

SUPPLEMENTAL APPENDIX – FOR ONLINE PUBLICATION ONLY

A.1. Other indicators of patent quality: foreign patent family members

We also examined information on the size of the “patent family,” the number of countries in which an invention is patented, as an alternative measure for the quality of patents. Intuitively, inventors are more likely to incur the costs of patenting an invention in more countries if the patent is more valuable and has a larger market (Putnam 1996, and Gambardella et al. 2008). For crops, and other types of biological inventions, however, this measure may be downward biased because biological inventions cannot be patented in all countries. The European Patent Office (EPO), for example, has traditionally not granted patents for hybrid corn. On January 21, 2014, the EPO denied Monsanto’s patent application No. 07871115 for “Methods for Hybrid Corn Seed Production and Compositions produced therefrom.”¹ In addition, breeders’ may choose not to apply for patents for GMOs in countries where GMOs are subject to strict regulation, which limits the marketability of GM hybrids in these countries. The European Union, for example, is subject to particularly strict regulation (Davison 2010). For example, Regulation (EC) No 1829/2003 of the European Parliament and Council (issued September 22, 2003) specifies that “in order to protect human and animal health, food and feed consisting of, containing or produced from genetically modified organisms (...) should undergo a safety assessment through a Community procedure before being placed on the market within the Community.” However, EU member countries might impose even stricter rules. On April 14, 2009, Germany’s Federal Office of Consumer Protection and Food Safety forbid farmers to plant corn hybrids that carry Monsanto’s trait MON810 for insect resistance.² Quoting a report of the European Food Safety Authority from October 29, 2008, Monsanto appealed this decision arguing that MON810 had not been rigorously shown to carried no documented risks for food or feed. On May 4, 2009, the Administrative Court of Braunschweig, Germany denied Monsanto’s appeal arguing that a ban is legal as long as new or additional information indicate that people or animals might be harmed even in the absence of definite scientific proof.³ We find that none of the 269 US patents issued for hybrid corn had a foreign patent family member.⁴

¹ EPO case number T 2362/10 (European Case Law Identifier: ECLI:EP:BA:2014:T236210.20140121).

² A similar ban was also imposed by Austria, France, Greece, Hungary and Italy (Davison 2010).

³ Administrative court Braunschweig (Germany), case number 2 B 111/09.

⁴ Data on patent families are available from the EPO at <http://worldwide.espacenet.com>, accessed on June 2014.

A.2. Erroneous citations

We also examine the title and abstract of all 1,157 citing patents to check whether citations may be added erroneously as a result of typos or other types of errors. For example, US6,518,986 for “Method and apparatus for providing an on-screen guide for a multiple channel broadcasting system” (issued February 11, 2003, assigned to Sony Corporation) cites US6,114,614 for “Hybrid maize plant and seed 33B50” as relevant prior art. The issue date and inventor names that are listed on Sony’s patent, are, however, different from the issue date and inventor names of US6,114,614. Information on the issue date and the name of the inventors indicates that the citation is “off” in the fourth digit of the patent number: US6,111,614 for “Method and apparatus for displaying an electronic menu having components with differing levels of transparency” issued on August 29, 2000 and assigned to Sony Corporation. Checking all 1,157 patents reveals 16 erroneous citations (1.4 percent). All of these erroneous citations are due to typographical errors; excluding them from the analysis leaves the estimates substantially unchanged.

TABLE A1 – EXAMPLE OF HYBRID CORN TRAITS REPORTED IN FIELD TRIALS

| Traits | Description | # of Observations |
|--|--|-------------------|
| <u>Traits that farmers use in income calculations</u> | | |
| <i>Yields</i> | Yield of the grain at harvest in bushels per acre | 315 |
| <i>Harvest moisture</i> | Actual percentage moisture of grain at harvest | 315 |
| <u>Traits that farmers do NOT use in income calculations</u> | | |
| <i>Not stalk lodged</i> | Plants that did not stalk lodge (stalk breakage) | 219 |
| <i>Dry-down</i> | Rate at which acceptable harvest moisture is reached | 114 |
| <i>Seedling vigor</i> | Vegetative growth after emergence at seedling stage | 31 |
| <i>Not root lodged</i> | Stalks not root lodged at harvest | n/a |
| <i>Early stand</i> | Number of plants that emerge | n/a |
| <i>Plant height</i> | Height of the plant from ground to tip of the tassel | n/a |
| <i>Ear height</i> | Height from ground to highest placed developed ear | n/a |
| <i>Not barren</i> | Plants that were not barren (lack ears) | n/a |
| <i>Stay green</i> | Plant health near time of black layer formation | n/a |

Notes: Included are all traits reported in field trial data included in DeKalb’s patent US4,629,819 for hybrid dk524. *Yield* and *moisture* are main traits that farmers use to calculate gross income. A typical gross income equation takes the current market price per bushel of corn as given and assumes a drying cost of \$0.02 per percentage point moisture above 15.5 percent (e.g., US6,835,877 for Pioneer’s hybrid 34m94). Pioneer, for example, provides product performance information in terms of individual plot reports for various regions on its website and provides the following explanation on how gross income per acre is derived: “Income per acre is calculated based on a \$0.04 dry down cost and 15.00% moisture. The following market values are currently applied for Corn: Conventional = \$3.5/bushel price.” (available at www.pioneer.com; accessed Dec. 2015). *n/a* refers non-consistent reported data. Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A2 – POISSON, DEPENDENT VARIABLE IS FORWARD CITATIONS TO PATENT - HYBRID PAIRS, CONTROLLING FOR ADDITIONAL TRAITS

| | (1) | (2) | (3) | (4) | (5) |
|--|--------------------|-------------------|--------------------|-------------------|------------------|
| Yields | 0.592** (0.245) | 0.163* (0.084) | 0.353** (0.168) | 0.193 (0.148) | 0.418 (0.277) |
| Moisture | -0.029 (0.208) | -0.083 (0.063) | 0.009 (0.116) | -0.109 (0.149) | 0.057 (0.234) |
| Stalk lodging | 0.071 (0.324) | | 0.016 (0.135) | | 0.009 (0.253) |
| Dry-down | | -0.384 (0.382) | 0.518 (0.766) | | 0.330 (0.939) |
| Vigor | | | | 0.000 (0.062) | 0.004 (0.099) |
| Standard errors clustered at the level of hybrids. *** p<0.01, ** p<0.05, * p<0.10 | | | | | |
| N | 219 | 114 | 42 | 31 | 26 |
| Mean citations | 10.132 | 3.123 | 3.619 | 3.516 | 3.923 |
| R-squared | 0.653 | 0.158 | 0.190 | 0.133 | 0.207 |
| Year FE | YES | YES | YES | YES | YES |

Notes: The dependent variable *citations* measures the sum of forward citations to a patent - hybrid pair. The variable *yields* measures the improvement in yields (in percent) over existing hybrids. In case of multiple comparisons in the patent, we selected the highest-yielding comparison hybrid. *Moisture* measures the relative moisture level of the patented hybrid to the highest-yielding comparison hybrid. *Stalk lodging* measures the relative percentage of plants that did not stalk lodge of the patented hybrid to the highest-yielding comparison hybrid. *Dry-down* measures the relative rate at which the patented hybrid will reach acceptable harvest moisture to the highest-yielding comparison hybrid (a high score indicates a hybrid that dies relatively fast). *Vigor* measures the relative rate of the amount of vegetative growth after emergence at the seedling stage of the patented hybrid to the highest-yielding comparison hybrid (a high score indicates better vigor). Year fixed effects control for the year of the patent application (1985 + t). All specifications estimate the average marginal effects of unconditional fixed effects Poisson regressions; “R-squared” is the pseudo R-squared of the equivalent regression that estimates Poisson coefficients. Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A3 – POISSON, DEPENDENT VARIABLE IS FORWARD CITATIONS (COLUMNS 1-3), SELF-CITATIONS (COLUMN 4) AND EXAMINER-ADDED CITATIONS (COLUMN 5) TO PATENT - HYBRID PAIRS, CONTROLLING FOR THE SIGNIFICANCE LEVEL OF DIFFERENCES IN YIELDS AND MOISTURE

| | All citations (1-4) | | | Self- citations | Examiner- added |
|--|------------------------|---------------------|---------------------|---------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) |
| Yields | 0.681** (0.284) | 0.926*** (0.277) | 1.130** (0.458) | 0.092 (0.060) | 0.012 (0.037) |
| Moisture | 0.015 (0.125) | -0.011 (0.116) | -0.066 (0.199) | -0.059 (0.070) | -0.006 (0.016) |
| Insect resistant | | | -9.476 (7.225) | -1.274 (3.629) | -0.065 (0.782) |
| Herbicide tolerant | | | -9.126 (8.349) | -2.361 (3.303) | -0.313 (0.706) |
| Insect resistant follow-on hybrid | | | 4.138** (1.936) | 2.035** (0.844) | -0.028 (0.242) |
| Herbicide tolerant follow-on hybrid | | | 7.050*** (2.209) | 3.633*** (0.905) | -0.073 (0.240) |
| First patents | | 38.36*** (3.569) | 41.60*** (7.623) | 21.57*** (1.820) | -13.81*** (1.467) |
| Standard errors clustered at the level of hybrids. *** p<0.01, ** p<0.05, * p<0.10 | | | | | |
| N | 315 | 315 | 174 | 174 | 174 |
| Mean citations | 8.314 | 8.314 | 9.402 | 3.954 | 0.897 |
| R-squared | 0.619 | 0.806 | 0.874 | 0.706 | 0.147 |
| Year FE | YES | YES | YES | YES | YES |

Notes: The dependent variable *citations* measures the sum of forward citations to a patent - hybrid pair (columns 1-3). *Self-citations* measure the sum of self-citations to a patent - hybrid pair (column 4). *Examiner-added citations (after 2000)* counts citations that the USPTO’s examiner added to the list of relevant prior art (column 5); examiner-added citations are only observable for patents that were issued after 2000. The variable *yields* measures the improvement in yields (in percent) over existing hybrids. In case of multiple comparisons in the patent, we selected the highest-yielding comparison hybrid. The variable *yields* is set to zero if the difference between the patented hybrid and the comparison hybrid is not significant at the 1% level. *Moisture* measures the relative moisture level of the patented hybrid to the highest-yielding comparison hybrid. The variable *moisture* is set to zero if the difference between the patented hybrid and the comparison hybrid is not significant at the 1% level. *Insect resistant* equals 1 if the patented hybrid is insect resistant while the comparison hybrid is not. *Herbicide tolerant* equals 1 if the patented hybrid is herbicide tolerant while the comparison hybrid is not. *Insect resistant follow-on hybrid* equals 1 if a genetically modified hybrid, which shares the same base genetics, but is also insect resistant, is introduced by the same breeder as a follow-on hybrid. *Herbicide tolerant follow-on hybrid* equals 1 if a genetically-modified hybrid, which shares the same base genetics, but is also herbicide tolerant, is introduced by the same breeder as a follow-on hybrid. The variable *first patents* is an indicator for the first four patents that the USPTO issued for hybrid corn (US4,607,453; US4,629,819; US4,731,499; US 4,737,596); it also captures one patent (US6,433,261) that later patents cite along with US4,731,499 (see Table 3 for a detailed description). Year fixed effects control for the year of the patent application (1985 + t). All specifications estimate the average marginal effects of unconditional fixed effects Poisson regressions; “R-squared” is the pseudo R-squared of the equivalent regression that estimates Poisson coefficients. Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A4 – POISSON, DEPENDENT VARIABLE IS FORWARD CITATIONS (COLUMNS 1-3), SELF-CITATIONS (COLUMN 4) AND EXAMINER-ADDED CITATIONS (COLUMN 5) TO PATENT - HYBRID PAIRS, CONTROLLING FOR MULTIPLE PATENTS PER HYBRID AND MULTIPLE HYBRIDS PER PATENT

| | All citations (1-4) | | | Self- citations | Examiner- added |
|--|------------------------|---------------------|---------------------|---------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) |
| Yields | 0.818*** (0.317) | 0.728*** (0.267) | 0.880* (0.464) | 0.028 (0.041) | 0.014 (0.021) |
| Moisture | -0.153 (0.164) | -0.058 (0.119) | -0.043 (0.201) | -0.076 (0.068) | -0.015 (0.015) |
| Insect resistant | | | -10.62 (8.340) | -0.896 (3.697) | -0.073 (0.803) |
| Herbicide tolerant | | | -9.355 (8.128) | -2.377 (3.367) | -0.358 (0.730) |
| Insect resistant follow-on hybrid | | | 3.767* (1.987) | 2.099** (0.858) | -0.145 (0.263) |
| Herbicide tolerant follow-on hybrid | | | 8.008*** (2.417) | 3.683*** (0.953) | 0.048 (0.262) |
| First patents | | 36.72*** (4.062) | 39.16*** (8.872) | 20.17*** (2.204) | -10.58*** (1.108) |
| Standard errors clustered at the level of hybrids. *** p<0.01, ** p<0.05, * p<0.10 | | | | | |
| N | 315 | 315 | 174 | 174 | 174 |
| Mean citations | 8.314 | 8.314 | 9.402 | 3.954 | 0.897 |
| R-squared | 0.633 | 0.806 | 0.869 | 0.706 | 0.201 |
| Year FE | YES | YES | YES | YES | YES |
| > 1 patent FE | YES | YES | YES | YES | YES |
| > 1 hybrid FE | YES | YES | YES | YES | YES |

Notes: The dependent variable *citations* measures the sum of forward citations to a patent - hybrid pair (columns 1-3). *Self-citations* measure the sum of self-citations to a patent - hybrid pair (column 4). *Examiner-added citations (after 2000)* counts citations that the USPTO's examiner added to the list of relevant prior art (column 5); examiner-added citations are only observable for patents that were issued after 2000. The variable *yields* measures the improvement in yields (in percent) over existing hybrids. In case of multiple comparisons in the patent, we selected the highest-yielding comparison hybrid. *Insect resistant* equals 1 if the patented hybrid is insect resistant while the comparison hybrid is not. *Herbicide tolerant* equals 1 if the patented hybrid is herbicide tolerant while the comparison hybrid is not. *Insect resistant follow-on hybrid* equals 1 if a genetically modified hybrid, which shares the same base genetics, but is also insect resistant, is introduced by the same breeder as a follow-on hybrid. *Herbicide tolerant follow-on hybrid* equals 1 if a genetically-modified hybrid, which shares the same base genetics, but is also herbicide tolerant, is introduced by the same breeder as a follow-on hybrid. The variable *first patents* is an indicator for the first four patents that the USPTO issued for hybrid corn (US4,607,453; US4,629,819; US4,731,499; US 4,737,596); it also captures one patent (US6,433,261) that later patents cite along with US4,731,499 (see Table 3 for a detailed description). Year fixed effects control for the year of the patent application (1985 + t). The control variable *> 1 patent* equals 1 if the same hybrid is the subject of more than 1 utility patent. The control variable *> 1 hybrid* equals 1 if the same utility patent covers more than 1 hybrid. All specifications estimate the average marginal effects of unconditional fixed effects Poisson regressions; "R-squared" is the pseudo R-squared of the equivalent regression that estimates Poisson coefficients. Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A5 – POISSON, DEPENDENT VARIABLE IS FORWARD CITATIONS (COLUMNS 1-3), SELF-CITATIONS (COLUMN 4) AND EXAMINER-ADDED CITATIONS (COLUMN 5) TO PATENT - HYBRID PAIRS, CONTROLLING FOR THE GRANT YEAR

| | All citations (1-4) | | | Self- citations | Examiner- added |
|--|------------------------|---------------------|---------------------|---------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) |
| Yields | 0.907*** (0.319) | 0.802*** (0.267) | 0.892* (0.464) | 0.021 (0.041) | 0.008 (0.025) |
| Moisture | -0.085 (0.142) | -0.013 (0.111) | 0.041 (0.200) | -0.027 (0.067) | -0.012 (0.016) |
| Insect resistant | | | -14.73* (8.096) | -2.664 (3.493) | -0.043 (0.782) |
| Herbicide tolerant | | | -12.09 (8.324) | -3.812 (3.093) | -0.227 (0.785) |
| Insect resistant follow-on hybrid | | | 4.587** (2.009) | 2.345*** (0.832) | 0.001 (0.238) |
| Herbicide tolerant follow-on hybrid | | | 6.735*** (2.233) | 3.378*** (0.928) | -0.120 (0.245) |
| First patents | | 37.47*** (4.047) | 41.96*** (8.067) | 21.21*** (1.643) | -12.64*** (1.456) |
| Standard errors clustered at the level of hybrids. *** p<0.01, ** p<0.05, * p<0.10 | | | | | |
| N | 315 | 315 | 174 | 174 | 174 |
| Mean citations | 8.314 | 8.314 | 9.402 | 3.954 | 0.897 |
| R-squared | 0.629 | 0.805 | 0.867 | 0.690 | 0.126 |
| Grant Year FE | YES | YES | YES | YES | YES |

Notes: The dependent variable *citations* measures the sum of forward citations to a patent - hybrid pair (columns 1-3). *Self-citations* measure the sum of self-citations to a patent - hybrid pair (column 4). *Examiner-added citations (after 2000)* counts citations that the USPTO's examiner added to the list of relevant prior art (column 5); examiner-added citations are only observable for patents that were issued after 2000. The variable *yields* measures the improvement in yields (in percent) over existing hybrids. In case of multiple comparisons in the patent, we selected the highest-yielding comparison hybrid. *Moisture* measures the relative moisture level of the patented hybrid to the highest-yielding comparison hybrid. *Insect resistant* equals 1 if the patented hybrid is insect resistant while the comparison hybrid is not. *Herbicide tolerant* equals 1 if the patented hybrid is herbicide tolerant while the comparison hybrid is not. *Insect resistant follow-on hybrid* equals 1 if a genetically modified hybrid, which shares the same base genetics, but is also insect resistant, is introduced by the same breeder as a follow-on hybrid. *Herbicide tolerant follow-on hybrid* equals 1 if a genetically-modified hybrid, which shares the same base genetics, but is also herbicide tolerant, is introduced by the same breeder as a follow-on hybrid. The variable *first patents* is an indicator for the first four patents that the USPTO issued for hybrid corn (US4,607,453; US4,629,819; US4,731,499; US 4,737,596); it also captures one patent (US6,433,261) that later patents cite along with US4,731,499 (see Table 3 for a detailed description). Year fixed effects control for the year the patent was granted. All specifications estimate the average marginal effects of unconditional fixed effects Poisson regressions; "R-squared" is the pseudo R-squared of the equivalent regression that estimates Poisson coefficients. Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A6 – OLS, DEPENDENT VARIABLE IS FORWARD CITATIONS TO PATENT - HYBRID PAIRS

| | (1) | (2) | (3) | (4) |
|--|--------------------|--------------------|-------------------|-------------------|
| Yields | 0.653** (0.301) | 0.668** (0.306) | 0.598 (0.438) | 0.571 (0.468) |
| Moisture | | -0.049 (0.080) | -0.053 (0.052) | -0.044 (0.054) |
| Insect resistant | | | | -3.758 (3.035) |
| Herbicide tolerant | | | | -1.447 (1.401) |
| Insect resistant follow-on hybrid | | | | 1.348 (0.873) |
| Herbicide tolerant follow-on hybrid | | | | 2.541* (1.422) |
| Standard errors clustered at the level of hybrids. *** p<0.01, ** p<0.05, * p<0.10 | | | | |
| N | 315 | 315 | 174 | 174 |
| Mean citations | 8.314 | 8.314 | 9.402 | 9.402 |
| R-squared | 0.554 | 0.554 | 0.706 | 0.707 |
| Year FE | YES | YES | YES | YES |

Notes: The dependent variable *citations* measures the sum of forward citations to a patent - hybrid pair. The variable *yields* measures the improvement in yields (in percent) over existing hybrids. In case of multiple comparisons in the patent, we selected the highest-yielding comparison hybrid. *Moisture* measures the relative moisture level of the patented hybrid to the highest-yielding comparison hybrid. *Insect resistant* equals 1 if the patented hybrid is insect resistant while the comparison hybrid is not. *Herbicide tolerant* equals 1 if the patented hybrid is herbicide tolerant while the comparison hybrid is not. *Insect resistant follow-on hybrid* equals 1 if a genetically modified hybrid, which shares the same base genetics, but is also insect resistant, is introduced by the same breeder as a follow-on hybrid. *Herbicide tolerant follow-on hybrid* equals 1 if a genetically-modified hybrid, which shares the same base genetics, but is also herbicide tolerant, is introduced by the same breeder as a follow-on hybrid. Year fixed effects control for the year of the patent application (1985 + t). Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A7 – OLS, DEPENDENT VARIABLE IS FORWARD CITATIONS (COLUMNS 1, 3-4), FORWARD CITATIONS AFTER 2000, EXCLUDING EXAMINER-ADDED CITATIONS (COLUMNS 2) AND SELF-CITATIONS (COLUMNS 5-6) TO PATENT - HYBRID PAIRS

| | All citations (1-4) (1) | All citations after 2000, excl. examiner- added (2) | All citations (3-4) (3) (4) | | Self-citations (5-6) (5) (6) | |
|--|-------------------------------|--|-------------------------------------|---------------------|--------------------------------------|---------------------|
| Yields | 0.510** (0.245) | 0.419* (0.235) | 0.598 (0.438) | 0.571 (0.468) | 0.056 (0.047) | -0.002 (0.044) |
| Moisture | -0.031 (0.046) | -0.0453 (0.032) | -0.053 (0.052) | -0.044 (0.054) | -0.033 (0.041) | -0.028 (0.0414) |
| Insect resistant | | | | -3.758 (3.035) | | 0.169 (0.906) |
| Herbicide tolerant | | | | -1.447 (1.401) | | -0.184 (0.791) |
| Insect resistant follow-on hybrid | | | | 1.348 (0.873) | | 0.954 (0.624) |
| Herbicide tolerant follow-on hybrid | | | | 2.541* (1.422) | | 3.432*** (1.028) |
| First patents | 384.5*** (1.139) | 381.3*** (0.778) | 134.0*** (1.718) | 135.0*** (1.919) | 123.6*** (0.591) | 124.8*** (0.791) |
| Standard errors clustered at the level of hybrids. *** p<0.01, ** p<0.05, * p<0.10 | | | | | | |
| N | 315 | 315 | 174 | 174 | 174 | 174 |
| Mean citations | 8.314 | 5.743 | 9.402 | 9.402 | 3.954 | 3.954 |
| R-squared | 0.766 | 0.725 | 0.706 | 0.707 | 0.939 | 0.954 |
| Year FE | YES | YES | YES | YES | YES | YES |

Notes: The dependent variable *citations* measures the sum of forward citations to a patent - hybrid pair (columns 1-4). *Self-citations* measure the sum of self-citations to a patent - hybrid pair (columns 5-6). The variable *yields* measures the improvement in yields (in percent) over existing hybrids. In case of multiple comparisons in the patent, we selected the highest-yielding comparison hybrid. *Moisture* measures the relative moisture level of the patented hybrid to the highest-yielding comparison hybrid. *Insect resistant* equals 1 if the patented hybrid is insect resistant while the comparison hybrid is not. *Herbicide tolerant* equals 1 if the patented hybrid is herbicide tolerant while the comparison hybrid is not. *Insect resistant follow-on hybrid* equals 1 if a genetically modified hybrid, which shares the same base genetics, but is also insect resistant, is introduced by the same breeder as a follow-on hybrid. *Herbicide tolerant follow-on hybrid* equals 1 if a genetically-modified hybrid, which shares the same base genetics, but is also herbicide tolerant, is introduced by the same breeder as a follow-on hybrid. The variable *first patents* is an indicator for the first four patents that the USPTO issued for hybrid corn (US4,607,453; US4,629,819; US4,731,499; US 4,737,596); it also captures one patent (US6,433,261) that later patents cite along with US4,731,499 (see Table 3 for a detailed description). Year fixed effects control for the year of the patent application (1985 + t). The dummy variable *highly-cited* is a linear combination of the year fixed effects in the reduced sample of 174 observations (column 3-4), therefore the coefficient estimates are identical to the ones reported in Table A6, columns 3-4. Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A8 – OLS, DEPENDENT VARIABLE IS FORWARD CITATIONS AFTER 2000 (COLUMNS 1-3) AND EXAMINER-ADDED CITATIONS (COLUMNS 4-6) TO PATENT - HYBRID PAIRS

| | All citations after 2000 (1-3) | | | Examiner-added citations (4-6) | | |
|--|--------------------------------|---------------------|---------------------|--------------------------------|----------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Yields | 0.506** (0.241) | 0.591 (0.431) | 0.565 (0.460) | 0.087* (0.045) | 0.010 (0.020) | 0.011 (0.020) |
| Moisture | -0.033 (0.046) | -0.056 (0.052) | -0.047 (0.054) | 0.012 (0.033) | -0.011 (0.014) | -0.011 (0.014) |
| Insect resistant | | | -3.725 (2.987) | | | -0.061 (0.639) |
| Herbicide tolerant | | | -1.465 (1.393) | | | -0.244 (0.472) |
| Insect resistant follow-on hybrid | | | 1.279 (0.866) | | | -0.026 (0.237) |
| Herbicide tolerant follow-on hybrid | | | 2.542* (1.408) | | | -0.072 (0.244) |
| First patents | 384.5*** (1.134) | 74.49*** (2.035) | 75.46*** (2.195) | 3.258*** (0.858) | -1.749*** (0.367) | -1.774*** (0.362) |
| Standard errors clustered at the level of hybrids. *** p<0.01, ** p<0.05, * p<0.10 | | | | | | |
| N | 315 | 174 | 174 | 315 | 174 | 174 |
| Mean citations | 7.460 | 7.862 | 7.862 | 1.717 | 0.897 | 0.897 |
| R-squared | 0.721 | 0.624 | 0.625 | 0.094 | 0.324 | 0.325 |
| Year FE | YES | YES | YES | YES | YES | YES |

Notes: The dependent variable *citations by patents issued after 2000* counts citations by patents that were issued after 2000 (columns 1-3). *Examiner-added citations (after 2000)* counts citations that the USPTO's examiner added to the list of relevant prior art (columns 4-6); examiner-added citations are only observable for patents that were issued after 2000. The variable *yields* measures the improvement in yields (in percent) over existing hybrids. In case of multiple comparisons in the patent, we selected the highest-yielding comparison hybrid. *Moisture* measures the relative moisture level of the patented hybrid to the highest-yielding comparison hybrid. *Insect resistant* equals 1 if the patented hybrid is insect resistant while the comparison hybrid is not. *Herbicide tolerant* equals 1 if the patented hybrid is herbicide tolerant while the comparison hybrid is not. *Insect resistant follow-on hybrid* equals 1 if a genetically modified hybrid, which shares the same base genetics, but is also insect resistant, is introduced by the same breeder as a follow-on hybrid. *Herbicide tolerant follow-on hybrid* equals 1 if a genetically-modified hybrid, which shares the same base genetics, but is also herbicide tolerant, is introduced by the same breeder as a follow-on hybrid. The variable *first patents* is an indicator for the first four patents that the USPTO issued for hybrid corn (US4,607,453; US4,629,819; US4,731,499; US 4,737,596); it also captures one patent (US6,433,261) that later patents cite along with US4,731,499 (see Table 3 for a detailed description). Year fixed effects control for the year of the patent application (1985 + t). Data include 315 patents – hybrid pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*.

TABLE A9 – SHARE OF RENEWED PATENTS BY TIME OF RENEWAL

| | Time of renewal | 4 years | 8 years | 12 years |
|------------------------------------|-----------------|---------|---------|----------|
| Patents issued 1986 – 2002 (N=233) | | 98.3% | 97.9% | 97.4% |
| Patents issued 2003 – 2005 (N=36) | | 100.0% | 100.0% | n/a |
| All patents (N=269) | | 98.5% | 98.1% | n/a |

Notes: Data include 269 U.S. utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*. Data on patent renewals is available at <https://ramps.uspto.gov/eram/patentMaintFees.do> and was accessed in 2014. The decision on patent renewal 12 years after issue can therefore not be observe for patents issued after 2002.

TABLE A10 - FIELD TRIAL DATA

| Institution conducting the Field Trials | Name of the Field Trial | Years |
|---|--------------------------------|-------------|
| University of Kentucky, College of Agriculture, Agricultural Experiment Station, Department of Agronomy | Hybrid Corn Performance Test | 1996 – 2005 |
| University of Wisconsin-Madison, College of Agricultural and Life Sciences | Corn Hybrid Performance Trial | 1996 – 2005 |
| Prince Edward Island, Department of Agriculture, Fisheries and Aquaculture, Agricultural Resources Division | Corn Guide to Hybrid Selection | 2006 |
| Ontario Corn Committee | Hybrid Corn Performance Trial | 2001 – 2003 |

Notes: Field trial reports are available from the following website: <http://www.ca.uky.edu/cornvarietytest/>;
<http://corn.agronomy.wisc.edu/HT/Default.aspx>; http://www.gov.pe.ca/photos/original/af_06cornguide.pdf;
<http://www.gocorn.net/v2006/CornReports/2001cornreport/2001performancetrials.html>;
<http://www.gocorn.net/v2006/CornReports/2002cornreport/2002performancetrials.html>;
<http://www.gocorn.net/v2006/CornReports/2003cornreport/2003performancetrials.htm>.

TABLE A11 – PATENTS AND CLAIMS BY BREEDER AND ATTORNEY

| Breeder | Attorney | # of patents | Average # of claims |
|-------------------------------|---|--------------|---------------------|
| Pioneer | Pioneer; IP counsel | 117 | 15.7 |
| | McKee, Voorhees & Sease | 23 | 23.2 |
| | Saidman, Sterne, Kessler & Goldstein | 2 | 5.0 |
| Dekalb | Arnold, White & Durkee | 62 | 36.4 |
| | Fulbright & Jaworski | 46 | 28.0 |
| | Knuth, Richardson & Monroe | 1 | 5.0 |
| | Sughrue, Mion, Zinn, Macpeak & Seas | 1 | 3.0 |
| Asgrow | Fulbright & Jaworski | 8 | 29.8 |
| Rustica Prograin Genetique | Patterson, Thuente, Skaar & Christensen | 3 | 50.0 |
| Monsanto | Fulbright & Jaworski | 2 | 29.0 |
| Kleinwanzlebener Saatzucht | Townsend, Townsend & Crew | 2 | 9.5 |
| Euralis | Patterson, Thuente, Skaar & Christensen | 1 | 31.0 |
| Sandoz | Marcus-Wyner & Norris | 1 | 16.0 |
| All patents | | 269 | 24.0 |

Notes: Data include 269 U.S. utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize*. Data on patent attorneys is available at <http://patft.uspto.gov>.

TABLE A12A – EXAMPLE OF AN EXAMINER’S SEARCH REPORT

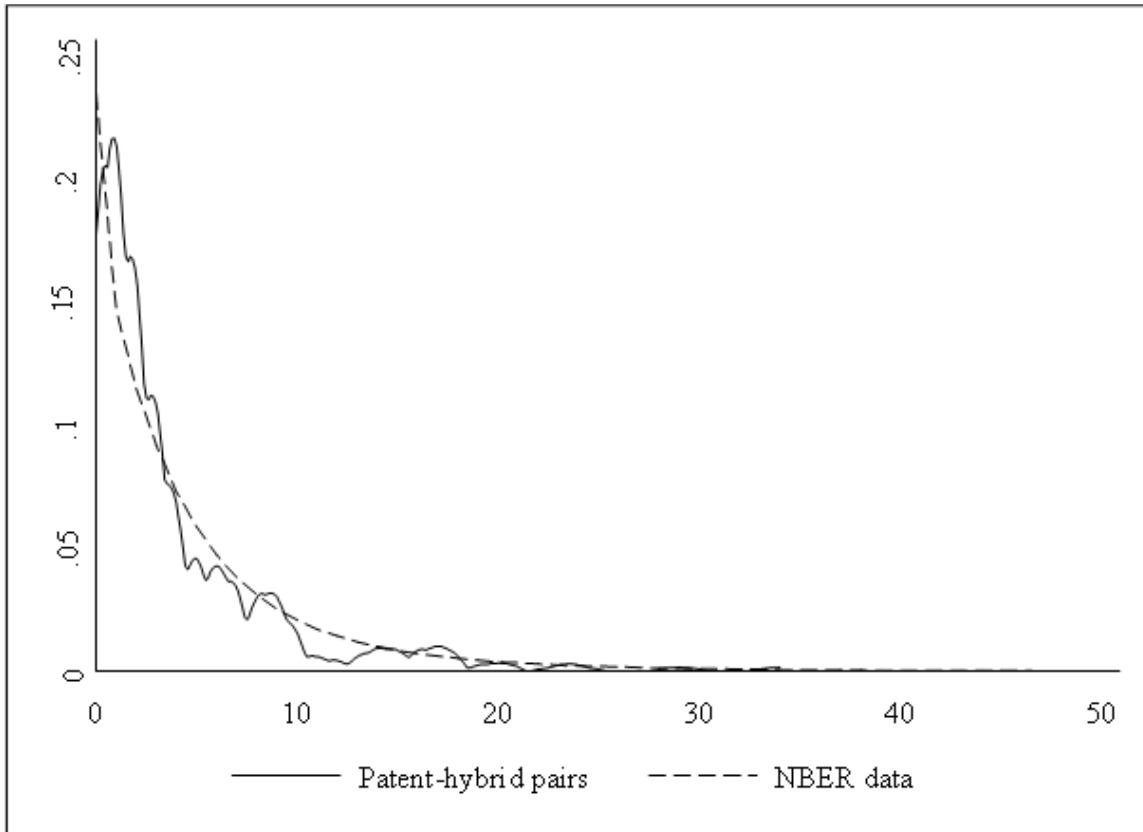
| Search History | | | |
|--|--|------------------|-----------------|
| DATE: Sunday, October 02, 2005 | | | |
| Printable Copy Create Case | | | |
| Set Name | Query | Hit Count | Set Name |
| side by side | | | result set |
| <i>DB=PGPB,USPT; PLUR=YES; OP=OR</i> | | | |
| <u>L18</u> | l12 and l17 | 10 | <u>L18</u> |
| <u>L17</u> | L16 and l11 | 11 | <u>L17</u> |
| <u>L16</u> | L14 and l9 | 18 | <u>L16</u> |
| <u>L15</u> | l8 and L14 | 2 | <u>L15</u> |
| <u>L14</u> | L6 and l7 | 175 | <u>L14</u> |
| <u>L13</u> | ((grey or gray) adj leaf adj spot) near10 (tolera\$ or resist\$) | 496 | <u>L13</u> |
| <u>L12</u> | cob near10 red | 531 | <u>L12</u> |
| <u>L11</u> | (ear or position) near10 horizontal | 181431 | <u>L11</u> |
| <u>L10</u> | silk near10 ((pale or light) adj yellow) | 18 | <u>L10</u> |
| <u>L9</u> | glume near10 purple | 230 | <u>L9</u> |
| <u>L8</u> | anther near10 ((pale or light) adj yellow) | 192 | <u>L8</u> |
| <u>L7</u> | (leaf or leaves) near10 (dark adj green) | 2705 | <u>L7</u> |
| <u>L6</u> | anthocyanin near10 (faint or light) | 606 | <u>L6</u> |
| <u>L5</u> | L4 not l3 | 1 | <u>L5</u> |
| <u>L4</u> | ge2085580 or ge514284 | 2 | <u>L4</u> |
| <u>L3</u> | 33y45 | 1 | <u>L3</u> |
| <u>L2</u> | L1 and (800/320.1).ccls. | 15 | <u>L2</u> |
| <u>L1</u> | colbert.in. near2 terry.in. | 15 | <u>L1</u> |
| END OF SEARCH HISTORY | | | |

TABLE A12B – EXCERPT OF SEARCH RESULTS

| | | | | | | | | | | | | | | |
|--|------------|-------------|-------|--------|----------------|----------|-----------|--------|----------------|---------|-----------|--------|------|---------|
| <input type="checkbox"/> 5. Document ID: US 6759577 B1 | | | | | | | | | | | | | | |
| L18: Entry 5 of 10 | File: USPT | Jul 6, 2004 | | | | | | | | | | | | |
| US-PAT-NO: 6759577 | | | | | | | | | | | | | | |
| DOCUMENT-IDENTIFIER: US 6759577 B1 | | | | | | | | | | | | | | |
| ** See image for <u>Certificate of Correction</u> ** | | | | | | | | | | | | | | |
| TITLE: Hybrid maize plant and seed 37Y15 | | | | | | | | | | | | | | |
| <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>Full</td> <td>Title</td> <td>Citation</td> <td>Front</td> <td>Review</td> <td>Classification</td> <td>Data</td> <td>Reference</td> <td>Claims</td> <td>KIMC</td> <td>Draw Da</td> </tr> </table> | | | | Full | Title | Citation | Front | Review | Classification | Data | Reference | Claims | KIMC | Draw Da |
| Full | Title | Citation | Front | Review | Classification | Data | Reference | Claims | KIMC | Draw Da | | | | |

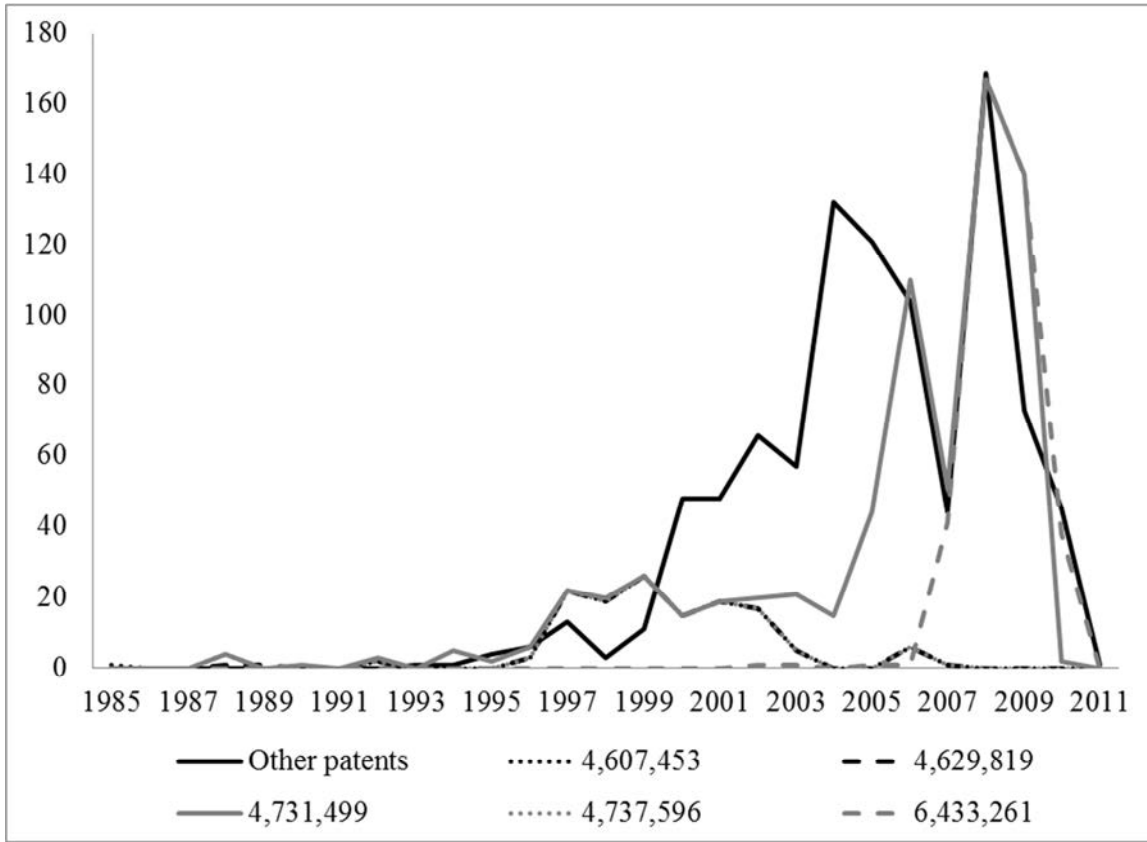
Notes: Information on examiner’s search reports is available at the USPTO’s Patent Application Information Retrieval portal: <http://portal.uspto.gov/pair/PublicPair>. Table 7A shows the examiner’s search history for US7,087,821. Table 7B shows information for one of the 10 patents that resulted from the search ‘L18’ in Table 7A. This is the only examiner-added citation to US7,087,821.

FIGURE A1 – CITATION COUNTS FOR PATENT-HYBRID PAIRS WITH 0 TO 34 CITATIONS, EXCLUDING 5 HIGHLY-CITED PATENTS THAT RECEIVE BETWEEN 136 AND 390 CITATIONS



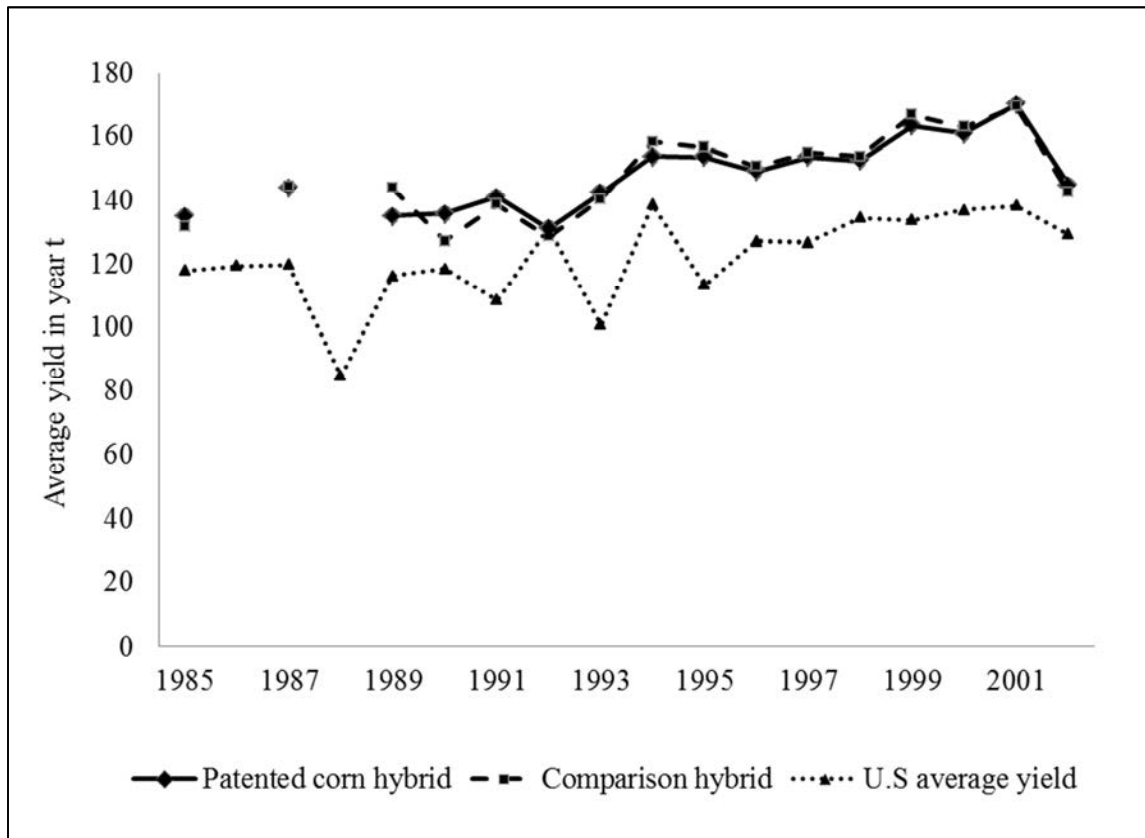
Notes: Citation counts for 310 patent – hybrid pairs for 264 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 *Maize* (available at www.uspto.gov). Excluding patents US4,607,453 (136 citations), US4,629,819 (137 citations), US4,731,499 (693 citations), US4,737,596 (139 citations), and US6,433,261 (390 citations).

FIGURE A2 – CITATIONS PER YEAR FOR PATENT-HYBRID PAIRS



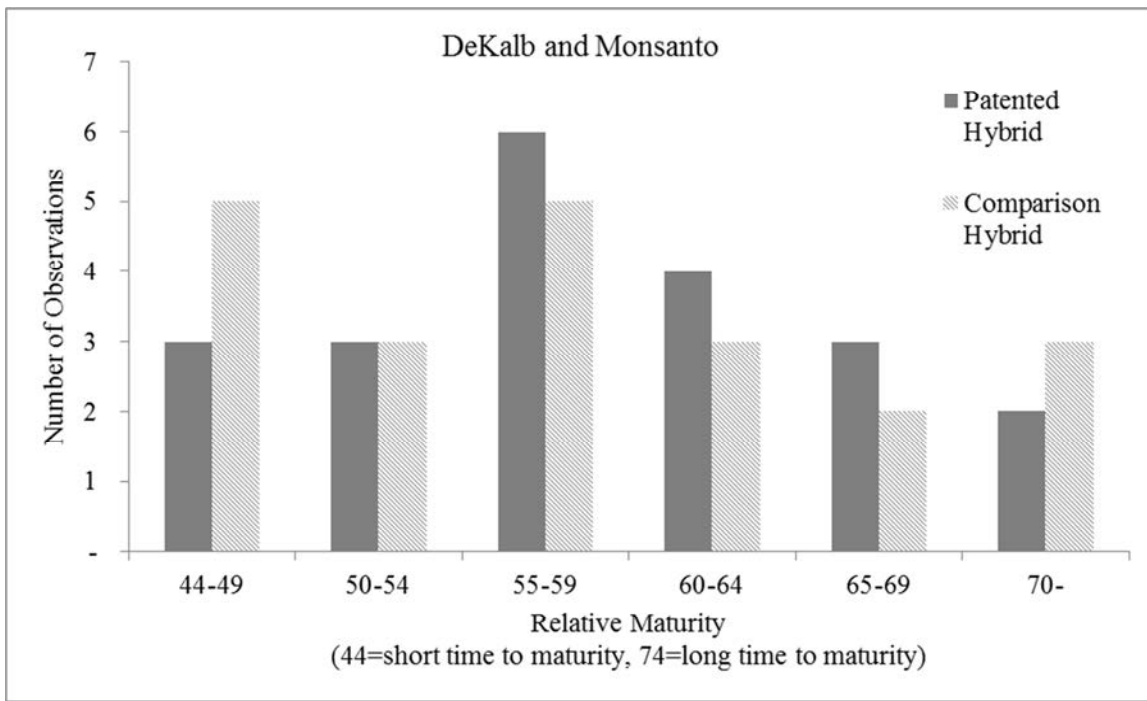
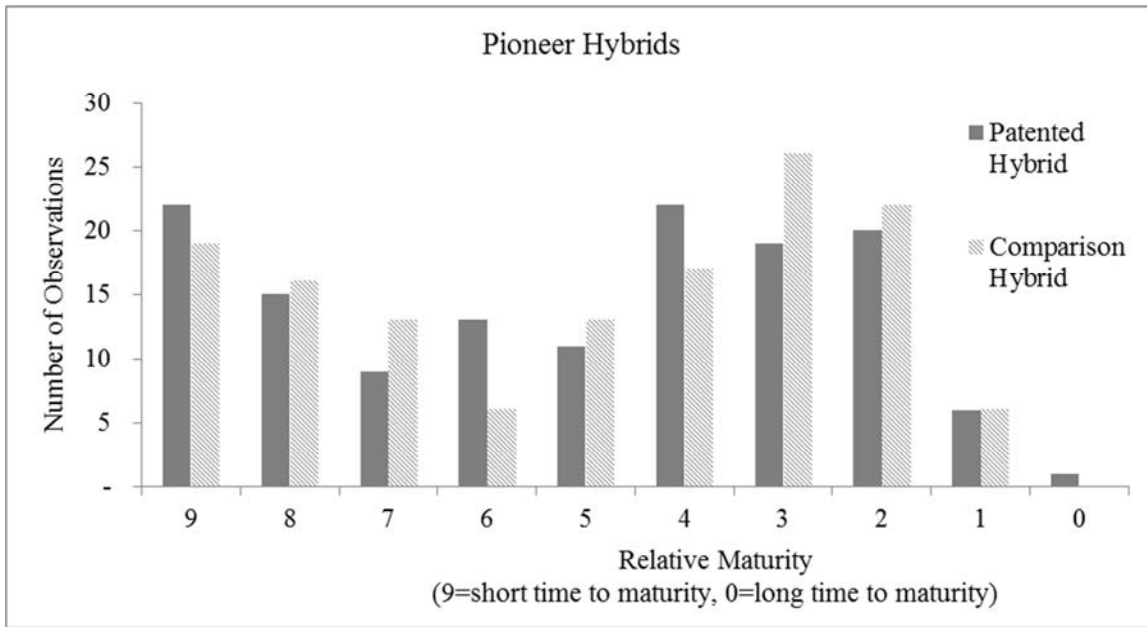
Notes: Citation counts per year for 315 patents – hybrid corn pairs for 269 US utility patents issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 Maize (available at www.uspto.gov). *Other patents* counts the sum of citations per year to 310 patent-hybrid pairs that received fewer than 100 citations. Among 5 patents with more than 100 citations, US4,607,453 received a total of 136 citations, USPTO 4,629,819 received a total of 137 citations, US4,731,499 received a total of 693 citations, US4,737,596 received a total of 139 citations and US6,433,261 received a total of 390 citations.

FIGURE A3 – AVERAGE YIELD PER YEAR, NEWLY PATENTED CORN HYBRIDS VERSUS COMPARISON HYBRIDS VERSUS U.S. AVERAGE YIELDS



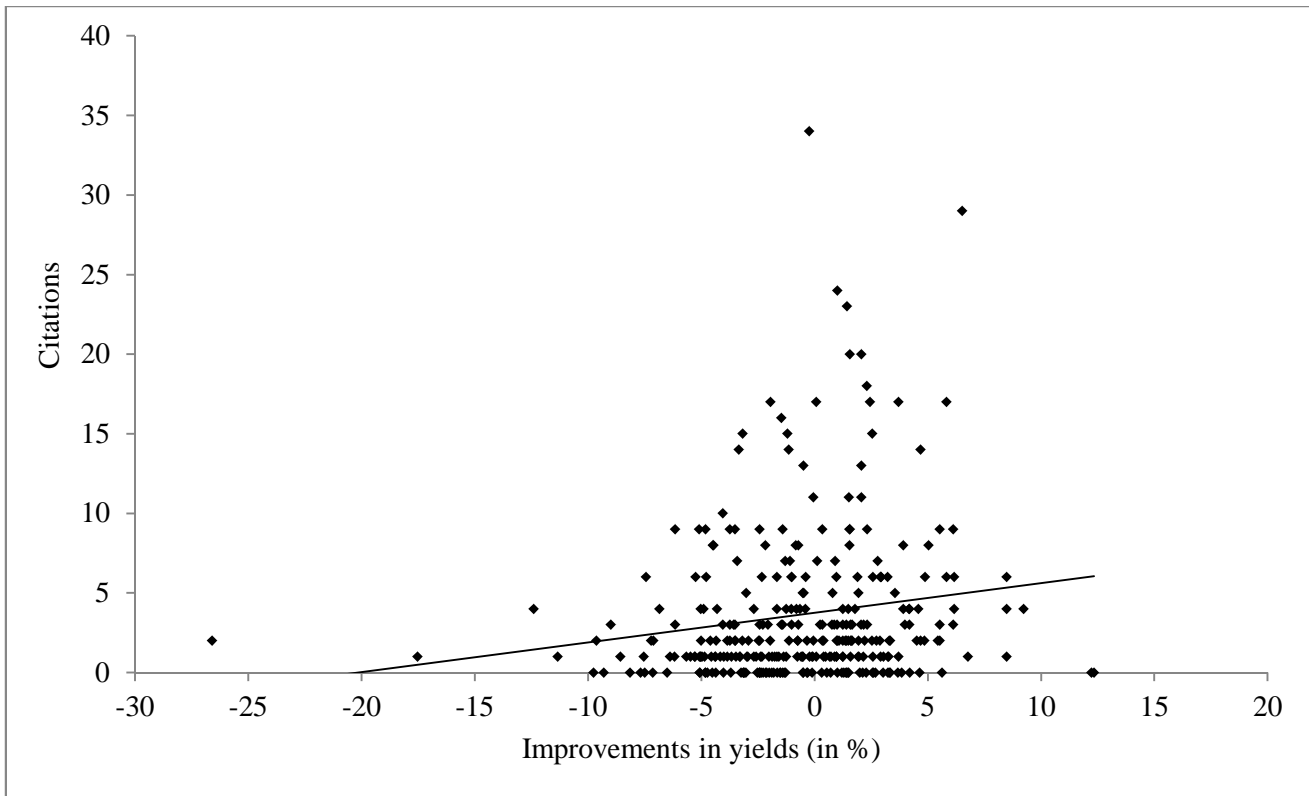
Notes: Average yields per year of application for 269 patents issued for new hybrids in subclass 800/320.1 *Maize* (available at www.uspto.gov). Yields are based on field trial data, which breeders report on patent applications. Data on U.S. averages from the United States Department of Agriculture (www.nass.usda.gov).

FIGURE A4 – DISTRIBUTION OF RELATIVE MATURITY FOR NEWLY PATENTED AND COMPARISON HYBRIDS



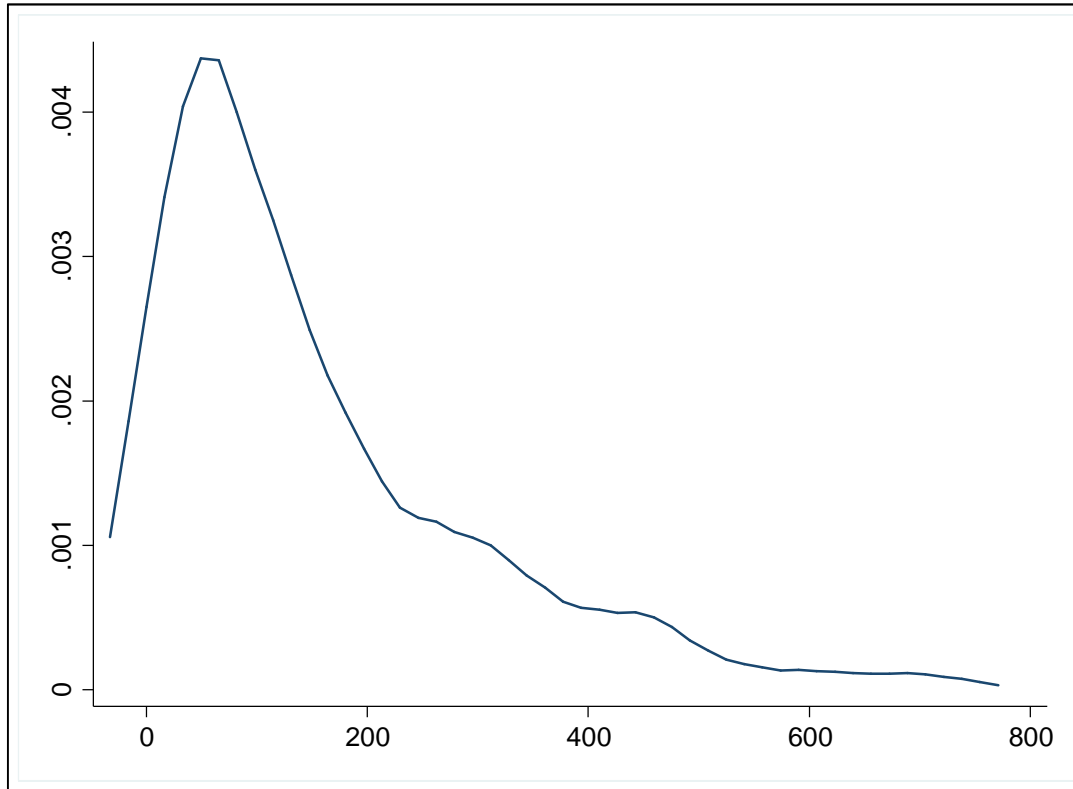
Notes: Information on relative maturity is encoded in the product name of new hybrids. The second digit of Pioneer’s hybrid name identifies its relative maturity on a scale from 0 (very full) to 9 (very short). See www.pioneer.com/home/site/ca/products/product-naming-system for a key to Pioneer’s naming practices. For DeKalb and Monsanto, the first two digits of a hybrid’s name identify its relative maturity; observed values of relative maturity range from 44 (short) to 74 (long).

FIGURE A5 – CITATIONS AND IMPROVEMENTS IN YIELDS FOR PATENT-HYBRID PAIRS WITH 0 TO 34 CITATIONS, EXCLUDING 5 HIGHLY-CITED PATENTS THAT RECEIVE BETWEEN 136 AND 390 CITATIONS



Notes: Improvements in corn yields and citations for 310 patent – hybrid pairs for 264 U.S. utility patents (excluding highly-cited patents) issued between August 26, 1986 and March 8, 2005 in subclass 800/320.1 Maize. Excluding patents US4,607,453 (136 citations), US4,629,819 (137 citations), US4,731,499 (693 citations), US4,737,596 (139 citations), and US6,433,261 (390 citations). Improvements in corn yields are calculated by comparing the yield of the new hybrid with the highest yield of comparison hybrids. The line fits a linear regression without controls, with an estimated intercept of 3.745, and a slope of 0.186 (with a standard deviation of 0.066).

FIGURE A6 – CITATION COUNTS FOR THE FIRST 500 PATENTS IN SUBCLASS 705/35 (FINANCE)



Notes: Citation counts for the first 500 US utility patents in subclass 705/35 *Finance* issued between October 25, 1977 and November 30, 2004 (available at www.uspto.gov).

