The Exogenous Effect of Corn Prices on Hog Prices Using Ethanol Production and Corn Seed Research and Development as Instrumental Variables

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Abstract

This paper examines the relationship between corn prices and hog prices in the United States using monthly time-series data in a two-stage least squares regression. Ethanol production and various types of genetically modified corn seed research and development are used as instrumental variables for corn prices to account for endogeneity in the model, by removing changes in corn and hog prices that occur due to the reverse-causal relationship between the two commodities. Ethanol production was determined to be the strongest instruments for corn prices. The results indicate that increases in the price of corn increase the price of hog by a smaller, yet still significant magnitude.

JEL codes: C26, C32, Q11, Q16

Keywords: U.S. Agriculture, Corn, Hog, Ethanol, Research and Development, Time Series Model

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1. Introduction

United States Agricultural subsidies have incentivized farmers to overproduce corn ever since Earl Butz, secretary of the United States Department of Agriculture (USDA) under President Nixon, dismantled the New Deal corn price support and replaced it with price loss coverage payments. Since then, corn has taken on new applications, such as feed for livestock, processing into high fructose corn syrup, corn starch, and corn flour that is used in many processed foods and drinks, and more recently, processing into ethanol, a renewable biofuel. Dating back to 1978, the United States government has developed policies aimed at decreasing greenhouse gas emission by incentivizing the production and blending of biofuels in gasoline. The first blending mandates were introduced in 1987 and included oxygenated fuels. At the time, methyl tertiary butyl ether (MTBE), a natural gas derivative, was the main biofuel produced and blended with gasoline. However, leaks in underground MTBE storage tanks contributed to contamination of drinking water in numerous cities and MTBE was eventually prohibited in half of the nation's states, paving the way for ethanol to take over as the government prescribed renewable fuel source for blending with gasoline (Carter, Rausser and Smith 2008). The Energy Policy Act of 2005 established the Renewable Fuel Standard (RFS), mandating the blending of 7.5 billion gallons of renewable fuel, all of which could come from corn-based ethanol, with gasoline by 2012. In 2007, The Energy Independence and Security Act updated the Renewable Fuel Standard (RFS2), expanding the blending mandate to 36 billion gallons of biofuels by 2022, 21 billion gallons of which could come from corn-based ethanol.

From 2000 to 2012, U.S. ethanol production has increased by more than 700 percent, growing from 1.6 billion gallons to 13.3 billion gallons annually, largely due to the blending mandates established in the RFS and RFS2. In this same time horizon, the real corn price received by farmers has more than doubled. Although ethanol subsidies have played a large role in corn price increases, corn seed research and development (R&D) have also played a significant role in the corn market. Following the installment of price loss coverage payments to farmers that cover the difference between the price received and the government deemed fair market value of a bushel of corn, investment in corn R&D has generated innovation in genetic engineering of corn seeds by biotechnology corporations that has greatly increased corn yields and production. However, the effect R&D has on corn prices varies depending on the goals of the participating institution (Hebert 2011). While for profit firms seek to increase yields and productivity of corn in the interest of attracting customers and increasing bottom lines, non-profit institutions typically seek to increase the quality of corn grown from their seeds. Over the past two decades, large scale consolidation has taken place in the agricultural biotech industry, and is now dominated by several conglomerates, namely Monsanto. Today, over 70% of all corn grown in the United States is genetically engineered; consequently, the vast majority of corn R&D is in GMO corn seeds (Fernandez-Cornejo and Caswell, 2006).

Although many studies have examined the effect ethanol subsidization and expansion in the early 2000s and corn seed R&D over the past few decades have had on corn prices, few have analyzed the implications for the livestock sector. Furthermore, studies that do explore this dynamic relationship focus on the cattle and poultry industry, with little attention given to the hog industry. A pig feed ration typically contains over 70 percent corn, approximately 20 percent soymeal and under 10 percent vitamins and minerals (Fabiosa 2012). Consequently, changes in the price of corn will effect the price of hog. However, changes in the price of hog due to other factors, will also have an effect on the price of corn. In order to examine the effect that changes in corn price have on hog price, free of feedback due to the reverse-causal relationship between corn and hog, ethanol production and GMO corn seed R&D will be used as instruments for corn price to remove endogeneity from the model, as these factors have become driving forces in the corn industry. The model employed includes a two-stage least squares regression analysis using time series data from 2000 through 2015. The study indicates that a change in the price of corn induces a corresponding change of lesser magnitude in the price of hog.

2. Relevant Literature

Many studies have looked into how United States governmental policies supporting ethanol have contributed to the ethanol boom between 2006 and 2008, and these policies' effects on the price of corn, as corn is the main input in ethanol production. Fortenbery and Park's (2008) study was conducted to examine the effect of ethanol production on the U.S. national corn price. They found that ethanol production has a positive impact on the national corn price and that the demand from food, alcohol and industrial use (FAI) has a greater impact on the

corn price than feed and export, the other two corn demand categories. Significant growth in ethanol production beginning around 2005 has been supported by public policy aimed at increasing biofuels as a percentage of overall fuel use and reducing greenhouse gas emissions. Consequently, FAI corn demand has increased rapidly; as of 2008, over half of FAI demand comes from the production of ethanol. Using quarterly data from 1995 through 2006, Fortenbery and Park (2006) constructed a system of equations to represent the supply and demand relationships in the corn market, focusing on the short-run corn price elasticity associated with ethanol production. Their results indicate that a 1% increase in ethanol production causes a .16% increase in corn price in the short run, ceteris paribus. Furthermore, their model suggests that ethanol's contribution to the corn price increase was approximately $0.41 per bushel between September 2006 and 2007.

Carter, Rausser and Smith (2013) conduct a similar study as Fortenbery and Park (2008), using more recent data. Their study differs in their modeling technique, as Carter et al (2013) use a two-period model incorporating three markets: supply and demand for use in period one, supply and demand for use in period two and storage between period one and two. They estimated that corn prices were 30% greater between 2006 and 2011 than they would have been if the increase in ethanol production had not occurred. They cite biofuel blending mandates as part of the renewable fuel standard (RFS) and its updated version (RFS2), which were part of The 2005 Energy Policy Act and The 2007 Energy Independence and Security Act, respectively, as the main drivers in corn price increases.

Since the expansion of biofuel blending mandates and other US government policies that incentivize ethanol production, a plethora of studies have been conducted to explore the effects that these policies have on the price of corn. Condon, Klemick and Wolverton (2013) conducted a meta-analysis of 18 studies that investigate ethanol expansion in the United States between 2006 and 2013. While the majority of studies included in the meta-analysis cite the renewable fuel standards as the drivers of ethanol expansion, there is large variance amongst their results; the increase in corn price resulting from ethanol policy and expansion ranges from .5%-70%. Condon et al (2013) determined that each additional billion-gallon expansion in ethanol production yields a 3% increase in corn prices in the long-run and a 5%-10% increase in the short-run.

Until several years ago, minimal studies had been conducted to explore the relationship between corn prices and livestock prices. The majority of livestock feed is comprised of corn; therefore, examining the relationship between corn prices and livestock prices is important in understanding market dynamics and how commodity prices affect one another. Hebert (2011) gathered panel data across the 41 corn producing states from 1990 through 2007 and conducted a two stage least squares (2SLS) regression to examine the relationship between various types of corn research and development and corn prices in the United States, and the corresponding exogenous changes in corn prices have on beef prices using corn research and development as an instrument for corn prices. Since data on research and development funding in corn seeds is difficult to collect across for profit and nonprofit institutions, genetically modified corn seed field trial applications were used as a proxy.

The vast majority of corn produced in the United States is genetically engineered, and field trial application to the United States Department of Agriculture is the most preliminary step in getting a type of genetically modified (GMO) corn seed approved for use; consequently, GMO corn seed field trial applications to the USDA best represent corn seed research and development funding. Research and development of GMO corn seeds was categorized by the type of institution that submitted the field trial application, as institutions have different objectives and varied success in engineering corn seeds. Specifically, institutions were categorized by Monsanto, for-profit, and non-profit. Non-profit institutions typically try to increase the quality of corn, while for-profit biotech corporations typically aim to increase corn yields and productivity to attract farmers to buy their GMO corn seeds (Hebert 2011). Even though Monsanto is a for-profit biotech corporation, it was given its own category due to their research and development acumen, and ability to engineer the most productive corn seeds. Consequently, the first stage of the 2SLS regression, indicated that Monsanto R&D lagged four years was the best instrument for corn prices. A four-year lag roughly corresponds to the lag between field trial application and commercial release application, verifying the strength of the aforementioned instrument. The results indicated that a 1% increase in the price of corn corresponds with a .86% decrease in the price of beef. Hebert (2011) attributes the negative relationship between corn and beef prices to the observation that farmers sell of their cattle earlier when feed prices increase. The literature acknowledges that the increase in ethanol production beginning in 2005 contributed to the increase in real corn prices after 2005, yet Hebert (2011) neglected to include ethanol production in her examination.

Although the effect of corn prices on livestock prices that consume mostly corn has received limited attention, studies that do investigate this topic mainly focus on beef or poultry. Additionally, since 2005, ethanol policy has had a large effect on corn prices, creating an indirect link between ethanol production levels and prices of livestock that consume corn. Fabiosa (2012) fills this void by analyzing the long-run impacts of ethanol subsidization and expansion on the United States corn and hog sectors. Using a backcasting method, Fabiosa (2012) estimates the effect ethanol production has had on corn and hog prices by holding ethanol production constant at its pre-boom level in 2004. The results indicate that ethanol subsidies accounted for only 3% of the increase in corn prices between 2004 and 2010; however, ethanol market-mediated impacts account for 26% of the increase in the price of corn in this time horizon. Specifically, when holding ethanol production constant at its 2004 pre-boom level, the price of corn decreases by 17% and the price of hog decreases by 8% (Fabiosa 2012). Although holding ethanol production levels at its 2004 level assumes that no change in ethanol production would have occurred if favorable ethanol policies had not been established, the study provides a foundation for examining how drivers of corn prices effect commodities whose' main input is corn. Although a backcasting method acknowledges that ethanol expansion has had large effects on corn prices, ethanol expansion does not directly affect hog prices, but rather indirectly affects hog prices through changes in corn prices. Therefore, I will combine Hebert's (2011) 2SLS model to explore the effects changes in corn prices have on pig prices while accounting for endogeneity between corn and hog prices, using types of corn seed research and development and ethanol production as instruments for corn price. This will allow me to determine the exogenous effect that changes in corn price have on hog price.

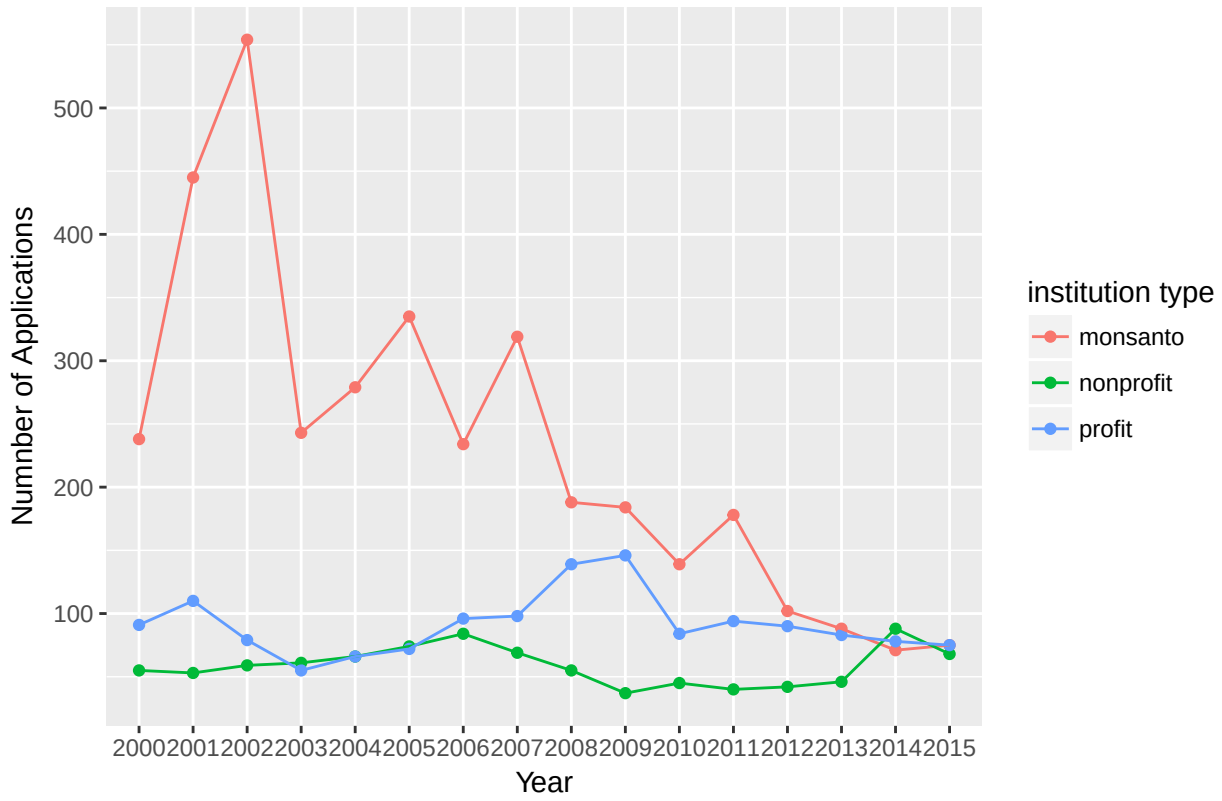
3. Empirical Model and Data

National monthly data on corn and hog prices are available from the United States Department of Agriculture's Economic Research Service (ERS) and National Agricultural Statistics Service (NASS), respectively. The prices in these data sets are the average nominal prices farmers received for the given commodity in that month. These prices were deflated using the 2008 Producer Price Index for commodities for the U.S. to obtain real prices. Corn prices are in dollars received per bushel and hog prices are in dollars received per hundredweight.

Data on corn seed research and development funding was not available. Consequently, the number of field trial applications for genetically engineered corn seeds were used as a proxy for R&D funding. The vast majority of corn grown in the United States is genetically modified; therefore, the majority of R&D in corn will be in genetically modified corn seeds. The preliminary step in releasing a genetically engineered crop in the United States is submitting a field trial application to the USDA. Data on these applications is available on the Information Systems for Biotechnology (ISB) website. The dataset downloaded from this institution includes applications for genetically modified corn seed field trial release, the requesting institution, date requested and date effective. Although data for patent applications were also available, they fail to fully capture GMO corn R&D funding. Genetically modified corn seed patent applications are much less frequent than field trial applications because they usually combine traits from a variety of genetically engineered corn seeds, each of which must be approved for field trial testing before being released (Hebert 2011). All projects aimed at introducing a new genetically engineered agricultural commodity into the market will be captured in this variable.

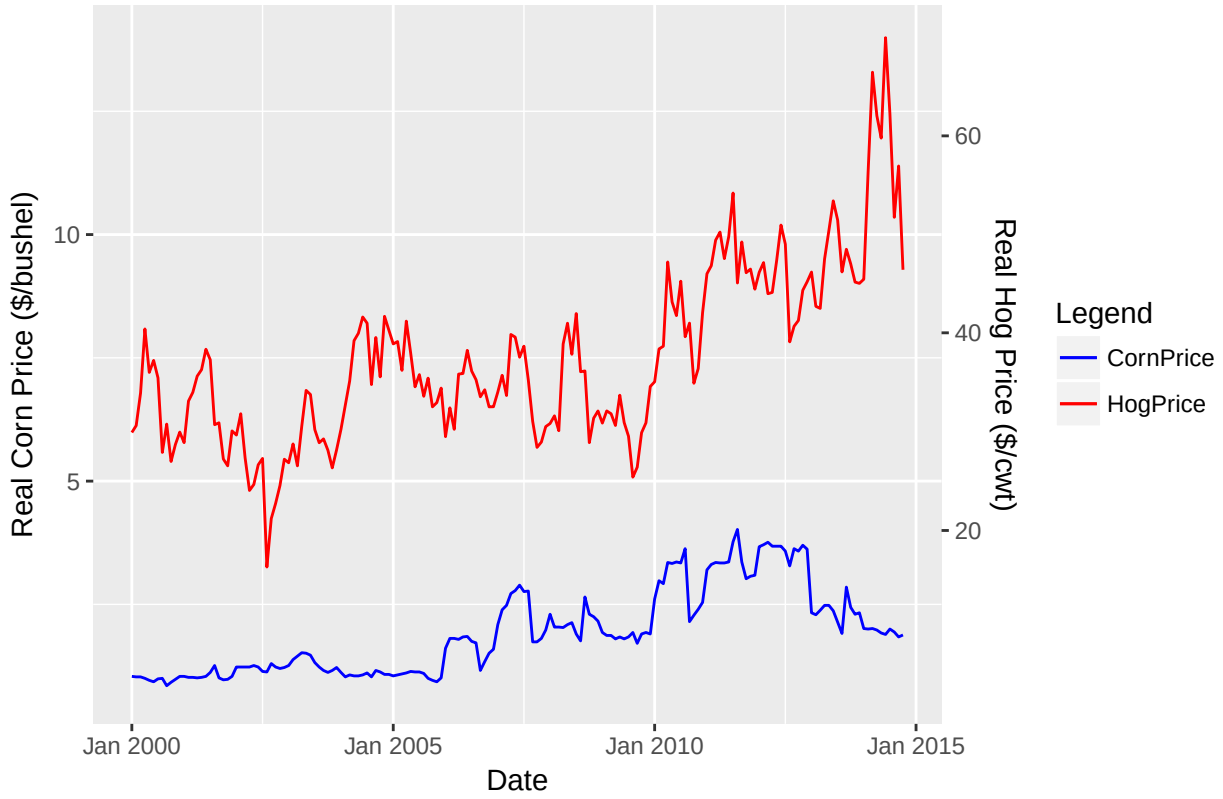
For my purposes, the dataset was reduced down to the date field trial was granted by the USDA and categorized by institution type: Monsanto, nonprofit, and profit. The reason Monsanto is given its own category is because the corporation accounts for nearly half of all GMO corn seed field trial applications in the time horizon. While the agricultural biotechnology industry has become dominated by several firms through mergers and acquisitions, Monsanto has distanced themselves as the clear leader. They are the most successful biotech corporation at increasing corn yields and productivity, therefore, grouping them with other, less successful for profit institutions would obscure the effects of both Monsanto R&D and for profit firms' R&D on the price of corn. Every genetically engineered corn seed field trial application incorporates a new trait. Figure 1 displays the agility with which Monsanto is able to develop and test new corn seed traits. Table 1 provides summary statistics for GMO corn seed field trial applications by institution. The dominance of Monsanto is apparent from these summary statistics. On average, Monsanto submits twelve more corn seed field trial applications per month than other for profit biotech institutions and fourteen more applications per month than non-profit firms. However, Figure 1 indicates that the number of genetically engineered corn seed field applications to the USDA, especially from Monsanto, has declined greatly over the past decade.

Figure 1



The relationship between real corn and real hog prices was explored using national level monthly time-series data from 2000 to 2015. Since hog feed is over 70 percent corn, any changes in the market for corn will have a resounding effect in the hog market, and vice versa. Figure 3 displays the real corn and hog price over time. Correlation between the prices for the commodities is evident, especially surrounding the expansion of ethanol mediated by the RFS and RFS2.

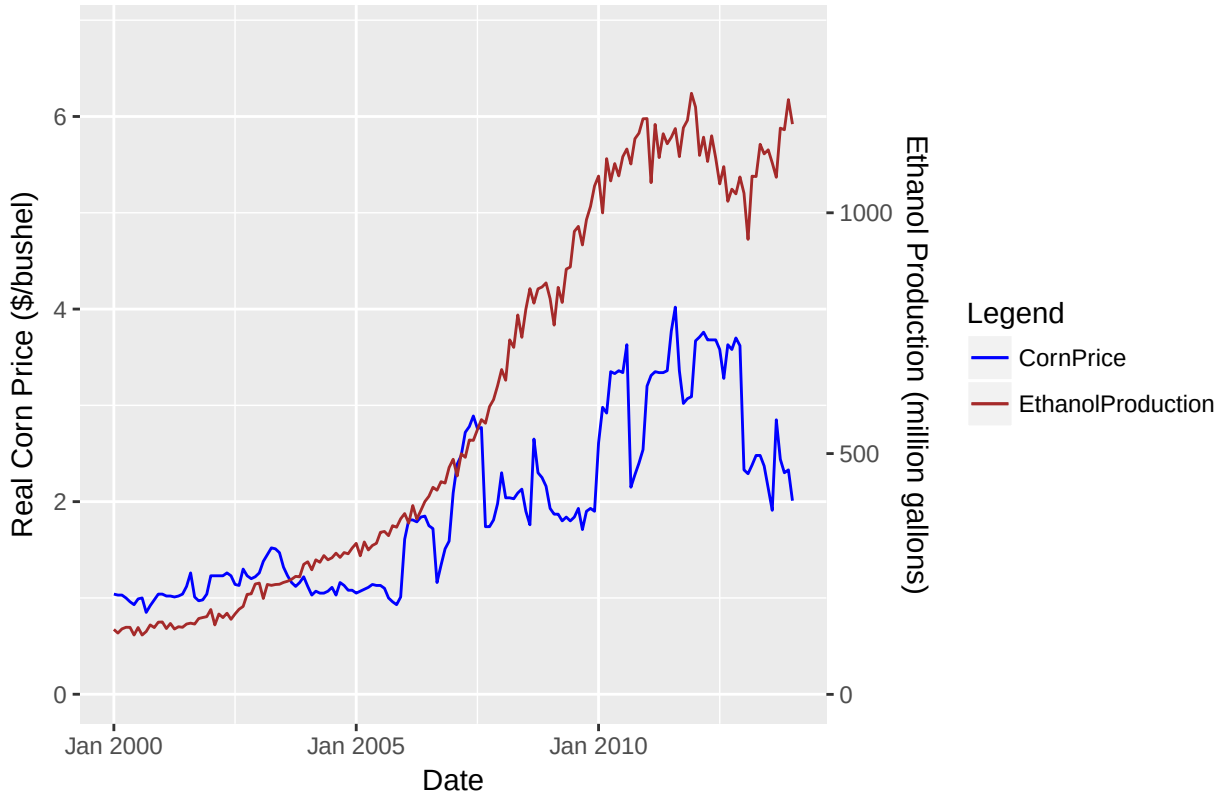
Figure 2



In order to remove any changes in corn price due to feedback from changes in hog price, instrumental variables are used for corn price. Ethanol production and corn seed R&D are both correlated with corn prices and uncorrelated with the error term. Consequently, the endogenous effect of corn prices on hog prices was removed from the model, and we were able to estimate the effect that the part of corn prices uncorrelated with the error term has on hog prices. Following Hebert's (2011) methodology, a two-stage least squares regression is used to separate the exogenous and endogenous effects. In the first stage of the 2SLS, Hebert (2011) determined that Monsanto R&D was the strongest instrument for corn prices and R&D from nonprofit and for profit firms were weak instruments.

Hebert's (2011) study investigates the exogenous portion of the relationship between corn and beef prices from 1990 through 2007. Rapid growth in ethanol production started in 2005, corresponding with the RFS; production continues to grow due to the updated and expanded biofuel blending mandate in RFS2. Since ethanol production had not yet become a driving force of corn prices, it was excluded from Hebert's (2011) model. Today, over half of the corn produced in the United States is used in the production of ethanol (Condon, Klemick and Wolverton 2013). Over the time period I investigate, increases in the real corn price are strongly correlated with increases in ethanol production. Therefore, I include ethanol production as an instrumental variable for corn prices in my 2SLS regression analysis. The U.S. Energy Information Administration (EIA) has monthly aggregate U.S. ethanol production data available on their website in the Fuel ethanol overview. The data are in millions of gallons. Figure 4 plots US ethanol production and the real corn price over time. Strong correlation is apparent between the two variables, confirming the strength of ethanol production as an instrument for corn prices in the model.

Figure 3



I also include variables to control for change that could be attributed to extraneous variables. Specifically, my control variables are US population and number of natural disasters in US. The population data is annual and was obtained from the GEOFRED website. I divided population figures by one million to facilitate regression analysis, therefore, the data is in millions of people. Data on natural disasters in the U.S. was obtained from FEMA. The original dataset included the date, state or territory that the natural disaster occurred in, the incident description and declaration type. I eliminate all observations in non-corn producing states and territories and aggregate the number of natural disasters that occurred in corn producing states each year, while eliminating all other variables.

In the first stage of the two-stage least squares regression, logged corn prices are regressed on ethanol production, different combinations of current period and lagged GMO corn seed R&D, the control variables and time yielding the fitted values of corn prices. I run several regressions in which I vary the R&D variables I include to explore the validity of using lagged and current R&D from different types of institutions as instruments for corn prices.

First stage:

$$\begin{aligned} ln(CornPrice)_t &= \beta_0 + \beta_1 Controls_t + \beta_2 Time_t + \alpha_1 EthanolProduction_t \\ &+ \alpha_2 Monsanto.RDt + \alpha_3 Profit.RDt + \alpha_4 Nonprofit.RDt + \epsilon_t \end{aligned}$$

In the second stage, logged hog prices are regressed on the fitted values of corn price to determine how changes in the price of corn affect the price of hog independent of feedback due to the reverse-causal relationship. The logs of corn and hog prices are used in the regression, allowing analysis of response of hog prices to exogenous changes in corn prices.

Second stage:

$$ln(HogPrice)_t = \delta_0 + \delta_1 Controls_t + \delta_2 Time + \gamma_1 lnCornPrice_t + \epsilon_t$$

The results from the second stage regression indicate the effects that the control variables and changes in the price of corn due to exogenous factors have on hog prices, ceteris paribus.

4. Results and Inference

Four 2SLS regressions were conducted. In the first regression, ethanol production and current period research and development across all institutions are used as instruments for corn prices. Results from this regression indicate that a 1% increase in the price of corn causes a 0.58% increase in the price of hog, this is significant at the 10% level. In the second regression, I decided to use ethanol production and corn research and development with a one year lag as instruments for corn prices. The results indicate that a 1% increase in the price of corn corresponds to a 0.32% increase in hog prices, although this is insignificant. Additional regressions were run using ethanol production and 2, 3 and 4 year lagged corn research and development as instruments for corn prices. However, as I increased the lag period, regression results lost significance. I attribute this to the fact that the number of field trial applications requesting release of GMO corn seed varieties has greatly decreased over the past decade. Consequently, it could be the case that corn seed field trial applications no longer serve as a strong proxy for corn research and development, or that corn seed biotech innovation has started to plateau. Therefore, my third regression incorporates only ethanol production and current period monsato research and development as instruments for corn prices and my fourth regression uses only ethanol production as an instrumental variable. Results across the first, third, and fourth regressions remain relatively constant and exhibit similar significances. This further suggests that GMO corn seed field trial applications have become a weak proxy for corn prices and/or that ethanol production has become the main driver of corn prices, and is the strongest instrument across the models. The first, third, and fourth regressions all indicate that a 1% increase in the price of corn contributes to an approximate 0.5% increase in the price of hog. Furthermore, population growth of one million in the United States decreases hog price by about 35% while the linear time trend variable indicates that with each year that passes, hog prices increase by about 95%, both of these results are highly significant. The pass-through from the corn industry to the hog industry is reasonable, because as corn prices increase, input prices for hog increase, thus livestock farmers are likely to charge a higher price for their goods to make up for increased operating costs. Although Hebert (2011) found that a 1% increase in the price of corn decreases the price of beef from 0.40%-0.80%, changes in the price of corn will have similar effects on livestock that mainly consume corn. The results of this study conflict with Hebert's (2011), suggesting that corn prices and livestock prices have a positive relationship.

The overall results also suggest genetically engineered corn seed trial applications serve as a weak proxy for research and development, or that the rate with which corn seed research and development increases yields and productivity has started to plateau. Decline in number of GMO corn seed field trial applications by Monsanto, the dominant firm in the industry, supports the notion that the effectiveness of genetically engineering corn seeds to increase yields and productivity is slowing down.

Ethanol production, however, has been a driving force in the corn market over the past decade. With corn making up approximately 78% of pig feed, further ethanol expansion will have continued impacts on the corn industry; concurrent changes in the price of corn will have resounding impacts on the hog industry and the livestock sector as a whole.

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List of Tables

1 Summary Statistics: GMO Corn Seed Field Trial Application by Institution Type 11
2 2SLS Regression Results 12

Table 1: Summary Statistics: GMO Corn Seed Field Trial Application by Institution Type

Statistic	N	Mean	St. Dev.	Min	Max
monsanto	192	19.125	29.038	0	207
profit	192	7.583	8.178	0	45
nonprofit	192	4.906	7.010	0	65

Table 2: 2SLS Regression Results

	Dependent variable:			
	lnhog			
	(1)	(2)	(3)	(4)
population	-0.375^{***}	-0.253^{*}	-0.363^{***}	-0.356^{***}
	(0.129)	(0.148)	(0.131)	(0.131)
naturaldisasters	0.0002	0.001	0.0003	0.0003
	(0.001)	(0.001)	(0.001)	(0.001)
time	0.981^{***}	0.684^{*}	0.951^{***}	0.932^{***}
	(0.318)	(0.366)	(0.323)	(0.325)
lncorn	0.579^{*}	0.322	0.548^{*}	0.530^{*}
	(0.303)	(0.339)	(0.309)	(0.311)
Constant	108.383^{***}	74.095^{*}	104.907^{***}	102.807^{***}
	(36.060)	(41.608)	(36.640)	(36.806)
Observations	192	168	192	192
R^2	0.370	0.500	0.389	0.400
Adjusted R^2	0.356	0.488	0.376	0.387
Residual Std. Error	0.181 (df = 187)	0.165 (df = 163)	0.178 (df = 187)	0.177 (df = 187)
Note:				*p<0.1; **p<0.05; ***p<0.01