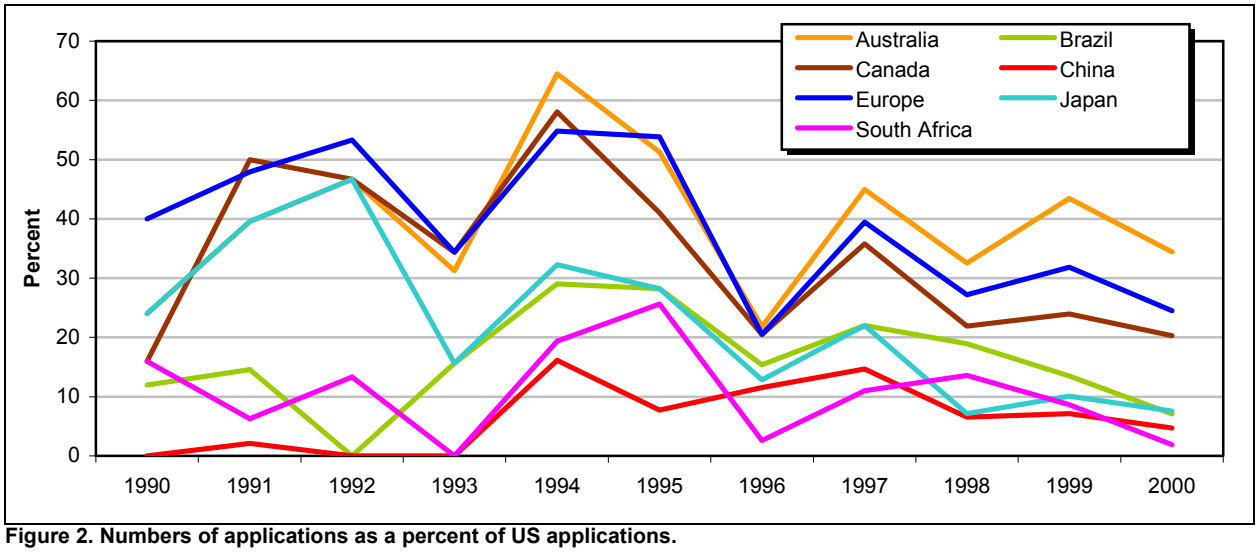

Figure 2. Numbers of applications as a percent of US applications.

Note. The drop in 2000 is due to data truncation. Numbers obtained by author calculations using data from Derwent (2002).

measured by area harvested (James, 2001). Also, because the United States was one of the first countries to allow for gene and variety patents and because of the ease of patent enforceability, the US legal environment provides large incentives for firms to create products for the US market.

Data

The agbiotech patent applications are identified using Thomson Derwent's Biotechnology Abstracts database (2002). These are then linked to Thomson Derwent's Innovation Index (2002–2004) to determine the other countries in which the firms decide to apply. The database also provides information on whether the patent was eventually issued for some patent authorities. The various patent offices (Canadian Intellectual Property Office, 2004; European Patent Office, 2004; Instituto Nacional Da Propriedade Industrial, 2003; IP Australia, 2004; State Intellectual Property Office of the People's Republic of China, 2003; US Patent and Trademark

Table 1. Application correlations among patent authorities.

Applied in (total inventions applied for)	Percent also applied in						
	Australia	Brazil	Canada	China	Europe	Japan	US
Australia (399)	100.0	37.6	66.2	17.8	78.2	34.6	100.0
Brazil (154)	97.4	100.0	84.4	39.0	96.1	53.9	100.0
Canada (286)	92.3	45.5	100.0	23.1	96.9	50.0	100.0
China (74)	97.3	82.2	97.3	100.0	97.3	68.5	100.0
Europe (340)	91.8	43.5	81.4	20.9	100.0	44.1	100.0
Japan (154)	89.6	53.9	92.9	32.5	97.4	100.0	100.0
United States (1,040)	38.4	14.8	27.5	7.1	32.7	14.8	100.0

Note. There are a total of 1,040 inventions in the sample. The numbers in parentheses are the number of applications received by the patent authority. For example, 399 inventions were applied for in Australia; of these 399 inventions, 66.2% were also applied for in Canada. Numbers obtained by author calculations using data from Derwent (2002).

Table 2. Area harvested (hectares), 2000.

Country	Corn	Rice	Soybeans	Wheat
Australia	82,262	133,300	56,000	12,141,000
Brazil	11,614,717	3,655,290	13,640,026	1,065,897
Canada	1,088,300	0	1,060,700	10,854,800
China	23,086,388	30,301,490	9,306,913	26,653,326
EU	4,236,416	401,122	351,432	17,974,028
Japan	73	1,770,000	122,500	183,000
S. Africa	3,813,840	1,300	93,787	854,000
US	29,316,000	1,230,364	29,302,790	21,502,390

Note. The statistics reported for the European Union includes the total over 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. Numbers obtained from FAOSTAT (2006).

Office, 2004) provide the remaining information on patent grant data not included in the Innovation Index data. Finally, patent renewal data was publicly available (on the World Wide Web) for three patent offices: Australia, Canada, and the EPO. Therefore, the paper includes renewal data only from these three sources. There are a total of 1,040 inventions included in the sample.

Applications by Country

Figure 1 illustrates the numbers of patent applications, of the 1,040 inventions in the sample, received by each patent authority. Examining only the data on patent applications in the United States, firms generally became more interested in patenting around 1995. It follows that the other countries received more patent applications for inventions following 1995. Of the seven patent authorities, Australia, Canada, and the EPO received the most applications.

Figure 2 illustrates the numbers of patent applications as a percent of those applied for in the United States. Although Figure 1 shows that the nine firms have increased the raw numbers of inventions they also apply for abroad, Figure 2 shows that the numbers of inventions applied for as a percent of inventions applied for in the United States have fluctuated over time. The percent of applications received by Australia, Canada, and the EPO are fairly correlated over time. At their peaks, the three received 55–65% of the applications filed in the United States. However, the numbers for both the EPO and Canada had dropped below 35% of US applications by 1999.

Given that the three most popular patent authorities are Australia, Canada, and the EPO, firms' decisions to patent among the three are likely highly correlated. Table 1 lists the correlations of patent applications among the different patent offices. The table shows that of the 1,040 inventions, 399 (or 38.4%) were also applied for in Australia. Of these 399 inventions applied for in Australia, 37.6% were also applied for in Brazil. According to the table, Australia, Canada, and the EPO generally have high correlations with one another. For instance, 96.9% of the inventions that were applied for in Canada were also applied for in the EPO, while 81.4% of the inventions applied for in the EPO were also applied for in Canada. This would seem to imply that technology made for Canada is easily transferable to Europe and vice versa. Figures 1 and 2 also show that Australia is the most popular country in which to patent abroad.

Crop Types

Individual patent application decisions are likely to differ among crop types. This is because countries produce different amounts of crops. Therefore, it follows that

Table 3. Country by crop application correlations.

Crop	Applied in (total inventions applied for)	Percent also applied in						
		Australia	Brazil	Canada	China	Europe	Japan	SA
Corn	Australia (332)	100.0	37.7	66.6	17.5	78.0	33.7	22.6
	Brazil (128)	97.7	100.0	85.9	41.4	98.4	53.9	33.4
	Canada (236)	93.6	46.6	100.0	22.9	97.5	49.2	26.7
	China (59)	98.3	89.8	91.5	100.0	98.3	67.8	39.0
	Europe (277)	93.5	45.5	83.0	20.9	100.0	43.3	24.5
	Japan (123)	91.1	56.1	94.3	32.5	97.6	100.0	29.3
	South Africa (76)	98.7	57.9	82.9	30.5	89.5	47.4	100.0
	United States (763)	43.5	16.8	30.9	7.7	36.3	16.1	10.0
Soybean	Australia (180)	100.0	41.1	63.3	17.8	76.7	33.3	19.4
	Brazil (76)	97.4	100.0	80.3	35.5	94.7	51.3	26.3
	Canada (126)	90.5	48.4	100.0	25.4	96.0	54.0	25.4
	China (33)	97.0	81.8	97.0	100.0	100.0	69.7	39.4
	Europe (154)	89.6	46.8	78.6	21.4	100.0	45.5	20.8
	Japan (70)	85.7	55.7	97.1	32.9	100.0	100.0	30.0
	South Africa (35)	100.0	57.1	91.4	37.1	91.4	60.0	100.0
	United States (435)	41.4	17.5	29.0	7.6	35.4	16.1	8.0
Rice	Australia (150)	100.0	39.3	62.7	16.7	76.7	34.7	14.0
	Brazil (59)	100.0	100.0	79.7	35.6	100.0	52.5	23.7
	Canada (98)	95.9	48.0	100.0	23.5	96.9	54.1	18.4
	China (25)	100.0	84.0	92.0	100.0	96.0	76.0	24.0
	Europe (121)	95.0	48.8	78.5	19.8	100.0	44.6	15.7
	Japan (55)	94.5	56.4	96.4	34.5	98.2	100.0	18.2
	South Africa (21)	100.0	66.7	85.7	28.6	90.5	47.6	100.0
	United States (172)	87.2	34.3	57.0	14.5	70.3	32.0	12.2
Wheat	Australia (142)	100.0	36.6	62.0	21.1	77.5	36.6	12.7
	Brazil (52)	100.0	100.0	80.0	44.2	100.0	59.6	21.2
	Canada (93)	94.6	45.2	100.0	30.1	96.8	57.0	15.1
	China (30)	100.0	76.7	93.3	100.0	100.0	73.3	20.0
	Europe (117)	94.0	44.4	76.9	25.6	100.0	47.0	13.7
	Japan (55)	94.5	56.4	96.4	40.0	100.0	100.0	14.5
	South Africa (18)	100.0	61.1	77.8	33.3	89.9	44.4	100.0
	United States (168)	84.5	31.0	55.4	17.9	69.6	32.7	10.7

Note. In the column headings, South Africa is abbreviated as "SA." Inventions within the sample often pertain to multiple crop types. Numbers obtained by author calculations using data from Derwent (2002).

firms might not find it valuable to patent inventions pertaining to particular crop types in all countries. Table 2 provides production and area harvested statistics for the countries included in the sample. Table 3 shows the correlation of patent applications for countries by crop.

Tables 2 and 3 illustrate several findings. Table 2 shows that countries indeed differ by crop production. However, Table 3 shows that the rank order in which countries receive patent applications does not vary by crop. Hence firms always apply more often for patents in Australia, the EPO, and Canada than in Japan, Brazil, China, or South Africa despite differences in crop production in the various countries. Also, the correlations of patent application decisions among countries do not vary by crop. That is, for all crops, patent applications among Australia, Canada, and the EPO remain high (for example, more than 60% of patents applied for in Australia are also applied for in Canada for corn, soybean, rice, and wheat inventions). Table 3, however, shows that the rate at which firms decide to apply overseas

Table 4. Patent type application counts by crop and country.

Patent type	Crop	Australia	Brazil	Canada	China	Europe	Japan	SA	US
Gene patent applications	**Corn**	228	79	152	34	187	76	38	272
	Soybean	118	46	73	20	100	38	15	148
	Wheat	88	31	50	17	69	30	7	100
	Rice	95	35	54	14	74	28	8	107
Variety patent applications	**Corn**	13	9	10	5	10	5	7	369
	Soybean	8	4	7	1	6	2	2	220
	Wheat	7	3	5	3	4	2	0	10
	Rice	6	3	4	1	3	1	0	9
Method patent applications	**Corn**	91	40	74	20	80	41	31	122
	Soybean	54	54	26	46	12	48	30	18
	Wheat	47	18	38	10	44	23	11	58
	Rice	49	21	40	10	44	26	13	56

Note. Numbers obtained by author calculations using data from Derwent (2002).

does in fact vary with crop type. That is, both corn and soybeans first applied for in the United States are less likely than wheat and rice inventions to be applied for internationally.

Part of the variation in general international application rates among crop types may be attributed to the type of invention. Recall that inventions were divided into gene, method, and variety inventions. Genes and method inventions are likely to be useful for multiple crop types; that is, they are considered to be relatively broad. In contrast, variety inventions specify a particular plant variety, and therefore are considered to be relatively narrow. Furthermore, plant hybrids typically produce vastly different yields in different regions due to differences in climates (Chrispeels & Sadava, 1994), and they often must survive against different pests or diseases that vary by region. Consequently, variety inventions made for the United States would be less marketable in other countries. Therefore, firms are more likely to apply abroad for gene and method patents, whereas they are less likely to apply abroad for variety patents.

Table 4 provides the number of patent applications for each country according to invention type. According to the table, 369 of the 763 corn inventions (or 48.4%) were variety patents. Also, 220 of the 386 soybean inventions (or 57.0%) were variety patents. In contrast, only 10 of the 168 wheat inventions (or 6.0%) and only nine of the 172 rice inventions (or 5.2%) were variety inventions. The inability to grow specific varieties in multiple countries provides a possible explanation for the low international application rates for both corn and soybean inventions.

Invention Types

Recall that some countries changed their patent laws during the sample time period. Therefore, firms' decisions to apply for patents are likely constrained by the current patent laws of the particular country. Consequently, countries may experience changes in the number of patent applications received in response to changes in their patent regimes.

Table 5 lists the number of patent applications by country, invention type, and application year. Brazil, China, and the EPO enacted patent law changes that allowed for gene patents in 1997, 1994, and 1999, respectively. According to Table 5, they all experienced an increase in gene patent applications at the time of the changes in their patent laws. Specifically, when Brazil introduced its law in 1997, it received more than twice as many patent applications in 1997 than it received in 1996. China only started receiving nonzero numbers after the introduction of its law. Finally, the EPO received more than twice as many patent applications when it changed its law in 1999 compared to the number it received in 1998. Although these increases cannot be differentiated[11] from the overall increase in patent applications that occurred merely because of a general increase in agbiotech innovation over the sample time period, it is noteworthy to mention the large increases that occurred concurrently with the major patent law changes. Specifically, both Brazil and the EPO experi-

11. *That is, without the use of a statistical model, the changes cannot be attributed to the patent law changes versus the overall increasing trend of patent innovation.*

Table 5. Annual patent type application counts by country.

Patent type	Year	Australia	Brazil	Canada	China	Europe	Japan	SA	US
Gene patent applications	**1990**	3	0	1	0	4	2	2	5
	1991	5	4	9	0	10	6	0	17
	1992	10	0	10	0	11	10	3	16
	1993	7	3	7	0	7	3	0	11
	1994	14	6	13	3	12	8	5	15
	1995	12	7	11	2	12	6	6	17
	1996	11	7	9	4	9	6	0	14
	1997	27	16	22	11	26	15	5	32
	1998	30	20	17	8	27	7	10	40
	1999	92	23	50	10	68	18	12	99
	2000	58	9	31	6	39	10	2	62
Variety patent applications	**1990**	0	0	0	0	0	0	0	12
	1991	1	1	2	1	1	1	2	13
	1992	0	0	0	0	0	0	0	7
	1993	0	0	0	0	0	0	0	13
	1994	0	0	1	0	1	1	0	9
	1995	3	1	1	0	3	1	2	14
	1996	2	2	2	2	2	1	1	56
	1997	4	1	4	1	2	0	0	55
	1998	3	2	3	0	2	0	1	105
	1999	4	3	2	2	3	1	3	143
	2000	2	1	1	1	1	2	0	135
Method patent applications	**1990**	3	3	3	0	6	4	2	8
	1991	13	2	13	0	12	12	1	18
	1992	4	0	4	0	5	4	1	7
	1993	3	2	4	0	4	2	0	8
	1994	6	3	4	2	4	1	1	7
	1995	5	3	4	1	6	4	2	8
	1996	4	3	5	3	5	3	1	8
	1997	18	7	13	4	15	9	7	22
	1998	22	10	17	3	17	5	12	24
	1999	20	10	12	7	14	8	8	25
	2000	13	5	11	3	12	4	2	15

Note. The drop in 2000 is due to data truncation. Numbers obtained by author calculations using data from Derwent (2002).

enced their largest increases in gene patent applications at the time their patent laws changed.[12]

The table also shows that firms appear to apply for particular invention types despite the fact that patent authorities may not technically allow patents for these invention types. For instance, even before the introduction of gene patent laws, both Brazil and the EPO received positive numbers of applications for gene inventions. There are a few explanations for this. First, invention types in this study were categorized according to their patent application titles and abstracts. However, a single patent application has multiple claims. Therefore, a title specifying a gene patent may also contain claims on the methods of isolation. Hence, firms may have been aiming to patent only a subset of the original claims. Second, evidence exists that patent authorities have actually issued patents on inventions that, according to their patent laws, were not technically patentable.

12. It is also possible that other country-specific factors occurred at the same time as the gene patent law change that increased patent application rates for a particular country.

Table 6. Firm applications by patent authority.

Company	Australia	Brazil	Canada	China	EPO	Japan	SA	US
Asgrow	3	2	2	1	2	0	1	85
Calgene	3	4	16	2	17	11	0	20
Dekalb	16	9	12	2	13	6	7	112
DuPont	94	43	43	12	75	21	23	110
Merck	3	0	4	1	4	4	3	5
Monsanto	53	29	44	21	50	27	13	144
Mycogen	17	10	13	5	17	15	4	27
Novartis	34	19	29	21	34	29	11	74
Pioneer	176	38	123	9	128	41	29	463

Note. Numbers obtained by author calculations using data from Derwent (2002).

In these cases, issued patents are typically challenged and later revoked.

Firms

Table 6 illustrates patent applications by firm. Firms tend to specialize in different types of inventions. For instance, Asgrow, Dekalb, and Pioneer tend to specialize in seed production, whereas DuPont tends to specialize in genes and methods. Some of this is reflected in Table 6; that is, Asgrow, Dekalb, and Pioneer generally tend to patent less internationally given their specialty in variety inventions. However, firms do not tend to vary much as to which countries they choose to apply for patents. That is, all firms tend to patent more often in Australia, Canada, and the EPO than in Brazil, China, Japan, or South Africa.

Patent Grants and Renewal Data

After firms file a patent application, patent authorities examine the applications based on the criteria of novelty, utility, and nonobviousness. These criteria must all be met in order for the patent authority to issue the patent. If not, the patent office may ask for revisions. The firm must then send revisions. Eventually the patent office will ultimately accept or reject the application. Applicants must pay several fees throughout the patent approval process. If the applicant fails to pay the fees on time, patent authorities consider the application as abandoned or expired. Fees include both examination fees and renewal fees. Some patent authorities require applicants to pay examination fees—fees to have the patent examined for approval. In contrast, renewal fees must be paid throughout the application process and after the patent issues according to the patent authority's renewal fee schedule.

Table 7 lists the percent of patent applications that have been issued (approved or granted) by the end of 2004. The table indicates that patent authority approval rates vary. The greatest numbers of approvals occur in the United States. This is mainly by construction of the data.[13] Australia, Canada, and the EPO have the highest approval rates, with Australia having the highest (after the US) at 29.8% of patent applications issued.

Table 7. Numbers of inventions applied for and granted by patent authority.

Country	Applications	Grants	Percent granted
Australia	399	119	29.8%
Brazil	154	5	3.3%
Canada	286	38	13.3%
China	73	3	4.1%
Europe	340	53	15.6%
Japan	154	13	8.4%
United States	1,040	847	81.4%

Note. The total number of inventions in the sample is 1,040. South Africa is not reported in this table, because patent approvals are based only on compliance with all formal filing requirements rather than the standard requirements of novelty, utility, and nonobviousness. Numbers obtained by author calculations using data from Derwent (2002) and the various patent offices.

Several things can affect the numbers of issued patents. This can occur either from decisions made by the patent authority or from the applicant. First, the time between application and approval may vary by patent authority. The EPO is known to have lengthy approval times. Therefore, because many of the patents in the sample were applied for in the later years, they may still be pending approval. Second, there may be idiosyn-

13. *Recall that the United States did not publish approved patent applications prior to 2000. Therefore, the sample includes either issued US patents or failed US patent applications that were applied for in other countries.*

Table 8. Grant correlations among patent authorities.

Granted in (total inventions granted)	Percent also granted in (number possible applications)					
	Australia	Brazil	Canada	China	Europe	Japan
Australia (119)	100 (119)	3.4 (63)	25.2 (113)	1.7 (38)	26.1 (118)	8.4 (81)
Brazil (5)	80.0 (5)	100 (5)	60.0 (5)	0.0 (1)	80.0 (5)	40.0 (3)
Canada (38)	79.0 (37)	7.9 (12)	100 (38)	0.0 (2)	55.3 (36)	13.2 (21)
China (3)	66.7 (2)	0.0 (1)	0.0 (3)	100 (3)	33.3 (2)	33.3 (3)
Europe (53)	58.5 (45)	7.6 (18)	39.6 (46)	1.9 (5)	100 (53)	13.2 (36)
Japan (13)	76.9 (12)	15.4 (7)	38.5 (11)	7.7 (2)	53.9 (12)	100 (13)
United States (847)	9.8 (216)	0.5 (91)	3.3 (177)	0.2 (47)	4.7 (201)	1.2 (104)

Note. The numbers in parentheses are the number of granted applications in the country's row that were also applied for in the country's column. For example, 113 out of 119 of Australia's grants were also applied for in Canada. Out of 119 of Australia's grants, 25.2% were also granted in Canada. Numbers obtained by author calculations using data from Derwent (2002) and various patent offices.

cratic differences in the manner in which the different patent authorities judge novelty, utility, and nonobviousness. Finally, as noted beforehand, patents may be denied because the patent authority has declared that particular types of inventions may not be patented. Moreover, other legal requirements may exist that create differences in the patentability of inventions across countries.

On the other hand, applicants may decide to withdraw their applications at any time during the approval process. That is, a firm may decide in the middle of the patent approval process to abandon pursuing the patent for whatever reason. A firm signals abandonment by failing to pay required examination or renewal fees.

Table 8 lists the correlation of patent decisions across patent authorities. Provided that the firm has not abandoned the application and that the patent laws are the same in the patent authorities, patent decisions in theory should be highly correlated across countries.[14] According to the table, the majority of patents issued in Australia were also applied for in both Canada and the EPO. However, as of 2004, only 25% were issued in Canada and only 26% were issued by the EPO. In contrast, for those patents issued in Canada, 79% had also been issued in Australia.

To examine whether in fact countries' low grant rates can be attributed to firms' early abandonment of applications, renewal data is used to examine the expiration status of patent applications. Table 9 divides patent applications for three of the patent authorities according to their examination status and lists the expiration status. The table shows that overall low grant rates can at least be partially explained by firms' decisions to abandon the patent application early. According to the table, almost 50% of patents applied for in Australia are abandoned even before examination. That is, if applications abandoned before examination are excluded, Australia's grant rate jumps to 57%.[15] This statistic reinforces the idea that the Australian patent office approves a higher rate of patents, because even less than the number originally applied for actually enter the examination process. However, it leaves open the question of why firms negatively reassess the value of so many of their Australian applications before patent examination. In contrast, roughly 60% of patent applications are abandoned after

Table 9. Percent examined by expiration status and country.

Country (total inventions applied for)	Not examined		Examined	
	Expired	Not expired	Expired	Not expired
Australia (399)	47.6	0.0	14.8	37.5
Canada (286)	11.3	14.1	60.1	14.4
Europe (340)	0.0	0.0	62.6	37.4

Note. In Australia, examination fees are typically paid approximately two years after the application is filed. In Canada, examination fees must be paid five or seven years after the application is filed. For the EPO, examination fees are typically paid approximately two years after the application is filed. Numbers obtained by author calculations using data from the various patent offices.

14. *That is, although there are differences in the legal requirement of patentability between jurisdictions, international agreements have standardized these requirements to a high degree.*

15. *Because 52.4% of the 399 applications were examined, this amounts to 209 applications that were not abandoned before examination. Of those 209 examined applications, 119 were issued, or 56.9% were issued.*

examination for both Canada and the EPO. This may result from either a negative report from the patent authority or the firm's decision to abandon the application for another reason.[16]

In the sample, the average time between application and grant was only 3.25 years in Australia, compared to 6.45 years and 6.68 years for Canada and the EPO, respectively. The overall higher and faster approval rate may help explain why firms apply for patents more often in Australia across all crop and invention types.

Conclusion

This paper describes the patent decisions of nine major firms in the agricultural biotechnology industry. The data shows that technology transfer, as measured by patent applications from the United States to other countries, is quite low. Furthermore, shares of patent applications received by other countries that originated from the United States vary widely across countries. Australia receives the greatest share of these patent applications, followed by the European Patent Office and Canada.

The possible reasons for these low application rates can be divided into firms' assessments of the market demand for their inventions and the patent laws of the various countries. Patent application rates vary by crop and invention type. Both of these characteristics affect the market size for the inventions in the different countries. However, differences in patent laws among the patent authorities may also affect the patent application rates for specific invention types.

Finally, the success rate of patent applications varies widely across patent authorities. Of the seven patent authorities examined in this paper, patents applied for in Australia tend to have the most favorable outcomes; however, firms often abandon patent applications before examination. In comparison, Canada and the European Patent Office tend to have lower approval rates, which may be partially explained by slower approval times. The majority of applications for these patent offices expire after examination.

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16. For example, the firm may reassess the patent's market value and deem it unprofitable as determined by market demand and costs of production and development.