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Market concentration and productivity in the United States corn sector: 2002-2009

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2012 Annual Meeting
Seattle WA, August 12-14, 2012

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Abstract

There is a large literature which investigates the relationship between market concentration and innovation. It is difficult to find a suitable measure for innovative output. We use a rich dataset based on university trials of corn hybrids to estimate, using fixed effects, a production function. We predict the fixed effects, by year and Crop Reporting District (CRD), for each hybrid to identify the amount of yield that is directly related to the genetics of the hybrids. We combine this dataset with one which provides information for market concentration, and find, using two stage least squares, that there is a positive relationship between market concentration and innovation.

Keywords: corn hybrids, innovation, instrumental variables, market concentration.

There is a large literature, much of it in the Schumpeterian tradition, which investigates the effect of firm size or market structure on innovation. To some extent these literatures overlap, possibly because to some extent the firms in a concentrated market could be expected to be large. Most studies have used a regression of some measure of innovative activity on a measure of firm size or market concentration. However, it is difficult to find an appropriate measure of both innovation and competition, given the lack of available data.

Typical studies have used cross-sectional samples restricted to R&D "performers", and attempted to determine the relationship between R&D (or R&D intensity) and firm size. However, Cohen and Levin (1989) suggest that measurement of innovative effort by expenditures on R&D or by personnel engaged in R&D is flawed, and Fisher and Temin (1973) argued that the relationship between firm size and innovation must be based on innovative output, not R&D (an innovative input). Other measures have included a proxy measure of innovative output such as patented inventions (Mansfield 1969), or counts of commercially significant innovations (Geroski 1994). Measures of patents suffer because not all patented inventions prove to be innovations, and many innovations are never patented

(Acs and Audretsch 1987), and the choice of commercially significant innovations is likely to be subjective.

Early studies across industries failed to control for industry effects, but later studies using multi-industry samples have controlled for industry differences by including technological opportunity in that industry, or industry fixed effects. Industry level studies avoid the problems caused by restricting the elasticity of R&D with respect to size to be constant across industries, but suffer from the limitation that there is generally a small sample size (Cohen 2010). Other limitations, discussed by Cohen (2010), are that samples have generally been non-random, the studies vary in the extent to which they control for characteristics of firms (other than size), and it is difficult to control for industry effects because most larger firms are aggregations of business units. A further challenge facing empirical studies of the relationship between competition and innovation comes from the fact that it is likely that competition and innovation are simultaneously determined, either with causality running in both directions, or with both innovation and competition codetermined by other exogenous factors.

In this paper we investigate the effect of concentration on innovation in plant breeding. We use a set of experimental field data from university trials of corn hybrids (described in Nolan and Santos (2010; 2011), and market research data (described in Shi, Chavas and Stiegert (2010)) on market concentration in individual Crop Reporting Districts (CRDs) where the individual trials are located, to investigate whether increased concentration in these local markets influences yield. If we consider increases in yield (productivity) to be the result of increased R&D, and hence innovation, then this will provide insight into the question as to whether increased market power promotes innovation.

We treat the trial data as panel data, with individual hybrids as the cross section, and use fixed effects to estimate the contribution of the genetics (including genetic modification) of each hybrid to yield. We estimate a fixed effects model for each CRD, and find the maximum fixed effect in each CRD in each year. We treat that as the maximum contribution of plant breeding research to yield in each CRD in each year, and use this as our measure of innovative output. We have 552 observations where we have both maximum fixed effect and concentration data lagged by two years. We assume that seed companies will trial their hybrids in areas where they intend to market the hybrid. We then regress the maximum fixed effect per CRD per year on our measure of market concentration, that is, the CR4 ratio in the corresponding CRD. Since it is also possible that there is reverse causality (that is that innovation may cause market concentration), we need to use instrumental variables to determine whether increased concentration leads to increased productivity.

This study is limited to an examination of a subset of an industry. Breeding of corn hybrids in the US is part of the US plant breeding industry, which in turn is part of a larger agrochemical industry. It is an industry which has become increasingly concentrated since the introduction of biotechnology. Mergers and acquisitions since the mid 1990s led to a situation where, in 2011, the four major biotechnology companies (Monsanto, Pioneer, Syngenta and Dow AgroSciences) controlled nearly 90% of the national corn seed market in the United States. This percentage is higher, in some cases as high as 100%, in some individual Crop Reporting Districts (CRDs).

There are advantages in limiting our analysis to a specific sub-industry. In particular, we do not need to allow for differences in industry characteristics, but avoid the problems of past studies where the sample size was small. We have clear measures of innovative output, and of market concentration. Neither the technological opportunities, nor the appropriability conditions will vary for the industry as a whole. We include a dummy variable for the breeder of the top hybrid in each CRD to allow for the possibility of differences between firms. We also consider that we can use the adoption rates for GM crops as a measure of the demand for technology in the industry. We present preliminary results. The main limitation of the analysis is that it is difficult to identify suitable instrumental variables, and this will be the subject of ongoing investigation. We also believe that the results from this case study could be applied more generally.

Background

In this section we discuss some of the literature relating to the measurement of innovation, in both the general economics and the agricultural economics literature. We also briefly review the literature dealing with the relationship between market structure and innovation. We then describe the changing structure of the US corn seed industry, and discuss why this industry provides a good basis for a case study investigating the effect of market structure on innovation.

Measuring innovation

Cohen and Levin (1989) suggest that a fundamental problem in the study of innovation and technical change is the absence of satisfactory measures of new knowledge and its contribution to technological progress. There are shortcomings with the most commonly used measures of innovation in studies concerned with the effects of firm size or market structure. The shortcomings are particularly apparent where the dependent variable is a measure of input to the innovation process, for example, expenditures on R&D (Scherer 1965) or by personnel engaged in R&D (Cohen and Levin 1989) or R&D intensity, rather than a measure of innovative output. R&D expenditure is difficult to measure accurately, and R&D measures indicate only the budgeted allocation towards trying to produce innovative activity, but not the actual amount of resulting innovations. Fisher and Temin (1973) argued that the relationship between firm size and innovation must be based on innovative output not R&D (an input), and Geroski (1994) also suggests that R&D expenditures are inputs into the innovation process but may not be suitable measures of its output.

Other direct studies of innovation generally depend on subjective identification and assessment of significant innovations. Acs and Audretsch (1987), for example, use a dataset of innovations identified by the US Small Business Administration, and use a measure of the number of innovations per employee, and the number of innovations divided by sales. Others measure innovative output, such as counts of commercially significant innovations drawn from the SPRU Innovations database (Geroski 1994; Blundell, Griffith and Reenen 1999). Geroski (1990) also includes measures of entry, exit, and the number of all firms, and finds a positive relationship between competition and innovation, which he attributes to his inclusion of a control for technological opportunity. Blundell, Griffith and Reenen (1999) find that market share has a positive effect on innovation, but that overall market concentration has a negative effect.

Others (for example, Mansfield 1969) have used a proxy measure of innovative output such as patented inventions, but the use of patent counts also has limitations (Griliches, Pakes and Hall 1986; Cohen and Levin 1989; Lanjouw, Pakes and Putnam 1998; Gallini 2002) given that its economic value is highly heterogeneous as a large number of patents may never be exploited commercially and only a very few are associated with major technological improvement. In the context of the breeding of new plant varieties, for example, Kolady and Lesser (2009) question whether the protection of breeders' rights, in the absence of merit standards, may have led to the patenting of trivial reformulations. Measures of patents suffer because not all patented inventions prove to be innovations, and many innovations are never patented.

Cohen (2010) suggests that cross sectional studies offer little insight to the relationship between concentration and R&D. Aggregate studies that pooled observations across industries restrict the elasticity of R&D with respect to size to be the same across industries. However, in most industry level studies, sample sizes are small for most individual industries (Cohen and Klepper 1996). Samples used in these studies tend to be non-random, and in most cases sample selection bias has been ignored. Studies also vary in the extent to which they control for firm characteristics other than size, even though firm characteristics have been found to be important in explaining R&D intensity, and Scott (1984) suggests that firm effects may be as important as industry effects.

Measures of technological change, or innovation, in agricultural economics

The effects of technological change have been empirically taken, in the agricultural economics literature, to be equivalent to the estimates of a time trend in econometric models, although it is recognized that this can only be an approximation (Peterson and Hayami 1977; Babcock and Foster 1991; Chavas et al. 2001; Alston and Venner 2002). In particular the use of a time trend does not allow for the separation of the effect of changes in varietal technology from improvements in management efficiency, changes in the quality of other inputs, in input-output mix or in scale (Traxler et al. 1995; O'Donnell 2010), all of which are hard to measure, particularly when using aggregate time series data.

As noted by Peterson and Hayami (1977) the use of the term "technical change" should be more properly understood as an indication that we do not know where at least a part of the change in output is coming from. The time trend is incorporated in a production function (for example, Babcock and Foster 1991; Alston and Venner 2002; Naseem, Oehmke and Schimmelpfennig 2005) and there is a long tradition in economics that deals with what can (and cannot) be identified with this approach (Peterson and Hayami 1977; Babcock and Foster 1991; Griliches and Mairesse 1998; Just and Pope 2001; Mundlak 2001).

Innovation and market concentration

Firms require the expectation of some form of transient market power to have the incentive to invest in R&D. Schumpeter argued that the possession of *ex ante* market power also favoured innovation, as rival behaviour would be more stable and predictable. He also suggested that the profits derived from the possession of *ex ante* market power provided firms with the financial resources needed for investment in innovative activity.

Most studies have found a positive relationship between market concentration and R&D. Acs and Audretsch (1987) found that large firms are more innovative in concentrated industries with high barriers to entry and high capital intensity, while smaller firms are more innovative in less concentrated industries that are less mature. Gilbert and Newbery (1982) argue that firms with greater market power have incentives to innovate in order to protect their above-normal profits by pre empting entry. Kohn and Scott (1982) find that relationships between firm size, R&D, and various Schumpeterian hypotheses could be influenced by differences in size of potential market shares, and access to efficient marketing channels.

Others argue that a firm's gains from innovation at the margin are larger in an industry that is competitive *ex ante* than under monopoly (Fellner 1951) and that insulation from competitive pressures breeds bureaucratic inertia and discourages innovation (Scherer 1980). Porter (1980) also suggests that, in competitive markets, fear of rivals getting ahead may stimulate innovation. Nickell (1996) finds a significant, positive and economically important relationship between competition and productivity growth.

Industries differ in the degree to which they engage in innovative activity, and the characteristics can be classified as product market demand, technological opportunity, and appropriability conditions (Cohen 2010). Cohen (2010) suggests that even before controlling for industry effects, the variance in R&D intensity explained by market concentration is small, and with the introduction of industry effects, either fixed effects or measures of characteristics such as technological opportunity, appropriability and demand, becomes imperceptible.

There is no clear definition, in this context, of technological opportunity and appropriability, and even where a variable is well defined, data are often not available. Technological opportunity is usually defined as the conditions that determine the number and kinds of innovation that it is feasible to produce given the existing knowledge base. These conditions are exogenous to the decisions of firms and they change only relatively slowly over time. Innovations are considered to be easier in some industries than in others, but it is difficult to determine how to measure this. Because a technical breakthrough must be embodied in a product before it can be marketed, the timing of introduction is likely to be influenced by the influence of rivals and the state of consumer demand (Geroski 1991). Industries where barriers to entry are low are apparently also industries where technological opportunities are particularly rich (Geroski 1991).

Most empirical work on appropriability has focused on the mechanisms facilitating and constraining the ability of firms to capture the returns from new technology as it is embodied in specific processes or products.

The benefits realised by the investment in innovation are proportional to the size of the market in which the innovation is used. More innovation would be expected in larger markets holding constant the cost of innovation (Cohen and Levin 1989). In regression studies of R&D, sales and the growth of sales are typically used to capture market size and growth effects.

It is likely that competition and innovation are simultaneously determined, either with causality running in both directions, or with both innovation and competition determined by other exogenous factors. Phillips (1966; 1971) proposed that causality might run from innovation to market structure, in that the nature and structure of R&D might feed back to, and influence the structure of, the market for resulting innovations. Recognising the potential simultaneity between innovation and concentration, Howe and McFettridge (1976), Levin, Cohen and Mowery (1985) and Blundell, Griffith and Reenen (1999) have instrumented for concentration or market share in regression studies of the effects of market structure on innovative activity, and Aghion et al. (2005) instrument for the Lerner index that is intended to reflect ex ante market power.

The corn seed industry

In this article we measure the effect of changes in plant breeding and the introduction of biotechnology on changes in productivity in the corn industry. The large number of mergers and acquisitions in agricultural inputs industries raises the question as to whether more concentrated markets increase or decrease the level of research and, presumably, future increases in agricultural productivity.

There are advantages in using corn as a case study. We use a quite specific measure for increases in productivity, and the increases can be directly related to plant genetics. We can avoid some of the problems associated with some of the studies mentioned above, in that we are dealing with one industry, and therefore can reasonably assume that industry characteristics such as technological opportunity and appropriability are consistent. We do have variability in that conditions in sub-markets vary, and so having a measure of concentration by Crop Reporting District and by year allows us to account for that variation. We are also able to identify the breeders of the most successful corn hybrids in each region, and are therefore able to account for firm effects in corn breeding.

Innovations in corn breeding

Two innovations in corn breeding have played a key role in increasing yields. The first was the introduction of hybrid corn in the 1930s. Corn hybrids benefited from heterosis (or hybrid vigor) that generated large gains in corn productivity (Griliches 1957; Griliches 1960; Griliches 1960; Fernandez-Cornejo 2004; Springer and Stupar 2007). Area devoted to hybrid corn grew from 1% of corn acreage in 1933 to 100% today.

Duvick (2005) notes that maize grain yields in the U.S. continued to rise since the 1930s as a result of continued investment in plant breeding and improved cultural practices through other agricultural innovations and technology. It has been estimated that since the 1930s, 50-60% of U.S. corn yields have come from changes in the genetic makeup of cultivars and 40-50% from changes in crop management (Thirtle 1985; Duvick 2005).

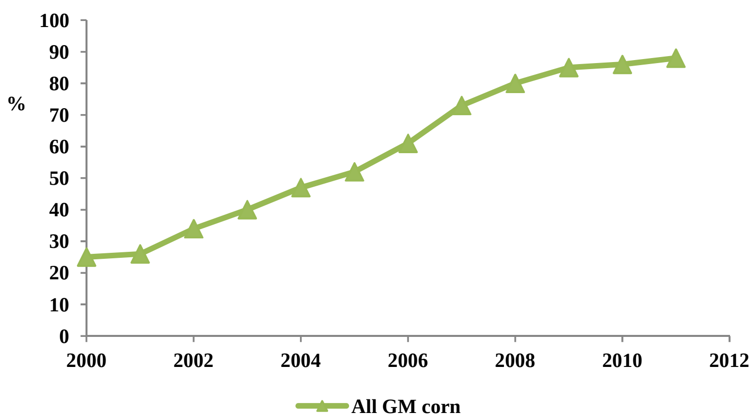

Figure 1. Percentage share of GM hybrids in acreage planted to corn

Source: USDA Economics Research Service (2011)

The second major innovation affecting corn was the introduction, in the 1990s, of genetically modified (GM) traits in seeds. Adoption of GM corn hybrids was rapid in the US. The first of these hybrids was introduced commercially in 1997, and by 2011, 88% of the corn acreage in the US was planted in hybrids with at least one GM trait, and 49% of corn acreage was planted to hybrids with at least three GM traits (USDA Economics Research Service 2011). The percentage of corn acreage planted to the different traits is shown in figure 1. The rate of adoption varies by state, as can be seen from figure 2.

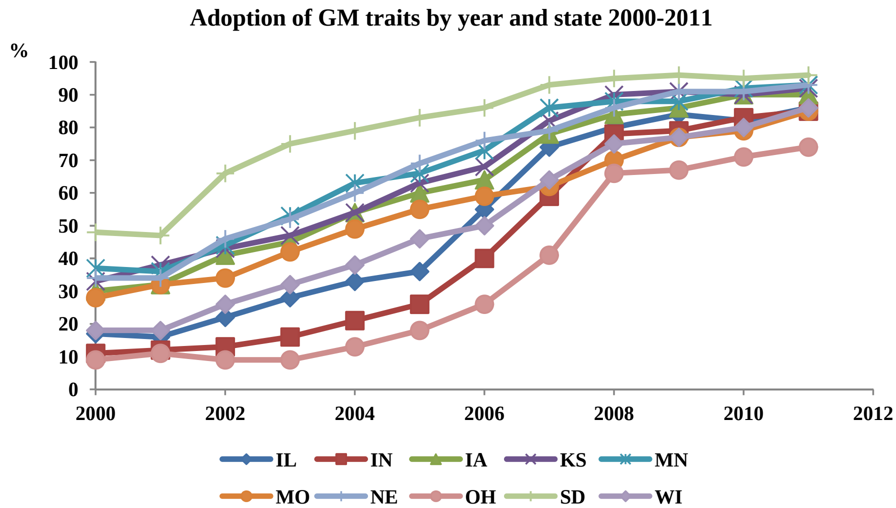

Figure 2. Adoption of GM corn hybrids by year and state

Source: USDA Economics Research Service (2011)

Changing structure of the corn seed industry

Corn has had the longest history of commercial seed breeding because of the ownership rights conferred by hybridisation. Corn growers no longer saved seed, as hybrid seed does not breed true to type. As long as the lineage of a hybrid was unknown to competitors or farmers, the breeder continued to hold a unique and marketable product until an even better hybrid was developed.

The introduction of genetically modified (GM) traits in seeds, following the development of gene transfer technology was the second major innovation, and development and commercialisation of modern agricultural biotechnology in a favourable climate provided by strong Intellectual Property Rights, has been followed by a rapid, dramatic and continuing consolidation in the US seed producing sector (Alston and Venner 2002; Wright and Pardey 2006). The trend to consolidation in the seed industry was driven by a number of factors: exploiting asset complementarities, mitigating contractual hazards, and/or seeking market power (Rausser, Scotchmer and Simon 1999; Graff, Rausser and Small 2003; Shi 2009). A trait developer will not want to invest if he thinks that most of the value will be captured by the seed lines instead of his own company (Chataway and Tait 2000; Wright and Pardey 2006), and a new and valuable trait cannot generate value unless it is incorporated in commercial seed lines which are produced and sold to farmers. Therefore, consolidation in breeding and distribution has been partly driven by the need for access to elite germplasm (Wright and Pardey 2006).

The four-firm concentration ratio (CR4) was 60 percent in 1983, but the corn seed industry is now dominated by four large biotech firms, all with subsidiary seed companies (Fernandez-Cornejo 2004; Shi, Chavas and Stiegert 2010). They are: DuPont (Pioneer International), Monsanto, Syngenta and Dow AgroSciences. By 2010, the four biotech firms supplied about 86% of the US corn seed market. A fifth group, AgReliant (a joint venture between the French Groupe Limagrain, and the German KWS) is also a player in the market. Much of the expansion of these vertically integrated biotech firms was achieved through mergers with, and acquisitions of, local seed companies. About 70% of the market is shared more or less equally between Monsanto and Pioneer. Figure 1 illustrates the market share trend for the four biotech firms over the last twenty years. There is substantial variation in CR4 between Crop Reporting Districts.

Sales of the GM component of corn seed are more concentrated than those of hybrid seed. Monsanto controls about 79% of traits in corn (Schenkelaars, de Vriend and Kalaitzandonakes 2011), and provides the Bt and RR (glyphosate tolerant) genes not only to its own subsidiaries but also to Pioneer and other companies. Cross licensing of traits is widespread in the seed industry, but, as can be seen from figure 3, because Monsanto is the only firm to have agreements with the other five major biotech firms it may have obtained a pivotal position in this network (Howard 2009; Schenkelaars, de Vriend and Kalaitzandonakes 2011).

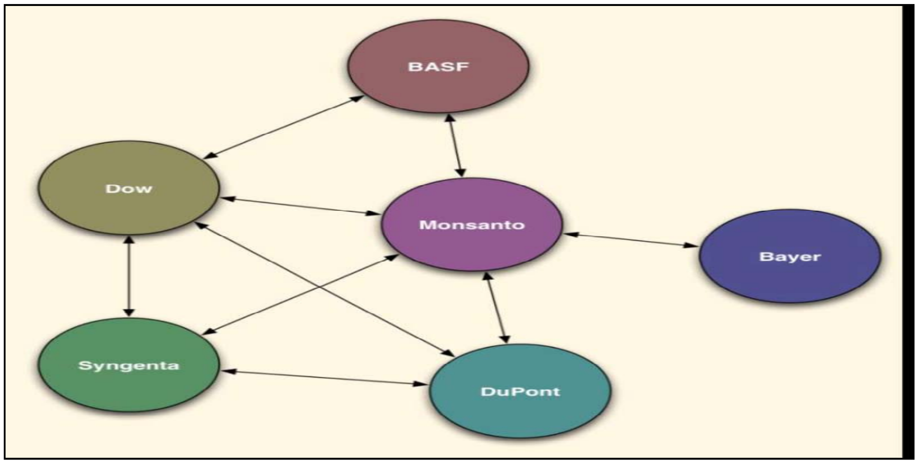

Figure 3. Cross licensing of biotechnology traits

Source: Howard (2009)

Small seed companies need to have access to technology, and licensing is important if these companies are to remain competitive in the market. However, reaching license agreements can be difficult because of the differ restrictions license holders seek to impose on licensees (Schenkelaars, de Vriend and Kalaitzandonakes 2011).

With the development of biotechnology, barriers to entry have increased. Because of the substantial costs of R&D seed markets are less contestable than in the pre biotechnology era. It is estimated that the cost of developing a GM trait in the US in 2004 was about $100 million, including costs related to regulatory approvals (Wilson and Dahl 2010), and that the time required to create a GM variety is ten years from proof of concept to the regulatory submission. The process of regulatory approval can take up to 10 years, and cost between $6 million and $15 million (Kalaitzandonakes, Alston and Bradford 2006). Innovation in plant breeding is only possible with substantial investment, and larger companies that are successful in the market earn a lot of money that can be reinvested in innovation (Schenkelaars, de Vriend and Kalaitzandonakes 2011).

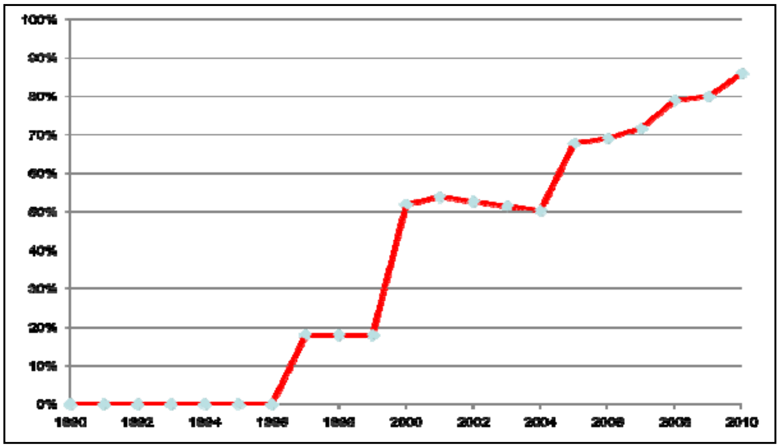

Figure 4. National market concentration

Source: Guanming Shi

Data

We use a dataset, described in Nolan and Santos (2010; 2011) which reports yield (adjusted for moisture content) in bushels per acre for trials of corn hybrids, in 79 individual CRDs in ten states. Agronomic practices and climatic conditions are also reported. We combine these data, whose summary statistics are reported in table 1, with information on the concentration ratio of the top four companies (CR4) in each market, and also the top four biotech companies (BiotechCR4) in each individual CRD. The market concentration data are from detailed information on the U.S. corn seed market, collected by dmrkynetec, and described in Shi, Chavas and Stiegert (2010). We limit our study to the period 2002-2009, for which we have 88,489 observations, as the market concentration information is available only for the period 2000-2007, and we lag the concentration ratios by two years, assuming that it will take time for the market structure to have an influence on innovation. Given that the substantive gains in yield due to the introduction of GM traits were only recorded after 2002 (Nolan and Santos 2010), this should not limit the interest of our results.

Table 1. Summary Statistics

Variable	Definition	Mean	Std. Dev.	Min	Max
Yield	Bushels per acre of shelled grain (56lb/bu)adjusted to a moisture content of 15.5%	190.37	41.07	1	317
Plant density	Plant density in thousands of kernels per acre	30.29	3.44	8.65	43.47
No or min till	Dummy variable indicating no or minimum till	0.08	0.28	0	1
Conventional	Conventional soil preparation methods (base case)	0.92	0.28	0	1
Irrigated	Dummy variable indicating crop grown with irrigation	0.14	0.35	0	1
Dryland	Crop grown without irrigation (base case)	0.86	0.35	0	1
Early	Dummy variable indicating an early trial	0.26	0.44	0	1
Late	Dummy variable indicating a late trial (base case)	0.74	0.44	0	1
Soybean	Dummy variable indicating that soybean was the previous crop in the rotation (base case)	0.86	0.35	0	1
Corn	Dummy variable to indicating that corn was the previous crop in the rotation	0.06	0.25	0	1
Wheat	Dummy variable to indicating that wheat was the previous crop in the rotation	0.05	0.21	0	1
Alfalfa	Dummy variable to indicating that alfalfa was the previous crop in the rotation	0.01	0.11	0	1
Other	Dummy variable to indicating that a crop other than those mentioned above was the previous crop in the rotation	0.02	0.14	0	1
Silt loam	Dummy variable indicating silt loam soil (base case)	0.58	0.49	0	1
Clay	Dummy variable indicating clay soil	0.03	0.16	0	1
Silty clay loam	Dummy variable indicating Silty clay loam soil	0.16	0.36	0	1
Clay loam	Dummy variable indicating Clay loam soil	0.09	0.29	0	1
Loam	Dummy variable indicating Loam	0.09	0.28	0	1
Sandy loam	Dummy variable indicating Sandy loam soil	0.05	0.23	0	1
Sand	Dummy variable indicating Sand	0.00	0.05	0	1
Nitrogen (lbs /ac)	Nitrogen application in lbs per acre	147.12	75.98	0	380
No GM	Dummy variable indicating conventional hybrids (base case)	0.19	0.39	0	1
CB	Dummy variable indicating hybrid has corn borer resistant trait only	0.24	0.42	0	1
RW	Dummy variable indicating hybrid has corn rootworm resistant trait only	0.00	0.07	0	1
Ht	Dummy variable indicating hybrid has herbicide tolerant trait only	0.05	0.22	0	1
CB and Ht	Dummy variable indicating hybrid has both corn borer resistant and herbicide tolerant traits	0.18	0.38	0	1
RW and Ht	Dummy variable indicating hybrid has both corn rootworm resistant and herbicide tolerant traits	0.02	0.13	0	1
CB and RW	Dummy variable indicating hybrid has both corn borer resistant and corn rootworm resistant traits	0.01	0.12	0	1
CB, RW and Ht	Dummy variable indicating hybrid is at least triple stacked with corn borer resistant, corn rootworm resistant and herbicide tolerant traits	0.31	0.46	0	1

Method and results

Treating the data as unbalanced panel data, we estimate a fixed effects model for each individual CRD with corn hybrids as the cross sectional element. The function takes the form:

$$(1) \quad y_{it} = x'_{it}\beta + \alpha_i + \mu_{it}$$

where α_i is the fixed effect for hybrid *i,* and represents the contribution of the genetics (including GM traits) of that hybrid to yield, and where y_{it} is the yield, adjusted for moisture content, of hybrid *i* in year *t*, x'_{it} is the set of covariates presented in table X, together with a set of dummy variables for interaction terms for year by Crop Reporting District that account for any location specific and year specific occurrences that were not accounted for elsewhere in the data, and μ_{it} is the idiosyncratic error.

We predict the fixed effect for each hybrid trialled in each CRD, and consider this to be the contribution of the genetics, include GM traits, of each hybrid to yield. We therefore have a measure of the output which is directly related to plant breeding. We estimate individual models for each CRD to determine the contribution of the genetics of each hybrid in each regional market. We then take the maximum fixed effect in each CRD and each year, and consider this to be the measure of maximum output from plant breeding innovation.

We regress the maximum fixed effects by CRD and year on the corresponding concentration ratios which are lagged by two years. We have two measures of concentration, one for the percentage share of the top four companies in a CRD, the second for the percentage market share of the top four biotechnology companies. We also include a dummy variable to identify the groups which were responsible for breeding the best hybrid, and dummy variables for the GM traits as an indication of the level of adoption of technology. Because the literature previously discussed, and intuition, suggest that innovation may cause market concentration,

Table 2. First-stage Regressions

	BiotechCR4 lagged	CR4 lagged	BiotechCR4 lagged (no traits)	CR4 lagged (no traits)
Corn Borer (CB)	-0.051	0.293		
	(2.087)	(1.628)		
Rootworm (RW)	-2.421	-8.34***		
	(3.349)	(3.044)		
Ht	-2.652286	-5.778*		
	(4.415)	(3.269)		
CBHt	1.615229	-0.251198		
	(2.159)	(1.879)		
CBRW	7.93308	6.852*		
	(4.798)	(4.167)		
RWHt	0.4734712	-3.436*		
	(2.588)	(1.975)		
CBRWHt	-1.500898	-3.825***		
	(2.109)	(1.688)		
Syngenta	-0.3071625	0.322	-0.052	0.845
	(3.074)	(2.734)	(3.004)	(2.779)
Pioneer	4.556785	3.815	4.320	3.522
	(3.494)	(2.737)	(3.519)	(2.858)
Monsanto	1.329656	1.712	0.883	0.611
	(1.567)	(1.263)	(1.551)	(1.249)
Dow	7.303**	9.223***	7.372**	8.832***
	(3.220)	(2.712)	(3.122)	(2.554)
AgReliant	5.049**	4.572***	5.174**	4.559***
	(2.549)	(2.011)	(2.559)	(2.112)
State adoption rate lagged	0.356***	0.217***	0.358***	0.202***
	(0.030)	(0.0239)	(0.027)	(0.021)
Constant	44.3766***	62.775***	44.218***	62.287***
	(1.967)	(1.510)	(1.410)	(1.096)
Number of obs	522	522	522	522
F(13, 508)	19.17	13.61	37.35	22.74
Prob > F	0.00	0.00	0.00	0.00
Centered R2	0.27	0.20	0.26	0.17
Uncentered R2	0.95	0.98	0.95	0.98

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3. Results of Two-Stage Least Squares Regressions for the CR4 by CRD for all Firms and the CR4 by CRD for Biotech Firms

VARIABLES	(1) BiotechCR4 CR4 lagged max_fe	(2) CR4 (top 4 of all firms) lagged max_fe	(3) BiotechCR4 lagged No traits max_fe	(4) CR4 (top 4 of all firms) lagged No traits max_fe
BiotechCR4 lagged	0.832***		0.912***	
	(0.197)		(0.153)	
CR4 (top 4 of all firms) lagged		1.366***		1.617***
		(0.341)		(0.296)
Corn Borer (CB)	-2.178	-2.620		
	(4.116)	(4.364)		
Rootworm (RW)	9.493	18.87		
	(10.78)	(11.79)		
Ht	5.152	10.84		
	(8.055)	(8.541)		
CBHt	0.384	2.072		
	(5.065)	(5.199)		
CBRW	-0.189	-2.948		
	(15.38)	(16.46)		
RWHt	5.808	10.90*		
	(6.022)	(6.359)		
CBRWHt	4.370	8.347*		
	(4.568)	(4.614)		
Syngenta	4.346	3.651	3.659	2.244
	(6.667)	(7.037)	(7.970)	(9.041)
Pioneer	-3.306	-4.725	-3.513	-5.271
	(6.001)	(6.367)	(4.995)	(5.993)
Monsanto	5.650*	4.419	7.071**	6.888*
	(3.367)	(3.623)	(3.187)	(3.548)
Dow	-1.856	-8.377	-1.739	-9.301
	(7.407)	(8.432)	(6.937)	(8.521)
AgReliant	-5.359	-7.404	-5.449	-8.105
	(5.555)	(6.028)	(5.740)	(6.564)
Constant	-10.84	-59.67**	-14.79*	-75.21***
	(11.38)	(23.92)	(8.729)	(20.57)
Observations	522	522	522	522

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

as well as market concentration leading to innovation, we estimate a two stage least squares model, with the GM adoption rate by state as the excluded instrument to deal with problems of endogeneity. The results of the Wu-Hausman test confirm that we cannot accept the null hypothesis that the lagged market concentration is exogenous. The estimates are efficient for arbitrary heteroscedasticity, and the statistics generated are robust to heteroscedasticity. We have also tested for under identification, over identification, and weak identification, and can reject all three possibilities.

The results are shown in table 3, and show that there is a positive relationship between market concentration and the maximum fixed effect in each CRD. Innovative output increases by 1.4-1.6 bu/ac for a 1% increase in market concentration if the lagged CR4 for all firms is used, and by 0.8 – 0.9 bu/ac if the CR4 of the main biotech companies is used as the measure of concentration. The firm effects are interesting as the fact that the Monsanto group has bred the best hybrid in a CRD has a positive and weakly significant effect on innovative output in three out of four models. This is consistent with the pivotal position of Monsanto in the biotechnology market. The GM traits have no statistically significant effect on innovative output.

Conclusion

The results resented in this paper are preliminary, and there is a need for further investigation, particularly into the suitability of the chosen excluded instrument. However, given its characteristics, the corn seed industry appears to provide a good basis for a case study into the effect of market concentration on innovation, and we suggest that the results of this study, could have implications for other industries. We propose a measure of innovation, and regress that measure on concentration ratios, at the same time controlling for firm effects. Our results suggest that there is a positive relationship between market concentration and innovation.

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