“How Disparate Government Support for Crops and Livestock Influences Cropland and Pastureland Values”

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Abstract

Land value studies consistently focus on the impact of government support for cropland, discounting potential impacts to other agricultural land uses such as pasture. We examine the history of disparate government support for the production of crops and livestock and its impact on land values, and derive a theoretical model of price transmission between cropland and pastureland that accounts for the simultaneity problem in the determination of related land values. We estimate this model under a two-stage regression discontinuity design, using county level data from 2,696 counties across the United States. We find that a positive shock to cropland demand translates to significantly higher pastureland values. In contrast, direct government spending on crop production decreases the relative value of pastureland substantially. Furthermore, we show that the change in producer behavior in terms of county corn plantings, following the adoption of the Renewable Fuel Standard (RFS), has a significant negative effect on the differential between cropland and pastureland values. In fact, we estimate that each one percent increase in corn plantings reduces the relative value of adjacent pastureland by -2.13% (95%–Bootstrapped C.I.: -.2.407%; -1.853%).

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1 Introduction

The United States has a long history of supporting crop production, while devoting comparably little support to the production of livestock. For example, the 2018 Farm Bill (P.L. 115-334) allocates almost $200 billion in projected government outlays from 2019-2029 for agricultural programs, nearly all of which is directed towards crops. These expenditures include subsidized insurance, commodity price supports, and resource conservation. At less than $10 billion, support for livestock producers is just a fraction of that–despite the fact that cash receipts for animal products in the United States routinely rival those of crops (CBO, 2022; ERS, 2022). Pastureland values lag behind cropland values in the United States, and the additional support for crops may be partially responsible according to the land value capitalization literature (Goodwin et al., 2003; Goodwin et al., 2011). Since 1997, the National Agricultural Statistics Service (NASS) has estimated that the average price for an acre of cropland increased by almost 5% annually. For Iowa cropland owners, that average change is 8-10%, according to the 2021 Iowa Land Values Survey (Zhang, 2021). In contrast, pastureland values increased less than 3% a year on average, (below the rate of inflation) since 1997 (NASS, 2022). Critically, other factors such as strong export demand for U.S. agricultural products, particularly grains and oilseeds; changes in trade policies, beginning with the 2017 Trade War; multi-year extreme droughts; and COVID-19 supply chain disruptions also affect crop prices and land values (Schnepf, 2017; Adjemian et al., 2021; Leister et al., 2015; Weersink et al., 2021). While there is a growing body of literature addressing each of these factors, a gap remains regarding the impact of government support on cropland and pastureland jointly. In this article, we critically assess the impact of disproportionate support for crops and livestock products on cropland and pastureland values. We find that cropland and pastureland values are inexorably tied by policy, and that the choice of mechanism employed determines the direction and magnitude of policy impacts.

Beyond the advantage in direct support, other forms of indirect governmental support (i.e. U.S. ethanol policies) act to widen the support gap even further (see e.g. Carter et al., 2017; Smith, 2019a). For example, in the mid-2000s, changes in U.S. ethanol policy supported ethanol production according to the Renewable Fuel Standard (RFS-I & RFS-II), policy initiatives enacted in 2005 and expanded in 2007 that mandate a fixed percentage of ethanol blending in commercial fuel. RFS is an important example of indirect support; it indirectly raised the value of crop land by creating a new source of demand for certain crops. It is likewise possible that these policies increase the option value of substitutable pastureland. To estimate the impact of RFS-I and RFS-II on cropland, Kropp and Peckham (2015) apply the capitalization approach of Goodwin et al. (2003) and Goodwin et al. (2011) to 10 years of cropland values. They control for distance to ethanol facility in their model and find that parcels closer to an ethanol facility are \$200-\$577 more valuable.

However, two concerns arise with respect to the capitalization approach employed in previous studies. First, researchers typically discount related types of agricultural land, omitting pastureland observations from their analyses. Since land with high croping potential carries a higher expected return on investment over other types of agricultural land, focusing on more relevant determinants (e.g., population growth or urban land demand) of cropland values and discounting pastureland is a valid approach to estimating the effect of government support on cropland. Goodwin et al. (2003), Goodwin et al. (2011), and Kropp and Peckham et al. (2015) motivate this type of partial equilibrium analysis with their cropland capitalization model. In contrast, estimating the effect of government support for agriculture on pastureland values without including the interactions between pastureland and cropland markets introduces an omitted variable, and therefore, potentially biases the estimated marginal effects of direct and indirect governmental support. Specifically, livestock producers rely on the derived products of cropland as inputs in their production function.

For example, in beef cattle production specifically, cattle raised on pasture are typically finished (i.e. brought to market weight) with corn or other coarse grains. Furthermore, crop production requires a similar set of inputs as pasture and forage production, specifically fertilizer and pesticide inputs. Lastly, cropland and pastureland values are tied together since they may be converted (with varying rates of quality, depending on the region and specific attributes of the plot). Yet, cursory treatments of pastureland values (and cropland values for that matter) in the literature analyze them as separate and unrelated assets, highlighting distinctions and neglecting interactions. Doye and Brorsen (2011) consider pastureland and cropland as distinct classes of economic assets. From a modeling perspective, since previous studies rely on a reduced-form capitalization model of land valuation that is not derived from a structural model, interpretation of the estimated parameters is unclear. For example, using the distance to an ethanol facility incorporates no real indication of a change in producer behavior–only the potential for behavioral change (i.e. proximity to an ethanol plant may increase the likelihood of a producer selling their corn as ethanol but it is not guaranteed). This is important because land values under a capitalization framework are simply the discounted sum of expected returns to the current land use, and according to economic theory, producer behavior is the realization of those expectations in the form of the choice to devote land to crop or pasture production. In contrast, the change in average corn plantings reflects actual changes to producer behavior brought on by changes in producer expectations, and therefore have real impacts on the value of agricultural land. Thus, the complexities of the dynamics between cropland, pastureland, and their derived products necessitates a well-grounded theoretical model of producer behavior and the interrelationships between agricultural land values.

The simultaneity problem between cropland and pastureland occurs because they require similar agronomic inputs, and the outputs derived from each are inter-related. We estimate the direct effect of cropland value changes on pastureland values by instrumenting cropland values on lagged weather and market returns in the first stage. Long-run weather histories such as rainfall and temperature inform expectations as to future expected returns, and therefore satisfy the exogeneity and relevance assumptions needed to preform instrumental variable analysis. We formally test these assumptions in our results. In the second stage, we estimate the direct effect of government support on pastureland values by including government crop support spending. Furthermore, we identify the indirect effect of U.S. biofuel policies on pastureland values with a regression discontinuity design (RDD). An RDD is appropriate because of the discrete change in our treatment variable: corn plantings, or the total amount of cropland planted in corn in a given county. In particular, following the adoption of RFS-II in 2007, average corn plantings across U.S. counties increases from 16% to 22% of all agricultural land. This significant change in producer behavior allows for consistent estimation of the marginal effect of U.S. biofuel policies on pastureland values.

We contribute to the literature by deriving a structural model of price transmission between cropland and pastureland that decomposes the impact of government policies targeted at crop production on pastureland values. In addition, we collect complete land, weather, and population statistics for 2,696 counties across the United States. We take this model to the data, including weather and market returns indicators as instruments for our endogenous cropland and pastureland values. Our two-stage least squares design accounts for the simultaneity problem inherent in the determination of supply and demand for cropland and pastureland.

Our results show that a 1% increase in cropland values increases pastureland values by 0.703% (95%–Bootstrapped C.I.: 0.582%; 0.823%). However, the effect on pastureland values of government spending on crop production is significantly negative, since each additional dollar allocated to crop production increases the opportunity costs of keeping land in pastureland use. In fact, a 1% increase government spending on crop production decreases pastureland values by -0.282% (95%–Bootstrapped C.I.: -0.299%; -0.266%). Finally, our

RDD results illustrate that following RFS-II in 2007, a 1% increase in corn plantings has the net effect of decreasing adjacent pastureland values by -2.13% (95%–Bootstrapped C.I.: -.2.407%; -1.853%). These results are consistent in terms of directional effect not only with our two-stage instrumental variable findings but with the previous work of Goodwin et al. and Kropp and Peckham. RFS-II increased the demand for cropland, driving up prices for cropland as well as the opportunity costs of keeping land in pasture.

The paper proceeds with a background on the historical trend of disparate support for cropland and pastureland values. Section 3 compares the traditional capitalization model of land values to our expanded price transmission approach. Section 4 derives the theoretical model of price transmission between related land types. Section 5 describes our data, presents our econometric models, and details our results with appropriate model diagnostic tests and robustness checks; Section 6 concludes with a discussion of policy implications and avenues for future research.

2 History of U.S. Agricultural Land Policy

Since the nation's founding, American farmers have been the focus of an evolving series of federal support policies, which can be organized into four distinct periods in U.S. history. Conflicting interests and objectives characterize each of these periods, so that public policy pursued in one period stems directly from the consequences of the previous (Effland, 2000). A common thread, despite the debate and often reactionary nature of reform, is that farmers' problems warrant public support. Liberalization of land distribution and reform characterizes the first epoch in U.S. land policy from the 1780s to 1890. In this era, the federal government prioritized transfer of the vast quantities of public land to small, independent white farmers, offering reduced prices and eventually full title for so-called illegal "squatters." The liberalization era of U.S. land reform culminated with the Homestead Act of 1862, which provided for free distribution of land to those who would settle and *farm* it (Gates, 1962). The enactment of the first Homestead act lead to similar legislation focused on previously excluded groups, such as recently freed slaves during Military Reconstruction in the post-Civil War decade (Saloutos, 1956). However, the Homestead Acts was not an exercise in costless land allocation (Saloutos, 1962). In fact, the Homestead Act specifically required homesteaders to reside on (for at least five years) and improve property before full ownership was conferred (Novack et al., 2015). The improvement requirement could be satisfied through either the cultivation of crops of the planting of trees under the Timber Culture Act of 1873 (McIntosh, 1975). Therefore, even from the genesis of U.S. land policy, the federal government supported cropland and timberland use over pastureland use, since the maintenance of pasture for livestock production precludes crop cultivation and timber establishment.

As the federal government opened millions of acres of public land in the West to settlement throughout the 19th century, it also began support policies aimed at farm productivity and quality of life. The impetus for this additional policy initiative stemmed from the South and East. These regions suffered from declining soil fertility due to poor production methods, decreasing the value of farmland. In addition, the vast supply of virgin land in the West further decreased the relative value of land in the older farming regions. In response, farmers organized for the first time to promote the need for agricultural research and education for the growing sector (Rausser, 1992; Rausser and Zilberman, 2014). The idea was that the Federal government was partially responsible for the loss of wealth in the South and East due to the increased competition it created, and so it must help farmers improve their productivity to reestablish parity (Effland, 2000). As a result, the government began to pursue a three-prong strategy of scientific research, education, and economic development. The Morrill Act of 1862 allocated support for the public land-grant university system across the country and laid the foundation for the cooperative extension system to disseminate the new ideas developed from scientific research (Novack et al., 2015). To complement research gains, the government also invested heavily in infrastructure improvements, including canals, railroads, and electrification, to lower the transaction costs of farmers seeking market access. The culmination of this second epoch of land policy in the United States occurred with the formal creation of the Cooperative Extension Service (CES) in 1914 and the Bureau of Agricultural Economics in 1924 (forerunner of the modern Economic Research Service, ERS)(Effland, 2000). For the past 100 years, the ERS and CES distributed improved production techniques, market information, and financed infrastructure development (e.g., farm-to-market roads) for the benefit of small rural producers.

The land expansion of the 19th century coupled with the gains from federally funded research and improvements in agricultural practices lead to chronic oversupply and depressed farm prices beginning in 1900. Simultaneously, manufacturing consolidation and standardization allowed the industrial sectors of the economy to surpass agriculture as the dominant industry. Farmers demanded parity, a living wage, and expected government intervention to achieve it. The result was a series of marketing reforms in the early 1920s, specifically the Capper-Volstead Act of 1922. Capper-Volstead leveled the playing field between manufacturing and agriculture by exempting agricultural producers from anti-trust regulations, allowing for the formation of lucrative producer owned cooperatives (Guth, 1982). Agricultural cooperatives enable producers to consolidate resources for the purchasing of inputs and the marketing of finished products and yielding real economic benefits to farmers, including The National Pork Council, Dairy Farmers of America, or The National Corn Growers Association. However, cooperation is not without added costs, especially for livestock producers. For example, the Packers and Stockyard Act of 1921 is the statute regulating concentration in the meat industry. The economies of scale required to safely process meat lend the industry to monopolization, and unfortunately, the key provisions of the act have not kept pace with the changing dynamics of the industry (Aduddell and Cain, 1981; Buhr, 2010). A fact well-documented in the empirical literature (e.g., Wohlgenant, 1987; Wohlgenant 2014; von Cramon-Taubadel et al. 2021). In fact, the industry concentration of the top four packers for steers and heifer slaughter is over 80% as of 2021 (Deese et al. 2021). As a result, while other commodities benefit from cooperation and government regulation of market middlemen, livestock producers do not.

The Great Depression provided the context for direct support, which became the central tenet of U.S. farm policy from 1933 until 1996. In their first iteration, price supports for the major crop commodities targeted supply to combat falling farm incomes. Supply controls functioned by incentivizing reduced plantings along with government storage of market depressing surpluses, specifically when prices fell below 1910 parity rates. Subsequently, marketing orders allowed for more efficient supply control methods. The system of price controls was successful in stabilizing farm incomes (Bruckner, 2016). Consequently, cropland values experienced a prolonged period of stable gains by reducing uncertainty around the expected returns from crop production (Working, 1945; Floyd, 1965; Lichtenberg and Zilberman, 1986; Weersink et al. 1999). In contrast, stabilizing net farm incomes for livestock producers, and thereby raising pastureland values was not so straightforward. Instead, the U.S. government pursued an indirect protectionist policy toward livestock production. For example, the Smoot-Hawley Tarrif of 1930 prohibited importation of animal meat products from any country infected with foot-and-mouth disease (FMD). The original act made no distinction between localized contained infections or full-scale epidemics. Hence, all the countries in Europe (with few exceptions) and all the countries of South America, specifically Argentina and Brazil, were affected. The result was that domestic producers no longer had to compete with the largest beef exporter: Argentina (Blackwell, 1980). However, the 1930s and 1940s saw reduced meat consumption due to the economic depression and subsequent World War, so that while the protectionist approach towards livestock markets was supported by domestic industry groups, its benefits to farm incomes and land values were mixed at best. In fact, most affected nations implemented retaliatory trade measures against the United States in response to the continued lack of market access[1]

High price supports coupled with a rebound in European agricultural production led to chronic surpluses in the subsequent decades. An intense debate ensued between advocates of price supports and other mandatory supply controls and those who rejected the need for direct market intervention. The Food and Agriculture Act of 1965 provided a compromise, making most production controls voluntary and pegged price supports to World prices instead of historic parity prices (Effland, 2000; Lehrer, 2020). However, supplementary deficiency payments were also introduced, which compensated farmers directly for lower support prices. During this time, livestock producers saw no equivalent policy reform. The 1965 Farm Bill staved off meaningful reform until the Farm Crisis of the 1980s. The crisis saw the failure of direct support to secure U.S. farm incomes in a global economy, since U.S. price supports reduced international marketing opportunities and higher global supplies weakened relative export shares (Lehrer, 2020). As such, the 1996 Farm Bill divorced income support payments and current farm prices, a first step towards complete decoupling. The reforms laid out by the act constituted a dramatic shift in federal assistance to farmers: (1) crop insurance replaced government subsidies; (2) complete planting flexibility was introduced; and (3) conservation contracts were expanded. Advocates of a more market-oriented strategy to stabilizing farm incomes championed the move. However, following its implementation, farm bill subsidies reached a record \$24.7 billion (Masterson, 2011). As a result, the literature is divided on the net benefits of an insurance approach. Critics point to the issues of adverse selection and the potential for rent-seeking behavior associated with poorly designed insurance schemes. For example, farmers currently face an array of insurance plans to choose from, with the most dominant being revenue protection plans. Under one of the

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[1] FMD bans continue to be a fixture of U.S. agricultural import policy. Since 2000, the United States implemented bans against Argentina, the United Kingdom, France, and more in response to outbreaks. Moreover, the removal of these bans are almost always met with opposition from the domestic industry.

most popular revenue-protection plans, a farmer can purchase a policy to insure yield losses or revenue losses on certain crops, but he bases that coverage on the highest price of the season. If a low yield drives up the price of a crop from spring to harvest, the farmer is insulated for lower yields at the higher harvest-time price; if the price falls throughout the season due to overproduction, the farmer may use the higher springtime baseline when calculating compensation. Either way, this option maximizes the payout from the insurer. Less appealing plans such as yield protection policies are hardly used since the downside risk to yield loss can not be minimized as easily as through revenue protection (Fessenden, 2015 and Smith, 2019b). Furthermore, insurance programs are subsidized by the government, with about 60 percent of the cost of farmers' insurance premiums as well as 100 percent of administrative and operating costs for insurers, which means farmers can sign up for policies that provide payouts far more generous than reflected by their actual cost. In contrast, Young et al. (2002) quantifies the change in producer behavior after the creation of the subsidized indemnity programs for certain crops. They find that insurance subsidies are likely to alter producer behavior because they lower the cost of risk management. And, the cost reduction represents a benefit to producers, raising expected returns per acre and providing an incentive to expand crop production. However, their model generates relatively small changes in planted acreage after indemnification, which they argue is the result of the inelastic demand for food crop products reducing the gains from rent-seeking. Further research by Goodwin support the small but significant effect on cropland values by subsidized insurance programs (Goodwin et al. 2003; Goodwin et al. 2011). Therefore, while direct government support is no more, crop farm incomes and by extension cropland values still benefit from market intervention. Livestock producers receive no such equivalent support.

Coinciding with the shift from price supports to subsidized insurance was the advent of the Conservation Reserve Program (CRP). Began in 1985, CRP allowed farmers to take land out of cultivation and manage the fallowed land to improve environmental health and soil quality. This voluntary supply control measure reduces the amount of available cropland, and since the demand for cropland is highly inelastic, theory suggests there should be positive benefits for cropland values. However, again the literature is mixed on its benefits to land values. Shoemaker (1989) analyzed the first CRP sign-ups, from 1986 to 1987, and found that CRP participation provided a huge windfall to farmers but had little effect on cropland values. Lence and Mishra (2003) used county-level data from 1996 to 2000 to examine effects of the CRP and other farm payment programs on cash rental rates in Iowa. Their results indicate that the effect of the CRP was again only marginally positive. In contrast to previous studies that assume all governmental payments are exogenous, Wu and Lin (2010) model CRP payments as an endogenous function of the probability of CRP participation. This framework recognizes the fact that farmers are not rewarded contracts if they bid to high for their willingness-to-accept in submitting contraction applications. Their results show average cropland values increased between \$18 and \$25 per acre in 1997 dollars. And, the distributional impact varied spatially across regions, with the more agricultural states seeing greater returns (Wu and Lin, 2010).

Yet, even in conservation policy there is a disparity between the levels of support for cropland and pastureland conservation. The Grassland Reserve Program (GRP) aimed specifically for pastureland owners, and it does not receive the same level of government support. For example, the 2014 Farm Bill reduced the amount of total enrolled acreage for CRP by 12 million acres, specifically repealing the GRP (Claassen, 2014). In addition, the number of grassland contracts and acreage enrolled is a fraction of CRP, even though the value of livestock products and crop products are nearly identical. In fact, the June 2022 CRP Statistics Report lists over 135,000 general CRP contracts as opposed to only 11,000 grassland contracts. Furthermore, the value of the total rental payments for general CRP totaled \$5.67 billion against only \$60 million for grassland (FSA, 2022). No prior study we are aware of considers the impact of CRP payments or really any other form of government support on cropland and pastureland values simultaneously.

2.1 Recent Trends in U.S. Land Values: 1997 to Today

The most significant policy change impacting farmland values over the past 25 years is implementation of federal support for biofuel production. Beginning with the 2005 Renewable Fuel Standard (RFS-I) and its expansion in 2007 (RFS-II), the federal government provided indirect support to staple crops–especially corn and soybeans–that can be used to produce ethanol and other biofuels. Lawmakers stated a three-fold purpose of the policy: (1) increase fuel efficiency and independence by producing fuel oxygenates domestically; (2) reduce the environmental impact of burning un-blended gasoline; and (3) stimulate demand for commodity crops thereby raising farm incomes (Yacobucci, 2012). While the scientific support for the first two objectives is scarce (see Moschini et al., 2012 or Lark et al., 2022), empirical support for the third objective is well-established. Carter et al. (2017) address the price gains precipitated by the implementation of RFS-II. In particular, they model RFS-II as a persistent shock to agricultural markets and find that every billion gallons of ethanol produced raises the price of corn by 5.6% (95% CI–0.9%,17%). Smith (2019a) applies the model to the most recent data and adds wheat and soybeans to estimate a cumulative increase to the corn price over the life of RFS-II at approximately 30%. Beyond raising crop farm income, this price increase affected land values. According to Kropp and Peckham (2015), the new ethanol demand for corn resulted in significantly higher prices for cropland and a change in producer behavior. Specifically, producers planted more land to corn, and as a result, the sharp decline in cropland acreage from 2002 to 2007 slowed from 2007 to 2012 and then increased from 2012 to 2017. This trend is highlighted in the left-hand panel in figure 1.. Figure 1 also illustrates a rise in real U.S. cropland prices since the 1990s, even through the global financial crisis and economic downturn of 2008-2009 owing at least in part to the combination of direct support (like insurance subsidies and CRP supply controls) and indirect support (e.g., biofuels). In contrast, pastureland values also increased in real terms but only marginally so, compared to cropland values[2]. And, the number of pastureland acres experienced a steady decline. One explanation for this trend is that higher commodity crop prices significantly reduce the margins of livestock producers, leading to lower net returns and a reduction in herd size under management (Davis, Adjemian, and Langemeier, 2022). Hence, pastureland values decrease as expectations about the future returns to livestock production weaken.

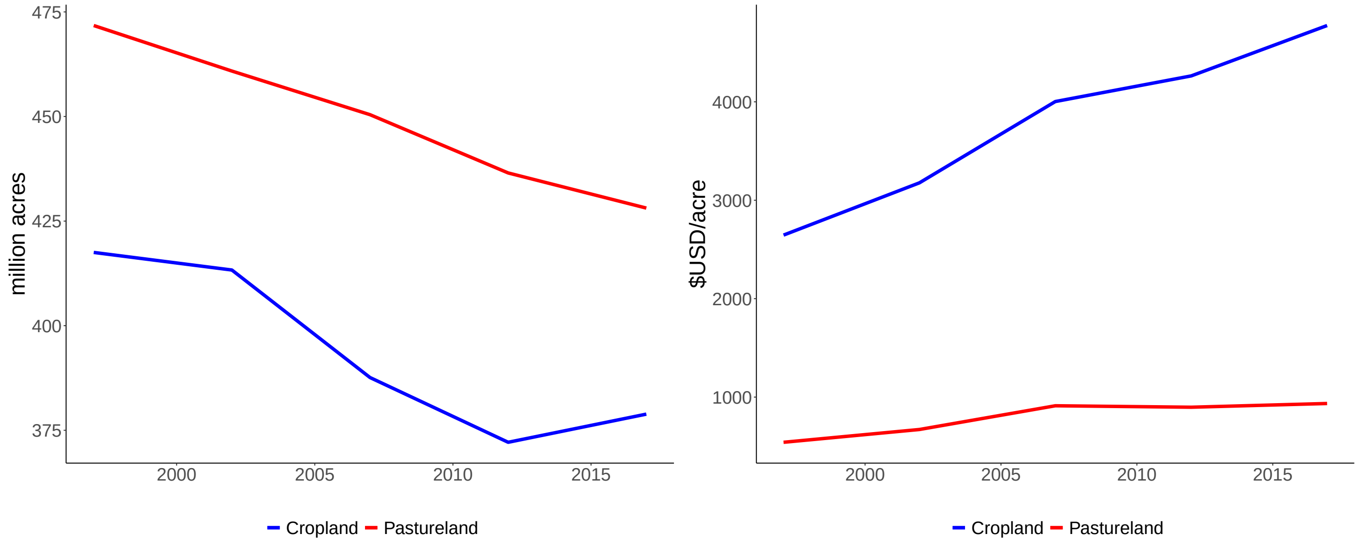

Figure 1: U.S. Cropland and Pastureland Acreage and Real Value, 1997-2017
Note: Land Values in Constant 2007 Dollars
Source: NASS 2022 and Author Calculations

We argue that both direct and indirect government support for crop production stimulated the demand for cropland thereby incentivizing the conversion of pastureland to crop production. This results in depressed pastureland values as the highest quality pastureland is moved into crop cultivation, leaving less-convertible pastureland behind. Complete statis-

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[2] The trend in land values at the county level is dependent on the major land use type within a specific county. For example, figure 5 in the appendix presents the underlying trends for 3 representative counties across the United States taken from the Census of Agriculture every five years. Majority crop counties, such as Kossuth County, Iowa, experienced a divergence between cropland and pastureland values, higher crop prices, and substantially more government support compared to pastureland-dominant counties (NASS, 2017a; NASS, 2017b; NASS, 2017c.

tics on land conversion are unfortunately are unavailable. However, NASS does compile two useful series, which may indicate its prevalence. Every five years, the agency collects data on the amount of "cropland used for pasture", land that is easily convertible between crop and livestock uses with minimal effort. Figure 2 plots this series from 1945 to 2012 (the last year of available data). From 2002 to 2012, cropland used for pasture fell from over 60 million acres to 12 million. This change roughly coincides with the increase in the number of cropland acres in figure 1, the implementation of RFS-II, and the expansion of CRP enrollment by the 2002 Farm Bill.

Figure 2: U.S. cropland used for pasture 1945 - 2012
Source: NASS 2022

The average amount of corn plantings across counties in the United States increased significantly during this time. Figure 3 plots average corn plantings. Prior to RFS-I and RFS-II, corn plantings accounted for approximately 16% of all agricultural land planted across each county on average. After the implementation of RFS-I and RFS-II, this percentage jumped to over 22%, suggesting farmers responded to higher corn prices and increased their demand for cropland. We use these data in our model of cropland and pastureland values for several theoretical and empirical reasons. First, corn is the primary commodity crop grown in the United States and it is present across the supply chains of almost all livestock products. Second, producers of corn and the producers of pasture and forage rely on similar inputs. Third, the change in corn plantings represents a significant change in producer behavior that motivates our theoretical model of price transmission between cropland and pastureland. In the next section, we formally derive our price transmission model as an extension to the capitalization models of land values.

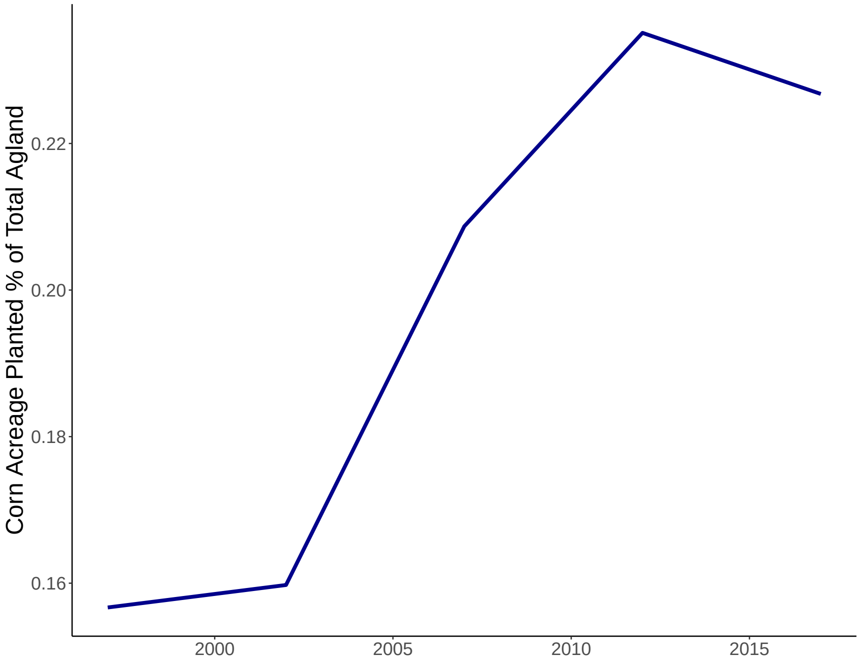

Figure 3: U.S. corn plantings 1997-2017
Source: NASS 2022

3 Capitalization vs Price Transmission Methodologies

In the capitalized values framework, the value of a parcel of cropland is the present discounted value of expected cash flows from crop production (e.g., market returns R_t^c, and government support) plus the option to convert it to non-agricultural uses. In addition, government support Gov_t is often disaggregated into 6 categories: (1) loan deficiency payments LDP_t, (2) decoupled payments DC_t, (3) Cropland Reserve Program payments CRP_t, (4) disaster payments DP_t, and (5) all other support. Goodwin et al. (2003) and Goodwin et al. (2011) establish and extend this framework respectively. Kropp and Peckham (2015) include the distance to the nearest ethanol processing plant to represent the monetized value of ethanol production mandates EP_t. To analyze the interaction between cropland and pastureland in this framework, the value of a parcel of pastureland can be defined in a similar way: as the present discounted value of expected cash flows from livestock production (e.g., market returns, R_t^p, and government support) plus the option to convert to cropland or urban uses. Furthermore, the option value of pastureland is defined as the sum of the present value of the stream of cash flows from converting to alternative uses, weighted by the probability of conversion.

$$\begin{aligned}\frac{Gov_t}{(1+r_{Gov})^t} = \frac{LDP_t}{(1+r_{LDP})^t} + \frac{DC_t}{(1+r_{DC})^t} + \frac{CRP_t}{(1+r_{CRP})^t} + \frac{DP_t}{(1+r_{DP})^t} + \\ \frac{EP_t}{(1+r_{EP})^t} + \frac{Other_t}{(1+r_{Other})^t}\end{aligned} \tag{1}$$

$$V_0^c = E\left[\sum_{t=1}^{\infty} \frac{R_t^c}{(1+r_R)^t} + \frac{Gov_t}{(1+r_{Gov})^t}\right] + Conv_0(Urban_t)$$

$$V_0^p = E\left[\sum_{t=1}^{\infty} \frac{R_t^p}{(1+r_R)^t} + \frac{Gov_t}{(1+r_{Gov})^t}\right] + \pi_1 Conv_0(Urban_t) + \pi_2 Conv_0(cropland_t)$$

Goodwin et al. (2003) identifies the econometric advantages of this approach over previous models that address agricultural land valuation. Specifically, land values are based on market expectations about the long-run stream of net returns from production and government support associated with the underlying land. These expectations are unobservable creating a latent-variables problem. Moreover, the complete set of land value determinants is also unobservable to the econometrician, resulting in attenuation bias. To account for latent expectations, the authors urge the use of appropriate strategies to identify the real long-term expectations that underscore observed asset values for agricultural land, i.e. including lagged market returns and government payments as indicators for expected returns. Similarly, to account for attenuation bias, they argue that detailed statistics from producers are needed to capture the correlation between farms and across regions and support type. For instance, they use data from the Agricultural Resource Management Survey[3] (ARMS) for the years 1998-2001 and disaggregate government support by type of payment. In addition, they use county averages of market returns, which they argue is a more appropriate measure of the long-term expectations of the owners of agricultural land. They estimate a reduced form capitalization model of cropland values as a function of market returns and the various types of government support. In addition, they include measures of population growth, housing, and urban sprawl to account for the impact of the non-agricultural demand for land. Their results indicate that government support payments increase land values, with loan deficiency payments (LDP) resulting in the largest impact at $6.55 per acre for every additional dollar spent. However, including each type of government support introduces an endogeneity problem, since certain support payments such as LDPs are not exogenously known prior to the year they are received. To address endogeneity, Patton et al. (2008) develop an alternative two-stage design to analyze the disparate impacts of coupled and de-coupled (the latter are intended to not affect production decisions or output) government support on rental rates. Goodwin et al. (2011) apply this methodology to ARMS survey data from 1998-2005. The authors argue that using four-year county averages for government support and market returns reduces attentuation bias. Similar to their results in Goodwin et al. (2003), the authors show that government support payments increase cash rental rates, with particular impact

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[3] ARMS is a regularly conducted survey of 8,000 to 10,000 farms across the United States. Respondents fill out a detailed confidential survey from which socioeconomic and agricultural trends are summarized and used in research and policy analysis.

magnitudes dependent on payment type. They also find that government support payments, like LDP, increase the differential between cash and profit-share rental rates, while disaster payments reduce this differential. Kropp et al. (2015) expand on previous work by developing and implementing a measure of the impact of government ethanol mandates. Their metric is based on the distance between farms within a county and ethanol production facilities. Using ARMS data from 1998-2008, they estimate the impact of government -mandated ethanol production on cropland values. Their results confirm that farms located in counties with at least one ethanol production facility command a higher price and rental rate.

More recently, Chen et al. (2022) analyze the impact of a change in producer behavior on land values. In particular, they estimate the marginal effect of no-till practices on cropland values, employing a two-stage Lewbel instrumental variables (IV) approach. They use both NASS Agricultural Census Data and Iowa Farmland Values Survey data to find that no-till practices are positively associated with cropland values. A notable exception to the practice of omitting pastureland values common to the above-cited literature is the study by Classen et al. (2011), which simulates the impact of denying crop insurance to land converted from native rangeland for crop production, analyzing several alternative conversion paths under the SODSAVER[4] program.

The main criticisms for the capitalized framework are two-fold. First, estimating land values through a reduced-form capitalization model provide no causal understanding for the determinants of land values unless they are explicitly derived from a well-defined structural model. Secondly, the capitalization model omits the impact of related asset markets, presuming that changes in producer behavior brought about by a policy change are effectively capitalized by market returns or government payments.

Conceptually, consider two adjacent parcels of land, one in pasture and the other in

---

[4] The SODSAVER program was established under the 2014 Farm Bill. Its provisions were deigned to nudge farmers to protect native grasslands by tying crop insurance premium subsidies to not till native prairies.

crops. It is true that the values of the two parcels of land will be the sum of the discounted net benefits plus the option value from conversion to the next best alternative, but only if you assume that pastureland and cropland are not substitutable. That is, suppose the government introduces a new blending requirement for domestic fuels that raises the price of grains, resulting in a higher capitalized value for the cropland parcel since the blending requirement raises expectations of future returns to crop production. Furthermore, given the persistence of this new government mandate, not only will this new policy raise the value of the cropland parcel but of all unimproved open land with the capacity to be cropped (e.g., the adjacent pastureland parcel). Therefore, even though in this example the level of direct government support for pastureland is nil, the value of government outlays and mandates are indirectly capitalized into pastureland values by way of cropland. We denote this result the *appreciation effect*. Therefore, the capitalization model as written in (1) for pastureland would bias this effect as it would consider only the capitalized value of government support to pastureland products and discount any change in producer behavior not capitalized by the market. For example, RFS-II stimulated the demand for corn land, resulting in an observable increase in corn plantings as shown in figure 3. While this change in producer behavior is capitalized in cropland values through an increased demand for cropland, its effect on pastureland values is unclear unless both cropland and pastureland values are modeled simultaneously. Further, the relationship between cropland and pastureland extends to the supply chains of their derived products. For instance, a rise in grain prices also decreases the margins of livestock producers who supplement their animals on pasture with purchased feed. In addition, pastureland owners also compete with cropland owners for inputs such as irrigation and chemical fertilizers further reducing livestock margins in the climate of higher grain prices. This effect, which we denote the *depreciation effect* would not be captured by the traditional capitalization model of land values.

Generalizing the preceding thought experiment to the complete market for cropland

and pastureland and assuming traditional Marshallian supply and demand relationships, we illustrate the two effects in figure 4. Suppose a new biofuel mandate is enacted, then in panel (A), the resulting higher grain prices lead to stronger demand for cropland on the part of producers (shift from D_C to $D_C^{'}$). This incentivizes producers to convert pastureland to crop production, shrinking its supply (S_P to ($S_P^{'}$), while raising its price by making it more scarce in panel (B). Simultaneously, in panel (C), tighter margins for livestock products due to higher grain prices decreases the value of remaining pastureland by diminishing the expected returns to pastureland use ($P^{'}$ to P" & $Q^{'}$ to Q").

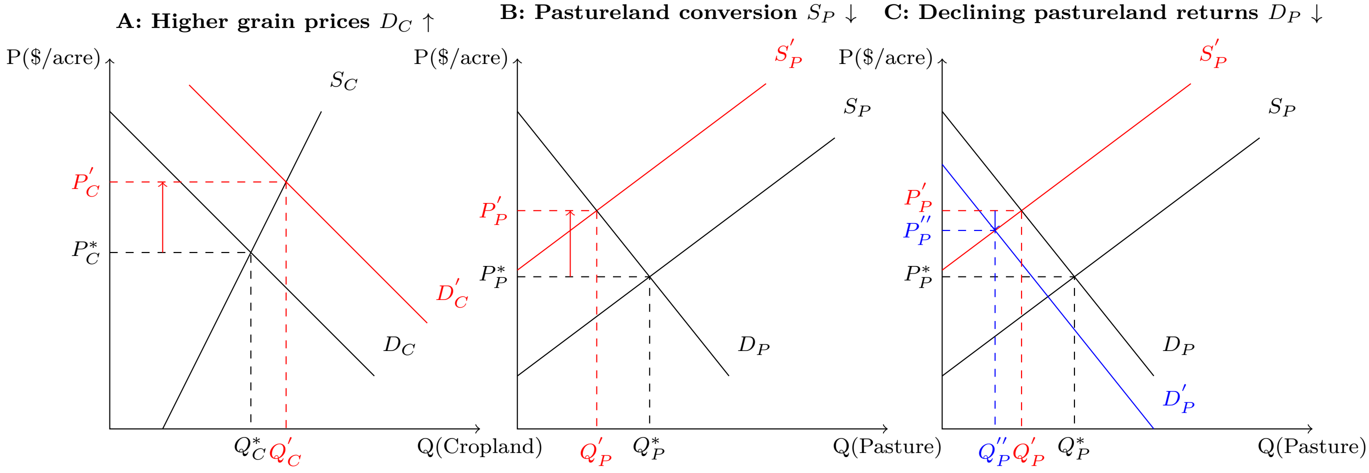

Figure 4: Changes in long-run demand and supply for crop and pastureland due to a persistent shock (e.g., biofuel blending mandates)

Note: In Panel A, biofuel policy raises the demand for cropland, increasing its price. In Panel B, this stimulates the conversion of quality pastureland, reducing its supply and raising its price. Finally, in Panel C, higher feed grain input prices decreases livestock margins and by extension the demand for pastureland.

In figure 4, it is clear that regardless of which effect dominates the equilibrium quantity of pastureland will decrease. However, the effect on the equilibrium price of pastureland will depend on if the appreciation effect is greater in magnitude than the depreciation effect. The same logic applies to a positive increase in government spending for crop production as opposed to a market mandate such as RFS-II. In fact, as spending for crop programs increases the demand for cropland, incentivizing conversion of pastureland, while also tightening livestock producer margins, reducing demand for pastureland. Moreover, figures 1-3 suggest that in the past two decades that the appreciation effect is only slightly larger than the depreciation effect since pastureland acreage declined significantly, while pastureland values only marginally increased.

We consider an alternative framework to the capitalization approach by modeling the determinants of agricultural land in the presence of external price shocks, related to the literature on price transmission in agricultural product markets. Gardner (1975) offers the first theoretical treatment of vertical price transmission (farm to retail and vice-versa) in a competitive food industry; his model defines a three-level supply chain: farm, factor, and retail. He then assumes perfect competition and specifies a system of six equations for supply, demand, and market clearing, where the demand functions are downward sloping and supply functions are non-negative. These six equations are solved and unique market equilibria determined. By differentiation with respect to the set of retail demand shifters, Gardner derives an expression for the elasticity of price transmission (EPT) between farm and retail (and vice-versa), which represents how changes in farm supply impact retail demand prices.

Wohlgenant (1989) extends Gardner's model by deriving a system of structural equations for raw farm products, marketing, and retail markets. In the reduced form, Wohlgenant provides a simple equation for the EPT, which is the ratio of the derived demand elasticity for the retail product and the derived demand elasticity for farm product. He applies his reduced-form model to commodity data and finds that input substitutability between farm outputs and marketing inputs increases derived demand elasticities for farm outputs. Wohlgenant concludes that price elasticity decreases as one moves up the supply chain from the retail level, so that the owners of the raw material do not receive the benefits from positive consumer demand shocks. Notable theoretical treatments of the Gardner-Wohlgenant framework include McCorriston et al. (2001), Wohlgenant (2006), and Kinnucan and Zhang (2015).

To adapt the model for our analysis, it is sufficient for pastureland to be considered as a potential raw material for the "production of cropland." In general, this is the case. Consider that, for land to be cropped, it must be cleared, somewhat well-drained, exhibit little or no slope, and possess appropriate climatic conditions[5]. Quality pastureland satisfies all of the conditions required, so that it carries with it an option value associated with conversion to cropland. By considering that option explicitly in a price transmission framework, along with the interactions between the derived products of pastureland and cropland, we present a more complete picture of how government policies affect various types of land values.

4 Theoretical Model

In this section, we derive a reduced-form system of equations for capitalized pasture and cropland values consistent with the Gardner-Wohlgenant price transmission model, which offers a clearer understanding of the interrelationship between cropland and pastureland values. Our model generates testable comparative statics. The structural model for related assets, assuming perfect competition in each asset market, is specified as:

$$Q^p_{t,d} = D^p_t(P, Z, C, W, M) \tag{2}$$

$$Q^p_{t,s} = S^p_t(P, T, L) \tag{3}$$

$$Q^p_{t,s} = Q^p_{t,d} \quad \forall t \tag{4}$$

$$Q^c_{t,d} = D^c_t(C, R, W, V, M) \tag{5}$$

$$Q^c_{t,s} \quad \text{predetermined} \tag{6}$$

---

[5] Conducive climatic conditions inlcude but are not limited to consistent rainfall and sunlight during the growing season. Furthermore, in the long run, the requirement that the land be cleared need not necessarily hold, since depending on the time frame if the other requirements do hold, then the land could be cleared and converted into cropland.

$$Q^c_{t,s} = Q^c_{t,d} \quad \forall t \tag{7}$$

where $Q^p_{t,d}$ is quantity of pastureland demanded, P is the asset price of pastureland, Z is an exogenous pastureland demand shifter such as livestock product sales, C is the asset price of cropland, and W represents county population characteristics (e.g., population growth rate). M is a set of indicators representing urban land demand, such as the ratio of county population to county agricultural land and the population growth percentage. In addition, T is average county-level government payments (of all types), L is a set of land use characteristics (e.g., cropland to pastureland ratio, corn plantings, etc.). $Q^c_{t,d}$ is the quantity of cropland demanded, R is an exogenous cropland demand shifter representing net returns to commodity crops in terms of farm sales and expenses, and V are exogenous weather variables, including precipitation and average temperature deviation during the growing season (taken to be March to September for most of the United States). The quantity of cropland supplied is assumed to be predetermined. This assumption allows for identification of the structural parameters and is consistent with the agronomic lags of the crop production process.

In equilibrium, (2-7) are written as

$$S^p_t(P, T, L) - D^p_t(P, Z, C, W, M) = 0 \tag{8}$$

$$Q^c_{t,s} - D^c_t(C, R, W, V, M) = 0 \tag{9}$$

Following Wohlgenant's method, if we totally differentiate and take the log of (8) and (9), then:

$$(e_P - \eta_P)\text{dln}P + e_C\text{dln}C = \eta_Z\text{dln}Z + \eta_W\text{dln}W + \eta_M\text{dln}M - e_T\text{dln}T - e_L\text{dln}L \tag{10}$$

$$-n_P\text{dln}P - n_C\text{dln}C = n_R\text{dln}R + n_W\text{dln}W + n_M\text{dln}M + n_V\text{dln}V - \text{dln}Q^c_{t,s} \tag{11}$$

where e_P is the elasticity of pastureland supply with respect to its own price, η_P is the elasticity of pastureland demand with respect to its own price, e_C is the elasticity of pastureland supply with respect to cropland prices, η_Z is the elasticity of pastureland demand with respect to Z, i.e. the exogenous set of derived pastureland product sales, η_W is the elasticity of pastureland demand with respect to W, i.e. the set of county population characteristics, η_M is the elasticity of pastureland demand with respect to M, the set of urban land demand indicators. e_T is the elasticity of pastureland supply with respect to government outlays, and e_L is the elasticity of pastureland supply with respect to land use characteristics. Similarly, for (12), n_P is the elasticity of cropland demand with respect to pastureland price, n_C is the own price elasticity of cropland demand, n_R is the elasticity of cropland demand with respect to the set of exogenous derived cropland product sales, n_W is the elasticity of cropland demand with respect to W, or the set of county population characteristics, and n_M is the elasticity of cropland demand with respect to urban land demand indicators. Finally, n_V is the elasticity of cropland with respect to weather variables. Important restrictions at the farm level apply to the county-level agricultural land markets: (1) individual landowner pastureland supply and cropland demand equations are homogeneous of degree zero (HDO), implying county-level supply and demand are HD0 as well; (2) Because pastureland and cropland demand functions are assumed HD0 in prices and income, then our structural equations are constant to proportional changes in P, C, and derived product prices Z and R. Finally, unlike the Wohlgenant-Gardner model of price transmission, we cannot assume a symmetric relationship between pastureland and cropland values since the spatial makeup of cropland and pastureland is not uniform nor does pastureland experience the same level of ownership turnover or investment. Instead, we assume e_C is negative, so that, following an unexpected positive shock to cropland values, the relative value of pastureland declines. Similarly, we let n_P be positive implying that as pastureland values rise cropland values also increase due to the competition for unimproved open land. We next derive the comparative statics of the reduced-form equations:

$$
\begin{aligned}
P &= P(R, W, V, Z, T, L, M, Q^c) \\
C &= C(R, W, V, Z, T, L, M, Q^c)
\end{aligned}
\tag{12}
$$

by solving accordingly for C and P yielding:

$$
\begin{aligned}
\mathrm{dln}C = D\mathrm{dln}Q^c_{t,s} - Dn_R\mathrm{dln}R + (C\eta_W - Dn_W)\mathrm{dln}W + (C\eta_M - Dn_M)\mathrm{dln}M \\
-Dn_V\mathrm{dln}V - C\eta_Z\mathrm{dln}Z - Ce_T\mathrm{dln}T - Ce_L\mathrm{dln}L \\
\mathrm{dln}P = B\eta_Z\mathrm{dln}Z + (B\eta_W - An_W)\mathrm{dln}W + (B\eta_M - An_M)\mathrm{dln}M - Be_T\mathrm{dln}T \\
-Be_L\mathrm{dln}L - A\mathrm{dln}Q^c_{t,s} - An_R\mathrm{dln}R - An_V\mathrm{dln}V
\end{aligned}
\tag{13}
$$

where:

$$A = \frac{e_C}{n_C(e_P - \eta_P) - e_C n_P} \tag{14}$$

$$B = \frac{n_C}{e_C}A \tag{15}$$

$$C = \frac{n_P}{e_C}A \tag{16}$$

$$D = \frac{e_P - \eta_P}{e_C}A \tag{17}$$

The expected signs of the reduced-form parameters A, B, C, and D are found by applying our assumptions with regard to the underlying own-price and cross price elasticities. Namely, A is (-), since $e_P - \eta_P > 0$, $e_C < 0$, and $n_P > 0$. Therefore, B is (+), and applying similar logic to C and D shows that they are (+) and (-) respectively, assuming that $0 < |n_C| < 1$. Unfortunately, since there are 14 elasticities in equations (10) and (11) and only 4 reduced-form parameters, the system is underidentified. As a result, we cannot recover unique values for the underlying supply and demand elasticities. However, if the vales of the own-price elasticities of supply and demand for pastureland and cropland are known (i.e. e, n, η), then we can obtain a value for e_C by estimating the reduced form parameter ($\hat{A}$) for the quantity of cropland in Equation (13). This value is:

$$e_C = \frac{\hat{A}n_C(e_P - \eta_P)}{1 + \hat{A}n_P} \tag{18}$$

As Wohlgenant (1989) details, the choice of functional form is an open question. For ease of estimation, we assume the elasticities in (13) are approximately constant so we can replace the instantaneous relative changes in the system by the first-differences in the logarithms, yielding:

$$\begin{aligned} \Delta\text{ln}C = D\Delta\text{ln}Q^c_{t,s} - Dn_R\Delta\text{ln}R + (C\eta_W - Dn_W)\Delta\text{ln}W + (C\eta_M - Dn_M)\Delta\text{ln}M \\ -Dn_V\Delta\text{ln}V - C\eta_Z\Delta\text{ln}Z - Ce_T\Delta\text{ln}T - Ce_L\Delta\text{ln}L \\ \\ \Delta\text{ln}P = B\eta_Z\Delta\text{ln}Z + (B\eta_W - An_W)\Delta\text{ln}W + (B\eta_M - An_M)\Delta\text{ln}M - Be_T\Delta\text{ln}T \\ -Be_L\Delta\text{ln}L - A\Delta\text{ln}Q^c_{t,s} - An_R\Delta\text{ln}R - An_V\Delta\text{ln}V \end{aligned} \tag{19}$$

For robustness, we relax the assumption of instantaneous relative changes with a relative price model on the levels in Section 5.4.

5 Empirical Framework

Our two-stage least squares design accounts for the simultaneity problem inherent in the determination of cropland and pastureland values. In the first stage, we regress cropland values on our chosen set of valid instruments along with any additional exogenous predictors. Valid instruments are defined as both exogenous and relevant to the dependent variable, pastureland values, in the second stage. So long as instrument validity holds, we then estimate the second stage by regressing pastureland values on the predicted values of cropland from the first stage with the remaining set of covariates. The result is an unbiased estimate of the marginal effect of cropland value changes on pastureland values. Section 5.2 details the exact assumptions invoked in our two-stage model and statistically assesses the validity of our chosen instruments for each model iteration.

In addition, we adapt our two-stage model using a RDD. In an RDD, a threshold value for the treatment variable is specified. In our formulation, we use the year 2007, the date of RFS-II implementation, as our threshold and specify county corn plantings as our treatment. Then, we compare observations on either side of that threshold to estimate the average treatment effect of RFS-II. Crucially, an RDD requires that all potentially relevant variables besides the treatment variable and outcome variable be continuous at the point where the treatment and outcome discontinuities occur, such as the jump in corn plantings between 2002 and 2012 shown in figure 3. The discontinuous jump in corn plantings pre-and-post 2007 allows us to estimate the effect of RFS-II on pastureland and cropland values simultaneously by exploiting observable changes in producer behavior, namely producers' decision to increase corn plantings.

5.1 Data

To analyze the relationship between cropland and pastureland values, we collected county-level indicators for 2,696 counties across the United States between 1997-2017 from NASS, giving us 13,480 total observations. Table 5 in the appendix presents each variable collected along with their unique symbol identifier, number of complete observations, and summary statistics. Following Goodwin et al. (2011), we collected the total acreage of cropland and pastureland (TC and TP respectively), land values (agricultural land values AGV), and market return data such as total sales for crops. We divide total crop sales by TC, yielding crop sales per acre (CCS). We also collected livestock product sales data (LPS) along with operating expenses (OP). Furthermore, we gathered total governmental receipts (GR) for government support programs by county. Next, we compiled relevant weather variables to use as instruments, a step not taken in previous studies. Weather characteristics of a county are exogenous to current land values yet highly relevant to the expected future returns, and thus a logical choice of instrument to include in the model. Yet, they could be correlated with the expected return distribution, violating the exogeneity assumption. However, our choice of lagged rainfall and temperature represents only a snapshot of the climatic history of a county not the trend in climatic conditions, which are used to formulate the expected return distribution. In particular, we drew from the National Oceanic and Atmospheric Administration (NOAA) county-level average precipitation ($PRECIP$) and the average temperature deviance (ATD) during the growing season. For convenience, we squared ATD to remove the negative, yielding the average squared temperature deviance measure ($ATDSQ$). Finally, we include county population (POP), sourced from the Census Bureau.

We then created a series of additional variables used in our analysis. First, the cropland to pastureland ratio (CPR), a measure of the relative demand for cropland over pastureland. Second, following Goodwin et al. (2011), we calculated the population percentage growth (PPG) as an indirect measure of the demand for land. Third, the agricultural land to population ratio (APR), a measure of the demand for developed land. We use these three variables to predict cropland values in a first stage, and then estimate pastureland values as a function our exogenous controls and the predicted values of cropland from the first stage. For the two-stage RDD, the variable of interest is corn plantings as a percentage of total agricultural land (CPA) within a county. CPA acts as our treatment variable and captures the discrete jump in the demand for cropland following the implementation of RFS-II. With the RDD, we estimate the effect this discrete exogenous shock had on pastureland values.

5.2 Econometric Model, Diagnostics, & Results

Econometric treatments of two-stage instrumental variables (IV) regression relies on identifying valid instruments: exogenous ($E(\epsilon|Z) = 0$) and relevant ($Corr(X, Z) \neq 0$). Canonical test are used to assess whether estimated models satisfy these assumptions, so that any meaningful conclusions drawn are consistent and unbiased. Our chosen set of instruments include lagged market returns for crops, governmental outlays, along with precipitation and temperature deviation from the mean. Goodwin et al. found that lagged market returns are suitable instruments for their capitalization model. Intuitively, lagged market returns are exogenous but relevant to the capitalized value of agricultural land. We invoke the same argument for our inclusion of precipitation and average deviance from the mean temperature. We present the results for tests of relevance and exogeneity in table 1. First, we performed a Wald test for weak instruments. Our results show that we can reject the null hypothesis for each model, meaning that at least one of our chosen instruments is strong, and our choice of instruments satisfies the relevance condition.

Table 1: Diagnostic Tests

Test	Df1	Df2	Test Statistic	Pr(>F)
		Model I		
Wald	3	13479	339.8	<0.01
Hausman	1	13470	12.41	<0.01
Sargan	2		5.81	0.0549
		Model II		
Wald	7	13479	241.71	<0.01
Hausman	1	13469	12.37	<0.01
Sargan	6		6.71	0.348
		Model III		
Wald	8	8710	340.64	<0.01
Hausman	1	8698	14.999	<0.01
Sargan	7		8.33	0.305

Next, we explicitly test for consistency of the IV estimator using the Hausman test. The null hypothesis is that the OLS and IV estimators are consistent, while under the alternative hypothesis only the IV estimator is consistent. As shown in table 1, we can reject the null and conclude the our estimated IV coefficients are consistent. Finally, each of our estimated models are over-identified. Therefore, we must test whether our instruments are exogenous and uncorrelated with the model residuals using the Sargan J test. Under the null hypothesis, the complete set of instruments is valid. In table 1, we fail to reject the null hypothesis for each of our estimated models.

For the two-stage empirical model, we first re-write our reduced form Eqn. (19), using composite coefficients β_i, which represent the combination of the structural parameters and elasticities. As such, we now take our reduced form model to the data. To account for the simultaneity problem inherent between cropland and pastureland, our preliminary Model I is composed of two stages. In the first stage, we estimate cropland values as a function of our instruments: the growing season precipitation, average squared temperature deviance, and crop commodity sales. The results of our diagnostic tests in table 1 confirm our choice of instruments is valid. In the second stage we use those predicted values, along with a set of other variables (the cropland to pastureland ratio, government outlays, livestock product sales, and the percentage population growth) to estimate the relationship between each and pastureland values. Model I results are presented in table 2.

Our econometric results are in line with our model predictions. For example, our model predicts that the coefficient for cropland ($\hat{\beta}_1$) will be positively signed (i.e. the *appreciation* effect), while the coefficient for government outlays ($\hat{\beta}_3$) will be negative (i.e. the *depreciation* effect). In table 1, the 0.603 appreciation effect coefficient is significantly greater than zero, while the depreciation effect coefficient is likewise statistically significant at -0.309. We can interpret these coefficients as elasticities: a 1% increase in cropland values leads to an appreciation of pastureland values of 0.603% (95%–C.I. 0.534%; 0.672%), while a 1% increase in government outlays depreciates pastureland values by -0.309% (95%–C.I. -0.319%; -0.299%). All other market returns, population, and land use variables also have the theoretically appropriate sign and are statistically significant. Livestock product sales increase pastureland values by almost 0.125% (95%–C.I. 0.116%; 0.134%) per unit percent increase. Furthermore, unit percent increases in the ratio of cropland to pastureland and population growth have a significant yet small negative impact of pastureland values.

$$
\begin{aligned}
\text{First Stage:}\quad & \Delta \ln CV_{it} = \gamma_0 + \gamma_1 \Delta PRECIP_{it} + \gamma_2 \Delta ATDSQ_{it} + \gamma_3 \Delta CCS_{i,t-1} + u_{it} \\
\text{Second Stage:}\quad & \Delta \ln PV_{it} = \beta_0 + \beta_1 \widehat{\Delta \ln CV}_{it} + \beta_2 \Delta CPR_{it} + \beta_3 \Delta \ln GR_{it} + \\
& \beta_4 \Delta \ln LPS_{it} + \beta_5 \Delta PPG_{i,t-1} + \eta_t + \epsilon_{it}
\end{aligned}
\tag{20}
$$

We re-estimate the model, including in both stages government receipts, the cropland to pastureland ratio, the agricultural land to population ratio (APR), and population percentage growth (PPG) in Model II. Adding government spending along with measures of urban and agricultural land demand to the first and second stages improves the statistical fit of the predicted values of cropland in estimating pastureland value determinants. The result is an increase in the goodness-of-fit according to the adjusted-R^2 of the first stage of Model II compared to Model I. Table 6 in the appendix presents the results of the estimated first stage for each model. Our second stage Model II results presented in table 2 are significant across all predictors with the theoretically appropriate signs. In fact, our results for Model II are somewhat similar to Model I, with an increase in the adjusted-R^2 or goodness-of-fit. The estimated marginal effects of cropland, government receipts, and livestock market returns are consistent with no significant change between Models I and II.

$$\begin{aligned}\text{Stage I:}\quad \Delta\ln CV_{it} &= \gamma_0 + \gamma_1\Delta PRECIP_{it} + \gamma_2\Delta ATDSQ_{it} + \gamma_3\Delta CCS_{i,t-1} + \\ &\gamma_4\Delta CPR_{it} + \gamma_5\Delta\ln GR_{it} + \gamma_6\Delta APR_{it} + \gamma_7\Delta PPG_{i,t-1} + u_{it} \\ \text{Stage II:}\quad \Delta\ln PV_{it} &= \beta_0 + \beta_1\widehat{\Delta\ln CV}_{it} + \beta_2\Delta CPR_{it} + \beta_3\Delta\ln GR_{it} + \\ &\beta_4\Delta\ln LPS_{it} + \beta_5\Delta PPG_{i,t-1} + \beta_6\Delta APR_{it} + \eta_t + \epsilon_{it}\end{aligned} \tag{21}$$

Next, we estimate our two-stage model with a RDD, using corn plantings (CPA) as a continuous treatment. Since statistics for corn plantings are not available for all counties (i.e. there are urban counties where agriculture is not a major land use), the sample size for the two-stage RDD is 8,711 instead of 13,480. For Model III, our supposition is that corn plantings jumped discretely, following RFS-II, and the subsequent rise in corn prices resulted in a devaluation of adjacent pastureland relative to cropland. To implement the RDD, we first identify a threshold that corresponds to the discrete jump in our treatment variable. Our threshold is the year RFS-II was adopted, 2007, thus our Model III is written as:

$$D = \begin{cases} 1 & \text{if} \quad \eta_t > 2007 \\ 0 & \text{otherwise} \end{cases}$$

$$\begin{aligned}\text{Stage I:}\quad \Delta\ln CV_{it} &= \gamma_0 + \gamma_1\Delta PRECIP_{it} + \gamma_2\Delta CCS_{i,t-1} + \gamma_3\Delta CPR_{it} + \\ &\gamma_4\ln\Delta GR_{it} + \gamma_5\Delta PPG_{i,t-1} + \gamma_6\Delta CPA_{it} + \tau D + u_{it}\end{aligned} \tag{22}$$

$$\begin{aligned}\text{Stage II:}\quad \Delta\ln PV_{it} &= \beta_0 + \beta_1\widehat{\Delta\ln CV}_{it} + \beta_2\Delta CPR_{it} + \beta_3\Delta\ln GR_{it} + \beta_4\Delta\ln LPS_{it} + \\ &\beta_5\Delta PPG_{i,t-1} + \beta_6\Delta APR_{it} + \beta_7\Delta CPA_{it} + \delta D + \beta_8 D \times \Delta CPA_{it} + \eta_t + \epsilon_{it}\end{aligned}$$

We interact our threshold indicator with our continuous treatment, corn plantings, ($D \times \Delta CPA_{it}$) to capture the additional marginal impact of the increased demand corn crop acreage, following the passage of RFS-II. We include the results for Model III in table 2. First, we see a significant increase in the goodness-of-fit for Model III (0.650) compared to Model II (0.591) in terms of the adj-R^2. Secondly, the estimated coefficient for predicted cropland values is significantly higher compared to Models I-II. The results for Model III indicate a 1% increase in the value of cropland appreciates pastureland values by 0.811% (95%–C.I. 0.597%; 1.02%). The estimated coefficient for livestock product sales and government outlays are again theoretically consistent in terms of sign and are approximately equivalent to those found from Models I-II. In contrast, the estimated coefficient for percentage population growth, PPG, and agricultural land to population ratio, APR, are no longer significant at the 0.05–α level. The estimated results for the continuous treatment show that a unit percent increase in the amount of corn plantings decreases adjacent pastureland values by -2.62% (95%–C.I. -2.97%; -2.27%) in the same county. This effect is moderated in the years following RFS-II. Specifically, the estimated coefficient for our interaction term, $D \times \Delta CPA_{it}$, is positive and only slightly significant: 0.324% (95%–C.I. 0.018; 0.630). We interpret this result to reflect the fact that following RFS-II mandate, the demand for cropland increased, so that the relative value of pastureland fell and the supply of pastureland declined. Yet, as the supply of pastureland tightened, pastureland values faced upward pressure due to scarcity; hence, the positive value of the interaction term.

We control for year fixed effects with η_t in Models I-III. This term captures those effects that do not vary across counties but do vary over time. It is included, for example, to account for a change in government policy with regard to ethanol production at the national that will impact all counties, such as RFS-II. In contrast, there are unobservables that differ across counties but are constant over time. In particular, agronomic characteristics like soil fertility and agronomic practices like conservation tillage vary from county to county but remain stationary over time. Therefore, we-estimate Model III including both year and county fixed effects. Table 2 presents the results of this regression in the column: (Model III w/FEs).

When controlling for county and year fixed effects, our results show that a 1% increase in cropland values produces a 0.683% (95%–C.I. 0.509%; 0.857%) increase in pastureland values, a slight but noticeable reduction than controlling for year fixed effects only. Moreover, the marginal effect of corn plantings on pastureland is also less than our results from the year effects only Model III (-2.402 vs -2.623). In contrast, the marginal effects of government support on pastureland values, livestock product returns, and our interaction term are approximately unchanged. The next section proceeds with a discussion of the validity of our instruments before interpreting the estimated marginal effects on pastureland values.

Table 2: Estimated Results from Second Stages

	Dependent variable:			
	$\Delta \ln PV_{it}$			
	(Model I)	(Model II)	(Model III)	(Model III w/FEs)
$\widehat{\Delta \ln CV}_{it}$	0.603^{***} (0.035)	0.599^{***} (0.034)	0.811^{***} (0.109)	0.683^{***} (0.089)
ΔCPR_{it}	-0.027^{***} (0.001)	-0.031^{***} (0.001)	-0.026^{***} (0.004)	-0.023^{***} (0.001)
$\Delta \ln GR_{it}$	-0.309^{***} (0.005)	-0.309^{***} (0.005)	-0.302^{***} (0.119)	-0.278^{***} (0.0161)
$\Delta \ln LPS_{it}$	0.125^{***} (0.005)	0.127^{***} (0.005)	0.137^{***} (0.005)	0.118^{***} (0.0141)
$\Delta PPG_{i,t-1}$	-0.043^{***} (0.003)	-0.014^{***} (0.004)	-0.007 (0.005)	0.001 (0.007)
ΔAPR_{it}		-0.001^{***} (0.0003)	-0.0005^{*} (0.0002)	-0.0005 (0.0004)
ΔCPA_{it}			-2.623^{***} (0.179)	-2.402^{***} (0.178)
D $\times \Delta CPA_{it}$			0.324^{**} (0.156)	0.301^{***} (0.075)
Constant	-0.001 (0.013)	-0.001 (0.013)	NA	NA
Observations	13,480	13,480	8,711	8,711
Year Fixed Effects	Yes	Yes	Yes	Yes
County Fixed Effects	No	No	No	Yes
R^2	0.590	0.591	0.651	0.586
Adjusted R^2	0.589	0.591	0.650	0.513
Residual Std. Error	0.713	0.711		
F Statistic	$2,150.337^{***}$	$1,947.977^{***}$	$2,026.024^{***}$	$1,308.992^{***}$
DF	9 & 13470	10 & 13469	8 & 8698	8 & 7410

Note: robust std. errors in parentheses; $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

5.3 Marginal Effects

From the final model, There are two direct effects and two indirect effects we analyze. The first direct effect is the appreciation of pastureland owing to an increased demand for cropland (Demand Appreciation Effect). The second direct effect is the depreciation impact from direct government support for crop production, which increase the opportunity costs of holding land in pasture (Supply Depreciation Effect). The first indirect effect is the depreciation effect of pastureland values associated with the conversion of quality pastureland to crop production, leaving only marginal pastureland (Demand Depreciation Effect). The second indirect effect is captured by the interaction term between our threshold and continuous treatment ($D \times CPA_{it}$). This specific variable represents the indirect impact of the demand for cropland on pastureland values, following the adoption of RFS-II (Supply Appreciation Effect). It is a positive effect because it represents the added value of holding unimproved pastureland as the amount of pastureland shrinks in the face of strong demand for such land from cropland owners. Hence, the scarcity from conversion of quality pastureland in the face of strong demand for cropland puts upward pressure on the price of pastureland. We bootstrap confidence intervals for these marginal effects in table 3. It is unclear whether the

Table 3: Bootstrapped Mean, Standard Errors, and Confidence Intervals

Direct Support Effects	Mean	S.E.	5% level	95% level
Demand Appreciation Eff.	0.703%	0.0616	0.582	0.823
Supply Depreciation Eff.	-0.282%	0.00833	-0.299	-0.266
Indirect Support Effects				
Demand Depreciation Eff.	-2.439%	0.128	-2.690	-2.189
Supply Appreciation Eff.	0.300%	0.0814	0.140	0.459

Note: author calculations from 1,000 replications and 10,000 random draws

net direct effects are positive. For example, if the change in government spending outpaces the change in demand cropland, then the supply depreciation effect will dominate as the relative value of pastureland falls due to the opportunity costs of keeping land in pasture, since it receives virtually no government spending. However, if the demand for cropland is strong, then pastureland values will increase, based on its associated conversion costs. In terms of indirect support, it is clear demand depreciation dominates. In fact, the net impact of the indirect effects is that for each unit percent increase in corn plantings after RFS-II adoption reduces pastureland values by -2.130% (95%–Bootstrapped C.I.: -2.407%; -1.853%). This suggests that an increase in the demand for cropland decreases the relative value of adjacent pastureland. In the next section, we present three separate robustness checks to our modeling approach and results.

5.4 Robustness Check I: Relative Pricing Model

One alternative approach to analyzing the relative impact of the disparate support for crops over livestock is a single-equation relative value model. Hence, we denote the relative value (RV) as the difference between the cropland and pastureland values in each county. Formally, we write write our relative value model as:

$$\begin{aligned} RV_{it} = \beta_0 + \beta_1 CPR_{it} + \beta_2 \ln GR_{it} + \beta_3 \ln CCS_{it} + \beta_4 \ln LPS_{it} + \beta_5 PPG_{it} + \\ \delta D + \beta_6 CPA_{it} + \beta_7 D \times CPA_{it} + \eta_t + \alpha_i + \epsilon_{it} \end{aligned} \tag{23}$$

We estimate the model using OLS, controlling for county and year fixed effects. Table 2 presents the estimated results. They conform to our two-stage RDD findings. First, government outlays, crop product sales, and livestock product sales have the theoretically appropriate sign and are statistically significant. Increasing market returns to crop production act to widen the gap in cropland and pastureland values, while increasing livestock returns act to decrease the differential. Although the magnitude for the effect of crop market returns is significantly larger. In terms of direct government support, each percentage increase in government outlays increases the differential between cropland and pastureland values by \$230.47 (95%–C.I. \$194.62; \$266.33). The largest effect is the impact of corn plantings after RFS-II ($D \times CPA_{it}$). In fact, each percentage increase in the demand cropland for corn significantly expands the differential in land values by \$367.11 (95%–C.I. \$265.97; \$468.24).

5.5 Robustness Check II: Internal IV Estimation

For our second robustness check, we implement the moment-based Lewbel IV estimator to account for potential endogeneity due to correlations between county-year-varying unobservables left over in the second stage error term and land values. In Model III, we already account for endogeneity due to year and county fixed effects. However, it is possible that there may be residual endogeneity that jointly influence government spending, market returns, urban land demand and agricultural land values. For instance, county-year-varying unobservables associated with land development policies and real estate market factors (e.g., mortgage rates) or private conservation initiatives such as carbon off-set markets may be positively correlated with product market returns and urban land demand, and these unobservables may also be positively correlated to different degrees with cropland and pastureland values, thereby biasing our estimates. The typical approach in this case is to use IV based panel fixed effects models (IV-FE), as we do in our final main model, where the IVs are correlated with the potentially endogenous main independent variable but uncorrelated with the outcome variable. Although our main model results support the validity of our external instruments, we consider whether our estimated marginal effects are robust to the absence of external instruments by following the Lewbel IV procedure in Chen et al. (2022).

The Lewbel IV estimator exploits the heteroscedasticity in the error term from the first-stage regression. According to Lewbel (2012), the model is identified if the error term in the first-stage equation is heteroscedastic. If so, then the subset (or all) of the mean-centered covariates multiplied by first-stage residuals represent a valid set of instruments. We begin by removing the external instruments in the first stage of Model III. We then re-estimate it regressing cropland values on internal instruments generated from government outlays, livestock product sales, county population growth, and the agricultural land to population ratio. Hence, according to the procedure outlined in Lewbel (2012) and implemented by Chen et al. (2022), our first stage regression becomes:

$$\begin{gathered} \Delta \ln CV_{it} = \gamma_{\boldsymbol{x}} \boldsymbol{X}_{it} + u_{it} \\ \boldsymbol{X}' = [GR \quad LPS \quad PPG \quad APR] \end{gathered} \tag{24}$$

If $Cov(\boldsymbol{X}_{it}, u_{it}^2) \neq 0$ and $Cov(\boldsymbol{X}_{it}, \varepsilon_{it} u_{it}) = 0$, then $(\boldsymbol{X}_{it} - \bar{\boldsymbol{X}})\hat{u}_{it}$ is a valid IV for a two-stage least squares design. The first assumption is satisfied if there is heteroscedasticity in Equation (24). We use the Breusch-Pagan (BP) test to validate the presence of heteroscedasticity in our first-stage regression (Breusch Pagan, 1979). The BP test rejects the null hypothesis of homoscedasticity the first stage with a test statistic of 77.23 (p-value « 0.05). The Sargan J of overidentifying restrictions is used to test the second assumption. We fail to reject the hypothesis that our instruments are valid at the 1% significance level.

With the necessary assumptions satisfied, we present the results of the Lewbel-IV second stage estimation in table 4. They are consistent with our external IV RDD estimation results. For instance, using Lewbel-IV, we find that a 1% increase in cropland values inflates pastureland values by 0.632% (95%–C.I. 0.409%; 0.853%). This confidence region is directly comparable to the confidence region of the estimated marginal effect of cropland values using our identified external IVs. The same is true for the estimated marginal effects of government outlays, livestock product sales, and corn plantings.

5.6 Robustness Check III: Reverse Transmission

Another test of the consistency of our price transmission model is to consider how changes in pastureland values pass through to cropland values. To apply this test, we switch the dependent variables in the first and second stages of the final estimated model. The results of this estimation should reflect those found by previous traditional capitalization studies. Specifically, in this formulation, we expect that the marginal effect of direct government spending is small and positive, while the impact of the change in the demand for cropland following RFS-II is large and positive. In contrast, according to our theoretical model, the direct effect of pastureland value shocks to cropland values is positive but smaller in magnitude than the effect in the opposite direction. For example, a positive shock to pastureland values implies higher prices for livestock products, which further implies stronger demand for feed crops and hence higher cropland values. Moreover, positive shocks to pastureland values signals a stimulated demand for the same land characteristics valued in cropland, in particular fertile open land. Formally, equation (25) defines our reverse transmission model, using cropland as the dependent variable in the second stage and estimating pastureland values with market returns and weather characteristics as instruments in the first stage. Again, we control for county and year fixed effects. Table 4 presents the estimated results. And, results from Wald, Hausman, and Sargan tests of the instruments included in this regression support the validity of our chosen instruments.

$$D = \begin{cases} 1 & \text{if} \quad \eta_t > 2007 \\ 0 & \text{otherwise} \end{cases}$$

$$\begin{aligned} \text{Stage I:} \quad \Delta \ln PV_{it} = \gamma_0 + \gamma_1 \Delta PRECIP_{it} + \gamma_2 \Delta \ln LPS_{it} + \gamma_3 \Delta CPR_{it} + \\ \gamma_4 \ln \Delta GR_{it} + \gamma_5 \Delta PPG_{i,t-1} + \gamma_6 \Delta CPA_{it} + \tau D + u_{it} \end{aligned} \tag{25}$$

$$\begin{aligned} \text{Stage II:} \quad \Delta \ln CV_{it} = \beta_0 + \beta_1 \widehat{\Delta \ln PV}_{it} + \beta_2 \Delta CPR_{it} + \beta_3 \Delta \ln GR_{it} + \beta_4 \Delta CCS_{i,t-1} + \\ \beta_5 \Delta PPG_{i,t-1} + \beta_6 \Delta APR_{it} + \beta_7 \Delta CPA_{it} + \delta D + \beta_8 D \times \Delta CPA_{it} + \eta_t + \alpha_i + \epsilon_{it} \end{aligned}$$

Our results in table 4 show that pastureland values have a significant positive effect on cropland values. We find a 1% increase in pastureland values increases cropland values by 0.422% (95%–C.I. 0.369%; 0.475%). To compare the price transmission rate of pastureland to cropland versus cropland to pastureland, we divide the estimated marginal effect of cropland in Model III by the estimated marginal effect of pastureland. We find that changes in cropland values transmit to pastureland values at almost twice the rate of the reverse case 1.63 (95%–C.I. 1.33; 1.95). The estimated marginal effect of government support is also consistent with Goodwin et al. (2003), Goodwin et al. (2011), and Kropp and Peckham (2015). In fact, we find that a 1% increase in direct government spending raises cropland values by 0.088% (95%–C.I. 0.0.050%; 0.126%). Similarly, the estimated marginal effect of the demand for corn land is consistent with our two-stage RDD results, with a 1% increase in corn plantings inflating cropland values by 1.926% (95%–C.I. 1.65%; 2.21%). However, unlike our two-stage RDD results, the estimated marginal effect of the incremental increase in the demand for corn land after RFS-II is insignificant. One possible explanation for this result is that cropland owners updated their expectations with regard to their land values prior to the implementation of RFS-II as they witnessed the progressive move toward government mandated ethanol production. As such, cropland values capitalized this information more quickly than other agricultural land values were the impact of ethanol policy is not as clear.

Table 4: Relative Value, Internal IV, and Reverse Transmission Robustness Checks

	Dependent variable:		
	RV_{it}	$\Delta\ln PV_{it}$	$\Delta\ln CV_{it}$
	(Relative Value)	(Internal IV)	(Reverse Trasmission)
CPR_{it}	5.257^{***}		
	(0.708)		
$\ln \text{GR}_{it}$	230.474^{***}		
	(18.295)		
$\ln \text{CCS}_{it}$	214.742^{***}		
	(21.892)		
$\ln \text{LPS}_{it}$	-139.842^{***}		
	(15.642)		
PPG_{it}	-32.504^{***}		
	(5.759)		
APR_{it}	-3.816		
	(3.069)		
$\widehat{\Delta\ln CV}_{it}$		0.632^{***}	
		(0.114)	
$\widehat{\Delta\ln PV}_{it}$			0.422^{***}
			(0.060)
ΔCPR_{it}		-0.022^{***}	0.013^{***}
		(0.001)	(0.0015)
$\Delta\ln GR_{it}$		-0.281^{***}	0.088^{***}
		(0.010)	(0.0192)
$\Delta\ln LPS_{it}$		0.093^{***}	
		(0.009)	
$\Delta CCS_{i,t-1}$			-0.004^{*}
			(0.0022)
$\Delta PPG_{i,t-1}$		-0.008	-0.014^{**}
		(0.005)	(0.0057)
ΔAPR_{it}		$\text{-}0.0005^{**}$	-0.0003
		(0.0002)	(0.0004)
ΔCPA_{it}	-75.371	-2.187^{***}	1.926^{***}
	(61.819)	(0.201)	(0.143)
$\text{D} \times \Delta CPA_{it}$	367.107^{***}	0.307^{**}	0.247^{***}
	(51.598)	(0.128)	(0.055)
Observations	8,712	8,712	8,711
Year Fixed Effects	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes
R^2	0.352	0.683	0.214
Adjusted R^2	0.238	0.682	0.077
F Statistic	502.569^{***}	1539.000^{***}	252.700^{***}
DF	8 & 7411	8 & 6674	8 & 7410

Note: robust std. errors in parentheses *p<0.1; **p<0.05; ***p<0.01

6 Policy Implications and Further Research

The implications of our results are multi-facted. First, if a county's land use mix is dominated by corn, then the relative value of pastureland will fluctuate, depending on corn market expectations and the demand for cropland. Hence, pastureland owners should diversify to limit their exposure. On the supply side, the owners of pastureland could attempt to de-couple the value of their asset with cropland by substituting inputs, i.e. using organic as opposed to industrial inorganic fertilizer. Similarly, on the demand side and in particular for cattle producers, they should consider the outside option of finishing cattle with an alternative to corn like cotton seed or alfalfa. Nevertheless, our results establish that there is a critical link between cropland and pastureland values that impacts the welfare of both crop and livestock producers. Including price transmission components in the estimation of land values represents a logical extension to the traditional model of agricultural land value determinants.

Policy makers considering prescriptions to stabilize crop farm incomes, whether directly through government spending or indirectly through demand creation, should consider spillover effects to related markets that increase economic inefficiency. Our results show that U.S. farm and land policy, as currently applied, disproportionately favors crop production yielding significant distortions to the values of pastureland. We find that positive gains in cropland values do pass through to pastureland markets, however, these gains are more than reversed due to the high of opportunity costs associated with maintaining land in pasture. The next step in evaluating the dynamics between cropland and pastureland values is to use richer data such as the ARMS data. Using farm-level survey data would allow for more precise estimation of individual farmer behavior in response to changes in government support.

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7 Appendix

Table 5: Summary Statistics: Variables of Interest 1997-2017

Variables Name	**Symbol**	**Observations**	**Mean**	**St.dev**	**Description**
Total Cropland (acres)	TC	13,480	143,997	153,466	County level cropland from
Total Pastureland (acres)	TP	13,480	156,036	327,449	County level cropland from
Crop vs. Pastureland Ratio	CPR	13,480	6.77	16.25	Ratio of County Cropland to Pastureland
Agland Values ($/acres)	AGV	13,480	2,924	2,765	Average Agland Values by County 1997-2017
Cropland Values ($/acres)	CV	13,480	4,857	4,790	Average Cropland Values by County
Pastureland Values ($/acres)	PV	13,480	990.971	1,252	Average Cropland Values by County
Crop Commodity Sales ($)	CCS	13,480	147,918	236,827	Gross Crop Commodity Sales per Operation by County
Operating Expenses ($)	OP	13,480	123,744	203,561	Crop Commodity Operating Expenses per Operation by County
Livestock Product Sales ($)	LPS	13,480	50,866,556	108,211,872	Gross Animal Product Sales by County
Government Receipts ($)	GR	13,480	2,507,446	3,027,567	Total Government Support for Agriculture (e.g., Crop Insurance, Disaster Payments, etc.)
Precipitation (in.)	PRECIP	13,480	20.401	8.13	Total Rainfall by County from April to September
Average Temperature Deviance (°F)	ATDSQ	13,480	0.89	1.57	Squared Deviance from the Mean Temperature by County from April to September
Population (# of residents)	POP	13,480	90,474	308,195	Total Population by County
Population Percent Growth (%)	PPG	13,480	0.39	1.52	Percentage Growth Rate by County
Agland vs Population Ratio (acres/# of residents)	APR	13,480	2.28	22.60	Agland Acres per Number of Residents by County

Note: These data were sourced from NASS Census of Agriculture Database using 2,696 counties across the United States from Census years: 1997, 2002, 2007, 2012, and 2017. The result is 13, 480 observations.

Table 6: First-Stage Estimated Model Results

	Dependent variable:		
	$\Delta \ln CV_{it}$		
	(Model I)	(Model II)	(Model III)
$\Delta PRECIP_{it}$	0.033^{***}	0.033^{***}	0.023^{***}
	(0.001)	(0.001)	(0.001)
$\Delta ATDSQ_{it}$	-0.004	-0.005^{**}	
	(0.003)	(0.003)	
$\Delta CCS_{i,t-1}$	-0.003^{***}	-0.002^{**}	-0.003^{***}
	(0.001)	(0.001)	(0.001)
ΔCPR_{it}		0.006^{***}	0.002^{***}
		(0.0003)	(0.0003)
$\Delta \ln GR_{it}$		0.001	-0.020^{***}
		(0.004)	(0.004)
$\Delta PPG_{i,t-1}$		-0.047^{***}	-0.040^{***}
		(0.003)	(0.004)
ΔAPR_{it}		-0.001^{***}	-0.001^{***}
		(0.0002)	(0.0002)
ΔCPA_{it}			1.794^{***}
			(0.046)
D			0.037^{***}
			(0.013)
Constant	-0.0001	-0.0001	0.040^{***}
	(0.006)	(0.006)	(0.008)
Observations	13,480	13,480	8,711
R^2	0.070	0.112	0.238
Adjusted R^2	0.070	0.111	0.238
Residual Std. Error	0.732	0.716	0.582
F Statistic	339.800^{***}	241.713^{***}	340.637^{***}
DF	3 & 13476	7 & 13472	8 & 8702
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

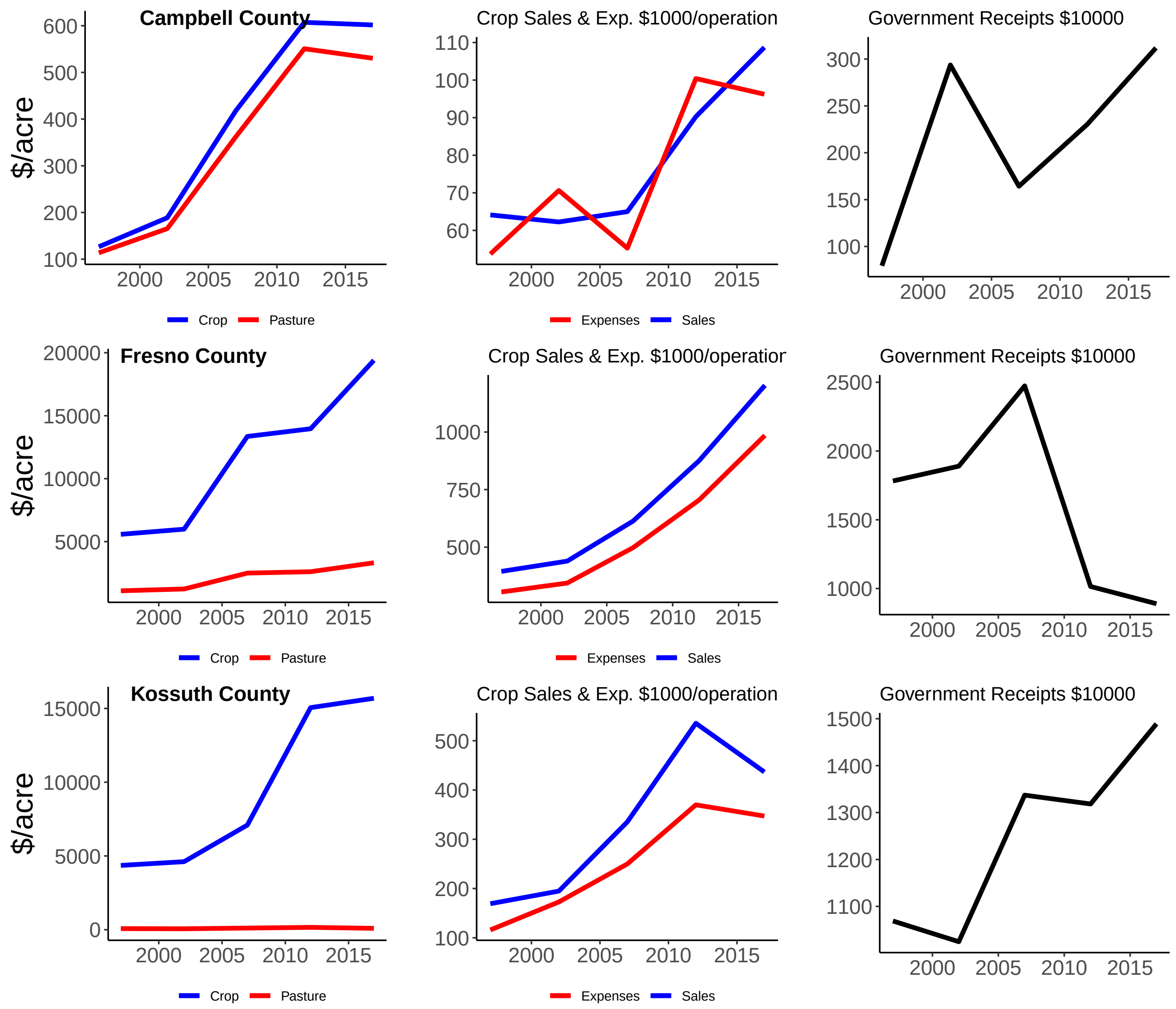

Figure 5

Source: NASS 2022

Note: Campbell, Wyoming > 96% of all Ag land in pasture according to 2017 Census. Fresno County, California 69% of Ag land in crops with greater than 70% of sales from crops. Kossuth County, Iowa 96% of Ag land in crops.