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The Impact of Agricultural Subsidies on the Corn Market with Farm Heterogeneity and Endogenous Entry and Exit

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We develop a model with farm-level heterogeneity in productivity and endogenous entry and exit decisions to analyze the effect of price supports and direct payments on the U.S. corn market. The analytical results show that, contrary to the existing literature, removal of direct payments augments productivity while removal of price supports does not impact productivity, and direct payments can lead to larger production distortions than price supports under certain conditions. The simulation results corroborate the theoretical findings in that if both policies are equal in magnitude, then direct payments result in larger price, output, and welfare distortions than price supports.

Key words: corn, coupled subsidies, decoupled payments, entry and exit, heterogeneity

Introduction

Over the last three decades, U.S. and European farm programs have changed to include significant decoupled policies (Environmental Working Group, 2013). These policy changes not only impact farms' scale of production and input mix but, due to the heterogeneous nature of farm productivity, they also influence operating decisions, such as whether farmers produce corn, produce other crops, or exit farming. This paper analyzes the impact of corn policy changes on production, input use, prices, productivity, and welfare by incorporating the endogenous entry and exit decisions of heterogeneous farms, which allows for both within- and across-farm reallocation of resources.

The Uruguay Round negotiations, which began in the mid-1980s, were contentious and prolonged because agriculture and its coupled policies were brought into the global trade agreement for the first time. The major disagreement was over reducing farm price supports, which augment production and distort both domestic and international markets. Consequently, during the course of the negotiations of the Uruguay Round Agreement on Agriculture (URAA), policy makers in the United States and the European Union had the ingenuity to curtail price-distorting policies yet continue to subsidize agriculture by developing a new farm support program: income supports (OECD, 2001). Since income supports—direct payments in the form of lump-sum transfers—were independent of commodity production, the term "decoupled subsidies" was coined to refer to direct income payments that supposedly do not distort production and prices. On the basis of these arguments, policy makers expanded farm program expenditure on decoupled payments after the URAA (OECD, 2001).

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The U.S. farm program's emphasis on decoupled payments starting in the early 1990s continued through several farm bills. Though the 2014 Farm Bill focuses on crop insurance, the Price Loss Coverage policy, which is similar to the Countercyclical Payment Program, operates as decoupled subsidies, as payments are based on base acres of the covered commodity. Moreover, since the 2003 Common Agricultural Policy, the European Union continues to heavily subsidize farmers using direct payments, which are not based on the volume of output, under the Single Payment Scheme (Ciaian, Kancs, and Swinnen, 2014). Thus, it is worth studying whether decoupled subsidies are more distortive—in terms of prices, output, productivity, and net welfare measures—than price-support policies.

Earlier studies found that decoupled payments had no impact on production (Burfisher and Hopkins, 2003). However, a review paper by Bhaskar and Beghin (2009) highlighted the fact that decoupled payments could distort production through the five channels: risk and wealth, credit constraints, labor-leisure decisions, land value capitalization, and farmers' expectations. Studies that examined the risk and wealth channel have shown that income-support policies augment input choices and output supply of a risk-averse farmer with stochastic production because of wealth and insurance effects (Hennessy, 1998; Young and Westcott, 2000; Antón and Mouël, 2004; Serra et al., 2005; Sckokai and Moro, 2006; Femenia, Gohin, and Carpentier, 2010). Research on the credit constraint channel has observed that direct payments influence farmers' saving patterns, giving them better access to credit and enhancing their investment decisions and production in the short run (Roe et al., 2003). Papers that studied the labor-leisure channel have shown that income supports influence labor-leisure decisions, off-farm employment, and thus production (El-Osta, Mishra, and Ahearn, 2004; Ahearn, El-Osta, and Dewbre, 2006). Studies that examined the land value capitalization channel have concluded that income from decoupled subsidies increases land values and rents; land consequently remains in agriculture longer than is optimal, which can expand production (Schertz and Johnston, 1998; Dewbre, Antón, and Thompton, 2001; Roberts, Kirwan, and Hopkins, 2003).[1] Studies that analyzed the expectation channel have found that the anticipatory adjustments based on farmers' expectation of size and timing of policy implementation impact the debt-to-asset ratio and, ultimately, production (Lagerkvist and Olson, 2002; Sumner, 2003; Coble, Miller, and Hudson, 2008).

Chau and de Gorter (2005) were the first to show that decoupled subsidies help farmers withstand losses and help marginal farms keep operating instead of exiting. They also concluded that the effect of income supports on aggregate output could be minimal only if the output of marginal farms is small.

One channel that has not been examined in the farm policy literature is how farm programs, both price supports and direct payments, impact farmers' input use and output supply when farms differ widely in productivity (i.e., farms are heterogeneous). For example, U.S. corn farms differ widely in terms of productivity and thus in cost of production. These productivity differences arise from differences in land quality, pest and disease proneness, systematic weather patterns, and also managerial skills. Foreman (2006) provides strong evidence of this heterogeneity among corn farms by highlighting its effect on cost of production with an illustration of a numerical cumulative distribution function of operating and ownership costs per bushel. The most productive 25% of corn farms have costs ranging from \$0.50 to \$1 per bushel, medium-productivity farms (which account for 50%) have costs ranging from \$1 to \$2 per bushel, and the least productive 25% of farms have production costs ranging from \$2 to \$5 per bushel.

Furthermore, increased mechanization and need for efficient production have caused the number of large corn farms with more than 500 acres to increase, while some farms with less than 500 acres have become unprofitable and exited the industry (U.S. Department of Agriculture, Economic Research Service, 2014a). The size of the average corn farm has increased from 200 acres in 1987 to 600 acres in 2007 (MacDonald, Korb, and Hoppe, 2013). Between 1996 and 2010, the percentage of

[1] Studies that analyzed land value capitalization in Europe found that the 2003 CAP reform, which moved toward a direct payment policy, increased land rents (Gohin, 2006; Ciaian and Kancs, 2012).

small corn farms (less than 250 acres) declined from 75% to 67%, whereas the percentage of large corn farms (greater than 750 acres) increased from 4% to 9% (Foreman, 2001, 2014). Because of the exit of the small and marginal farms and entry of large farms, resources such as land and machinery have been reallocated among these farms. For instance, between 1996 and 2010, the percentage of corn acres in small farms fell from 32% to 21% and, in contrast, the percentage of corn acres in large farms rose from 18% to 40%. Thus, from a policy standpoint, it is useful to model the response of farms with different productivity levels to changes in price support and direct payment policies.

We consider corn because it is the leading U.S. agricultural commodity, with 97.4 million acres planted and \$62.7 billion in production value in 2013 (U.S. Department of Agriculture, National Agricultural Statistics Service, 2014). Of the roughly 2.2 million farms in the United States, about 430,000 grow corn (U.S. Department of Agriculture, 2014). In 2001, about 87% of all corn farmers received government support, which averaged \$26,000 per farm (Foreman, 2006). Total price support payments to corn farms averaged \$1.52 billion over 2003–2007,[2] and total direct payments averaged \$2.84 billion over 2003–2010 (U.S. Department of Agriculture, Farm Service Agency, 2014).

The objectives of this study are to 1) develop a model with farm-level heterogeneity in productivity and endogenous entry and exit, 2) analytically show how both price supports and direct payments affect input use, output supply, prices, number of farms, productivity, and operating decisions, and 3) calibrate the model to the U.S. corn market and quantify through simulation the effects of price supports and direct payments on the endogenous variables identified in objective 2.

We contribute to the literature by analyzing a previously unexplored new link by explicitly modeling the heterogeneous nature of farm productivity to examine how various farm policies influence farmers' decisions to produce. In our model, the removal of direct payments causes inefficient farms to exit, leading to a reallocation of resources from low- to high-productivity farms and a gain in productivity. Through this inter-farm resource reallocation, direct payments influence input choice and thus output. However, removing price supports does not alter the minimum productivity level required to operate. Thus, inter-farm resource reallocation does not occur, leaving productivity unchanged. Consequently, price supports influence output only through intra-farm input use. As a result, the income-support policy can lead to more distortionary effects than the price-support policy, which is in contrast to the theoretical findings by previous studies in this literature. Both policies impact the measure of operating farms in corn production through farm profitability.

The quantitative findings indicate that decoupled payments impact production, prices, and welfare more than price supports. The results also confirm that these policies have contributed to the entry and exit decisions, resource reallocations, and changes in farm sizes observed in the data over the last few decades.

Model and Analysis

We draw upon the seminal work of Hopenhayn (1992)—who laid the foundation for endogenous production decisions of heterogeneous firms in an industry—to formulate a model of farms under perfect competition with different productivity levels and entry and exit decisions to analyze how these farms respond to policy shocks.

Consider a farm with productivity level z that uses a composite input $x(z)$ to produce corn $y(z)$. For analytical tractability, we consider a single composite input; however, in the numerical analysis we disaggregate this composite input into capital, labor, intermediate inputs, and land to model a more realistic corn production process. This farm chooses the level of composite input $x(z)$ to produce $y(x;z)$ by maximizing profits

$$\pi(z) = \max_{x(z)} \left((1+\sigma_y)py(x;z) - wx(z) - f_o + \sigma_d\right) \quad (1)$$

[2] Note that various price support payments ended after 2007.

subject to the technology constraint

$$y(x;z) = z^{1-\nu}x(z)^{\nu}. \tag{2}$$

Here σ_y is the price support or output subsidy, p is the corn price, $\nu \in (0,1)$ is firm-level returns to scale, w is the input price, f_o is the fixed operating cost which reflects the opportunity cost of producing other crops, and σ_d are additional decoupled payments accrued in the long run for updating the historical corn base acreage.[3]

A farm operates in corn production if it earns nonnegative profits; otherwise it exits corn production and switches to another crop. This farm will continue to receive direct payments for the current base acreage. The cutoff-productivity level, $\bar{z}$, at which a farm is willing to operate satisfies

$$\pi(\bar{z}) = 0. \tag{3}$$

Thus, the marginal corn farm earns zero profits, while farms with productivity greater than $\bar{z}$ earn positive profits.

To enter corn farming, a farmer incurs a fixed entry cost, f_e, to draw a productivity from the probability distribution $G(\cdot)$. The random draw of this productivity reflects the differences in land quality, weather conditions, pest and disease, and managerial skill. As a result of arbitrage, expected profit from entry must equal the fixed cost of entry:

$$\int_{\bar{z}}^{\infty} \pi(z)dG(z) = f_e. \tag{4}$$

Before entering corn farming, a farmer must assemble and assess information on land availability and quality and average regional weather conditions, appraise the farm equipment requirements, secure bank loans, etc. The time and expenses involved in these activities reflect the opportunity cost as captured by the entry fee f_e. All of this research and assessment must take place before a farmer fully realizes the true land productivity and capability as a manager. Thus, while farmers do not know their productivity before incurring f_e, they do realize their productivity after paying f_e and then decide whether or not to operate (i.e., produce corn) as per equation (3). Thus, farmers make production decisions only after knowing their productivity levels, which is consistent with Hopenhayn's (1992) framework and provides a theoretically sound and tractable method of randomly assigning productivity levels to entrants. Given that Foreman (2006) has provided substantial evidence of significant heterogeneity in corn farming, this is an appropriate method to conduct policy analysis for heterogeneous corn farms.

We assume that productivity draws follow a Pareto distribution, so $dG(z) = \psi\omega^{\psi}z^{-\psi-1}dz$, where the location parameter ω is such that $0 < \omega \leqslant z$ and the shape parameter satisfies $\psi > 1$ for a finite mean (also see Buera, Moll, and Shin, 2013). The Pareto distribution, in addition to allowing for analytical solutions, is consistent with size distribution data where only a small proportion of producers are large and highly productive.

Clearing in the input market requires that

$$m\int_{\bar{z}}^{\infty} x(z)dG(z) = Bw^{\theta}, \tag{5}$$

where the left side is aggregate input demand for corn production and the right side is the input supply function. Here m is the total measure (or mass) of farms, $B > 0$ is the scale parameter for the input supply function, and $\theta > 0$ is the input supply elasticity. The right side of equation (5), $m\int_{\bar{z}}^{\infty} x(z)dG(z)$, denotes aggregate input demand, which is equal to the total mass of farms times the input demand of operating farms in corn production; because the integration is from $\bar{z}$ to ∞, the farms

[3] We thank the editor Jeffrey Peterson for the clarity on the interpretation of the fixed operating cost and the decoupled subsidy.

that are not operating in corn production are excluded. Observe that productivity is drawn from the entire distribution but farms with $z < \bar{z}$ do not produce corn. Mathematically, the mass of farms with productivity below $\bar{z}$ is multiplied with zero input demand, or, equivalently, farms with productivity below $\bar{z}$ are given zero weight in the integration. Finally, clearing in the output market requires that

$$Ap^{-\phi} = m\int_{\bar{z}}^{\infty} y(z)dG(z), \tag{6}$$

where the left side of the equation is the corn demand function and the right side is aggregate corn supply. Here $A > 0$ is the scale parameter of the demand function and $-\phi < 0$ is the demand elasticity. The interpretation of integration from $\bar{z}$ to ∞ is similar to that discussed above for input demand.

Equilibrium Values of Endogenous Variables

In this subsection, we solve for the equilibrium of the above model. Taking prices as given, profit maximization implies that an operating corn farm with productivity z chooses an input quantity of

$$x(z) = \left(\frac{\nu p(1+\sigma_y)}{w}\right)^{\frac{1}{1-\nu}} z. \tag{7}$$

This, in turn, can be used to solve for the output and profit functions. We can then solve for four endogenous variables—p, m, w, and $\bar{z}$—using the system of four equations (3)–(6). To simplify the notation in the following expressions, we let $\Gamma_1,\ldots,\Gamma_7$ denote positive constants that do not depend on policy parameters (we specify the values of these constants in the appendix). In terms of parameters, the equilibrium output price, measure of farms, input price, and cutoff-productivity level are, respectively,

$$p = (1+\sigma_y)^{\frac{\theta+1-\nu}{\nu(1-\phi)-(1+\theta)}} (f_o - \sigma_d)^{-\frac{(1+\theta)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}} \Gamma_1 \tag{8}$$

$$m = (1+\sigma_y)^{\frac{-(1+\theta)\phi}{\nu(1-\phi)-(1+\theta)}} (f_o - \sigma_d)^{-\frac{(1+\theta)(1-\nu)(1-\phi)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}} \Gamma_2 \tag{9}$$

$$w = (1+\sigma_y)^{\frac{-\phi}{\nu(1-\phi)-(1+\theta)}} (f_o - \sigma_d)^{-\frac{(1-\phi)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}} \Gamma_3 \tag{10}$$

$$\bar{z} = \omega\left(\frac{f_o - \sigma_d}{(\psi-1)f_e}\right)^{1/\psi}. \tag{11}$$

Notice that the cutoff-productivity level depends only on σ_d and not on price supports, σ_y. Under perfect competition, for the marginal farm with productivity $\bar{z}$, total revenues, including price support payments, cover input expenditures and the fixed cost. Consequently, to maintain the zero profit, the cutoff-productivity level for the marginal farm is not impacted by σ_y.[4]

[4] For the marginal farm with a homogeneous of degree ν production function $F(x;\bar{z})$, from Euler's theorem, $\nu F(x;\bar{z}) = F_x(x;\bar{z})x$. Multiply both sides by $(1+\sigma_y)p$ to obtain

$$(1+\sigma_y)p\nu F(x;\bar{z}) - (1+\sigma_y)pF_x(x;\bar{z})x = 0.$$

Since the marginal value product is equal to input price, it follows that

$$(1+\sigma_y)p\nu F(x;\bar{z}) - wx = 0.$$

Thus, changes in output price inclusive of the price support are fully reflected in w. The net revenue (after payments to inputs) is used to cover the fixed cost:

$$(1+\sigma_y)p(1-\nu)F(x;\bar{z}) = f_o - \sigma_d.$$

Aggregation and Productivity

In order to define total factor productivity (TFP), we specify aggregate output as a function of aggregate input use and the measure of operating corn farms. Aggregating across producers, we obtain total input use,

$$
\begin{aligned}
X &= m\int_{\bar{z}}^{\infty} x(z)dG(z) \\
&= (1+\sigma_y)^{\frac{-\theta\phi}{\nu(1-\phi)-(1+\theta)}}(f_o-\sigma_d)^{\frac{-\theta(1-\nu)(1-\phi)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}}\Gamma_4,
\end{aligned} \tag{12}
$$

and aggregate corn production,

$$
\begin{aligned}
Y &= m\int_{\bar{z}}^{\infty} z^{1-\nu}x(z)^{\nu}dG(z) \\
&= (1+\sigma_y)^{\frac{-(1+\theta-\nu)\phi}{\nu(1-\phi)-(1+\theta)}}(f_o-\sigma_d)^{\frac{\phi(1+\theta)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}}\Gamma_5.
\end{aligned} \tag{13}
$$

The measure of farms that choose to operate is

$$\bar{m} = m(1-G(\bar{z})). \tag{14}$$

Thus, m is the measure of farmers that pay the fixed cost to enter corn farming, while $\bar{m}$ is the measure of farmers that choose to produce corn. The difference, $m-\bar{m}$, is the mass of farmers potentially engaged in other crop production but who can still enter corn production if $\bar{z}$ decreases without incurring the entry fee, f_e, again. In contrast, a decline in m implies that farmers completely exit farming. Thus, a change in m refers to long-run entry into and exit from farming, while changes in $\bar{m}$ refer to entry into and exit from corn production.[5] Using m from equation (9) and $\bar{z}$ from equation (11), we get

$$\bar{m} = (1+\sigma_y)^{\frac{-(1+\theta)\phi}{\nu(1-\phi)-(1+\theta)}}(f_o-\sigma_d)^{\frac{-(1+\theta)(1-\nu)(1-\phi)(\psi-1)-\psi(\nu(1-\phi)-(1+\theta))}{\psi(\nu(1-\phi)-(1+\theta))}}\Gamma_6. \tag{15}$$

We can then express aggregate output in equation (13) as

$$Y = ZX^{\nu}\bar{m}^{1-\nu}, \tag{16}$$

where

$$Z = \left(\frac{\int_{\bar{z}}^{\infty} zdG(z)}{1-G(\bar{z})}\right)^{1-\nu} \tag{17}$$

is aggregate TFP, which is a weighted average of operating corn farms' productivities. As evident from the above equation, TFP depends only on the productivity cutoff $\bar{z}$; thus, similar to $\bar{z}$ in equation

Summing the previous two equations, we see that total revenue covers variable input expenditures and fixed cost:

$$(1+\sigma_y)\,pF(x;\bar{z}) - wx - f_o + \sigma_d = 0.$$

The above equation states that, for the marginal farm, total revenue is equal to variable input expenditure and fixed cost, implying profit is zero. Note that σ_d does not have a link to the input price as does σ_y in equation $[(1+\sigma_y)\,p\nu F(x;\bar{z}) - wx = 0]$. Consequently, w does not adjust to σ_d as it does to σ_y, and thus there is no offsetting effect on w. As a result, σ_d does exert influence on profits of the marginal farm, and thus on $\bar{z}$.

[5] Because f_o captures the opportunity cost of other endeavors net of direct payments, σ_d, corn farmers with productivity below $\bar{z}$ find it unprofitable, $\pi(z) < \pi(\bar{z})$, and switch to another crop but continue to receive σ_d on their base acres. However, if market conditions change such that m declines, then farmers exit the farm sector and do not receive σ_d.

(11), Z does not depend on the price support. In equilibrium,

$$(18)\qquad Z = (f_o - \sigma_d)^{\frac{1-\nu}{\psi}} \left(\frac{\omega\psi}{\left((\psi-1)^{1+\psi} f_e\right)^{1/\psi}} \right)^{1-\nu}.$$

Comparative Statics

We analyze comparative static results for the above eight equilibrium variables (p, w, m, $\bar{z}$, X, Y, $\bar{m}$, and Z) in equations (8)–(13), (15), and (18) for changes in subsidies. Since comparative static results of the equilibrium variables are partial derivatives of these equations with respect to σ_y and σ_d, the directional effects depend only on the sign of the exponent on $(1+\sigma_y)$ and the negative of the sign of the exponent on $(f_o - \sigma_d)$ because all other terms in the above equations are positive.

The comparative statics are mostly intuitive. Essentially, our model can be thought of as providing microeconomic foundations for an industry supply curve, which we can express as

$$(19)\qquad Y(p) = (p(1+\sigma_y))^{\frac{\theta+1-\nu}{\nu}} (f_o - \sigma_d)^{\frac{-(1+\theta)(1-\nu)(\psi-1)}{\nu\psi}} \Gamma_7.$$

A decrease in either subsidy has the same qualitative effect on the supply curve, causing it to shift to the left. Since the demand curve is fixed, a leftward shift in the supply curve causes the equilibrium quantity to decrease and the equilibrium price to increase. While the signs of the impacts of each subsidy on Y and p are the same, the magnitudes differ. Note that the term $\nu(1-\phi)-(\theta+1)$ in the denominator in the following comparative static results is negative irrespective of the magnitudes of $\phi > 0$ and $\theta > 0$:

$$(20)\qquad \text{sign}\left(\frac{\partial Y}{\partial \sigma_y}\right) = \text{sign}\left(\frac{-\phi(\theta+1-\nu)}{\nu(1-\phi)-(1+\theta)}\right) > 0$$

$$(21)\qquad \text{sign}\left(\frac{\partial p}{\partial \sigma_y}\right) = \text{sign}\left(\frac{\theta+1-\nu}{\nu(1-\phi)-(1+\theta)}\right) < 0$$

$$(22)\qquad \text{sign}\left(\frac{\partial Y}{\partial \sigma_d}\right) = \text{sign}\left(\frac{-\phi(1+\theta)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}\right) > 0$$

$$(23)\qquad \text{sign}\left(\frac{\partial p}{\partial \sigma_d}\right) = \text{sign}\left(\frac{(1+\theta)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}\right) < 0.$$

Next we examine the changes in revenue with respect to changes in σ_y and σ_d:

$$(24)\qquad \text{sign}\left(\frac{\partial(pY)}{\partial \sigma_y}\right) = \text{sign}\left(\frac{(1-\phi)(\theta+1-\nu)}{\nu(1-\phi)-(1+\theta)}\right) \gtrless 0 \text{ if } \phi \gtrless 1$$

$$(25)\qquad \text{sign}\left(\frac{\partial(pY)}{\partial \sigma_d}\right) = \text{sign}\left(\frac{(1-\phi)(1+\theta)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}\right) \gtrless 0 \text{ if } \phi \gtrless 1.$$

Notice that, as one would expect, the change in revenue depends on whether demand is elastic $(\phi > 1)$ or inelastic $(\phi < 1)$. With respect to the price support, the change in revenue including the price support is of greater interest because a decrease in the price support causes post-price-support revenue to fall regardless of whether demand is elastic or inelastic:

$$(26)\qquad \text{sign}\left(\frac{\partial((1+\sigma_y)pY)}{\partial \sigma_y}\right) = \text{sign}\left(\frac{-(1+\theta)\phi}{\nu(1-\phi)-(1+\theta)}\right) > 0.$$

Given our choice of a Cobb-Douglas production function, expenditure on inputs is fraction ν of a farm's post-price-support revenue (see footnote 4). Since the supply curve for inputs does not change, a shift in the demand curve for inputs has the same *qualitative* effect on the equilibrium input price and quantity as revenue changes in equations (25) and (26). Consistent with the results on post-price-support revenue above, for a change in the price support, we have

$$\text{(27)} \qquad \operatorname{sign}\left(\frac{\partial X}{\partial \sigma_y}\right) = \operatorname{sign}\left(\frac{-\theta\phi}{\nu(1-\phi)-(1+\theta)}\right) > 0$$

$$\text{(28)} \qquad \operatorname{sign}\left(\frac{\partial w}{\partial \sigma_y}\right) = \operatorname{sign}\left(\frac{-\phi}{\nu(1-\phi)-(1+\theta)}\right) > 0.$$

For a change in the decoupled subsidy, we have

$$\text{(29)} \qquad \operatorname{sign}\left(\frac{\partial X}{\partial \sigma_d}\right) = \operatorname{sign}\left(\frac{\theta(1-\phi)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}\right) \gtreqless 0 \text{ if } \phi \gtreqless 1$$

$$\text{(30)} \qquad \operatorname{sign}\left(\frac{\partial w}{\partial \sigma_d}\right) = \operatorname{sign}\left(\frac{(1-\phi)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}\right) \gtreqless 0 \text{ if } \phi \gtreqless 1.$$

Next we consider the effect of each subsidy on the cutoff productivity and aggregate TFP:

$$\text{(31)} \qquad \frac{\partial \bar{z}}{\partial \sigma_y} = \frac{\partial Z}{\partial \sigma_y} = 0.$$

Our results here run contrary to conventional wisdom about the effects of coupled versus decoupled subsidies. For given prices, a decrease in the price support clearly raises the productivity cutoff of operating farms in corn prodution. However, a decrease in the output price inclusive of the price support is exactly offset by changes in input price, leaving the marginal farm's profits unchanged (see the discussion in footnote 4). Thus the cutoff-productivity level and industry TFP remain unchanged.

By contrast, a decrease in decoupled subsidies has a direct effect on the cutoff-productivity level, which is not fully offset by changes in equilibrium prices:

$$\text{(32)} \qquad \operatorname{sign}\left(\frac{\partial \bar{z}}{\partial \sigma_d}\right) = \operatorname{sign}\left(-\frac{1}{\psi}\right) < 0.$$

This then affects TFP:

$$\text{(33)} \qquad \operatorname{sign}\left(\frac{\partial Z}{\partial \sigma_d}\right) = \operatorname{sign}\left(-\frac{1-\nu}{\psi}\right) < 0.$$

Finally, consider the effects on the measures of entrants in the farm sector and operating corn farms. Variable profits make up fraction $1-\nu$ of post-price-support revenue. Note that the no-arbitrage condition implies that industry net profits must equal industry fixed costs of operating and entry net of decoupled subsidies:

$$\text{(34)} \qquad (1-\nu)(1+\sigma_y)pY = m[f_e + (1-G(\bar{z}))(f_o - \sigma_d)].$$

For a decrease in the price support, the productivity cutoff does not change and therefore, as can be seen from the above equation, the change in the measure of entrants into farming or measure of operating corn farms matches the sign on post-price-support revenue:

$$\text{(35)} \qquad \operatorname{sign}\left(\frac{\partial m}{\partial \sigma_y}\right) = \operatorname{sign}\left(\frac{\partial \bar{m}}{\partial \sigma_y}\right) = \operatorname{sign}\left(\frac{-\phi(1+\theta)}{\nu(1-\phi)-(1+\theta)}\right) > 0.$$

On the other hand, for decoupled subsidies, the change in the measure of entrants into farming depends on the elasticity of demand:

$$\text{sign}\left(\frac{\partial m}{\partial \sigma_d}\right) = \text{sign}\left(\frac{(1+\theta)(1-\phi)(1-\nu)(\psi-1)}{\psi(\nu(1-\phi)-(1+\theta))}\right) \gtrless 0 \text{ if } \phi \gtrless 1. \tag{36}$$

But the change in cutoff productivity ensures that the measure of operating corn farms decreases as σ_d declines:

$$\text{sign}\left(\frac{\partial \bar{m}}{\partial \sigma_d}\right) = \text{sign}\left(\frac{(1+\theta)(1-\nu)(1-\phi)(\psi-1)+\psi(\nu(1-\phi)-(1+\theta))}{\psi(\nu(1-\phi)-(1+\theta))}\right) > 0. \tag{37}$$

Two points are worthy of note. First, changes in $\bar{z}$ do not indicate entry or exit; rather, $\bar{z}$ only defines the productivity level at which profits are zero. Second, changes in m explicitly capture entry decisions into farming and $\bar{m}$ reflects operating and exit decisions of corn farms. The link between $\bar{z}$ and entry and operating decisions is given by $\bar{m} = m(1-G(\bar{z}))$.

Given the above results, we can now intuitively discuss the simultaneous elimination of both subsidies without presenting the comparative static equations. For output, price, and operating corn farms, the effects of eliminating both price supports and direct payments reinforce each other, leading to a decline in Y, an increase in p, and a decrease in $\bar{m}$. Because price supports do not impact the cutoff-productivity level and TFP, the increase in $\bar{z}$ and Z is attributed only to direct payments reduction. For input quantity and price and the measure of total farms, the effects of price supports and direct payments operate in opposite directions when commodity demand is inelastic. Consequently, the analytical results for the total effects of simultaneous elimination of both policies are ambiguous. However, our numerical analysis shows that the quantitative effects of decoupled subsidies dominate price supports.

Which subsidy has a greater effect on output? To answer this question, we start from a no-support situation and consider a hypothetical case where there is an equal change in government spending on each subsidy, so $p^*Y^*\partial\sigma_y = \bar{m}^*\partial\sigma_d$, where an asterisk denotes an initial equilibrium value. Then the difference between the effect of price supports versus direct payments on output can be expressed as

$$\frac{\partial Y}{p^*Y^*\partial\sigma_y} - \frac{\partial Y}{\bar{m}^*\partial\sigma_d} = \tag{38}$$

$$\Theta\left[(1-\nu+\theta)\,\psi^{\frac{-\nu}{\nu(1-\phi)-(1+\theta)}}\,\omega^{\frac{-\nu\psi}{\nu(1-\phi)-(1+\theta)}} - (1+\theta)\,f_e^{\frac{-(1+\theta)(-1+\nu+\nu\psi)}{\psi(\nu(1-\phi)-(1+\theta))}}\right],$$

where $\Theta > 0$. If the price support is more (less) distortive than direct payments, then the above equation is positive (negative). Femenia, Gohin, and Carpentier (2010) present a similar analysis and find that price supports have a greater influence on output and prices than decoupled payments. By contrast, the sign of the above equation is ambiguous. The sign does, however, depend crucially on the magnitude of the fixed cost of entry, f_e. Since the exponent on f_e is negative, the sign of equation (39) is positive for sufficiently large values of f_e and negative for sufficiently small values. When f_e is small, it is easier for farmers to enter into corn production, which attracts more inefficient farmers and causes greater distortion. Moreover, our numerical results indicate that decoupled subsidies have a larger effect than price supports on output.

Welfare Analysis

To analyze the distortive effects of price supports and decoupled payments, we calculate producer surplus, consumer surplus, and government cost. Producer surplus, PS, is equal to total revenue, TR, minus total variable cost, TVC:

$$PS = TR - TVC. \tag{39}$$

Consumer surplus, CS, is the area below the demand curve and above the equilibrium price:

$$CS = \int_{p}^{\infty} A\tilde{p}^{-\phi} d\tilde{p}. \tag{40}$$

Government cost, GC, is expenditure on subsidies:

$$GC = pY\sigma_y + \bar{m}\sigma_d. \tag{41}$$

In the policy experiments below, we calculate the changes in producer surplus (ΔPS), changes in consumer surplus (ΔCS), and changes in government cost (ΔGC). The net change in welfare is then given by $NW = \Delta PS + \Delta CS - \Delta GC$.

Quantitative Analysis

In this section, we calibrate the model to the U.S. corn market and quantify the impact of the removal of price supports and direct payments on endogenous variables. We calibrate the model with both price supports and decoupled subsidies in place and run the baseline simulation. We then consider three alternate scenarios: removal of the price support, removal of the decoupled payment, and removal of both subsidies. Finally, we consider the case where both policies account for an equal share of the value of production to analyze whether price supports or direct payments are more distortive.

Model with Multiple Inputs

For our numerical analysis, we extend the theoretical model by including four inputs instead of one composite input. In this extended model, a farm with productivity z chooses capital $k(z)$, labor $l(z)$, intermediate inputs $x(z)$,[6] and land $h(z)$ to maximize profits:

$$\pi(z) = (1+\sigma_y)py(z) - rk(z) - wl(z) - qx(z) - sh(z) - f_o + \sigma_d, \tag{42}$$

subject to the technology constraint

$$y(z) = z^{1-\nu}\left(k(z)^{\alpha_1} l(z)^{\alpha_2} x(z)^{\alpha_3} h(z)^{1-\alpha_1-\alpha_2-\alpha_3}\right)^{\nu}. \tag{43}$$

The market-clearing conditions for the inputs are:

$$m\int_{\bar{z}}^{\infty} k(z)dG(z) = B^k r^{\theta^k} \tag{44}$$

$$m\int_{\bar{z}}^{\infty} l(z)dG(z) = B^l w^{\theta^l} \tag{45}$$

$$m\int_{\bar{z}}^{\infty} x(z)dG(z) = B^x q^{\theta^x} \tag{46}$$

$$m\int_{\bar{z}}^{\infty} h(z)dG(z) = B^h s^{\theta^h}, \tag{47}$$

where the left side of each equation is the supply function and the right side is aggregate demand by farms. The zero-cutoff-profit (equation 3), no-arbitrage (equation 4), and output-market-clearing (equation 6) conditions remain the same.

[6] Note that the variable $x(z)$ is used now to denote the intermediate input rather that the composite input used in the model with one input.

Our calculation of TFP must now take into account the four aggregate inputs (K, L, X, and H). After aggregating across operating corn farms, we can express total output as

$$Y = Z(K^{\alpha_1}L^{\alpha_2}X^{\alpha_3}H^{1-\alpha_1-\alpha_2-\alpha_3})^{\nu}\bar{m}^{1-\nu}, \tag{48}$$

where Z is TFP as defined in equation (17). We can then decompose changes in output arising from changes in TFP, each of the four inputs, and the measure of operating corn farms by totally differentiating the log of equation (48):

$$\begin{aligned} d\log Y &= d\log Z + \nu\alpha_1 d\log K + \nu\alpha_2 d\log L + \nu\alpha_3 d\log X \\ &\quad + \nu(1-\alpha_1-\alpha_2-\alpha_3)\, d\log H + (1-\nu) d\log \bar{m}. \end{aligned} \tag{49}$$

Calibration

For the numerical analysis, the parameter values for returns to scale (ν), input supply elasticities (θ^i where $i = k, l, x$, and h), and corn demand elasticity (ϕ) were obtained from the literature. We follow Capalbo (1988) and Luh and Stefanou (1991) in setting $\nu = 0.8$. Based on the studies reviewed in Devadoss and Luckstead (2008), labor supply elasticities average about 0.37, which we use in our simulation. According to Gardner (1979) and Barr et al. (2011), acreage response elasticities range from 0.01 to 0.1. We use 0.1 in our simulation. Edgerton (2011) reports that the elasticity of supply for farm machinery is around 3, which we employ in our simulation. The corn elasticity found in the literature varies considerably from -0.50 for feed (Skold and Westhoff, 1988), -0.51 for input use in biofuel production (Baier et al., 2009), and -1.11 for exports (Reimer, Zheng, and Gehlhar, 2012). Based on these studies, we use corn demand elasticity of -0.6 in our simulation.

Next we explain the calibration process for the remaining parameters (α_1, α_2, α_3, σ_y, σ_d, ψ, ω, f_o, f_e, A, B_i, where $i = k$, l, x, and h) using data for U.S. corn production. We choose parameters to match the average over 2003–2007 corn price of \$2.74 per bushel and corn production of 11.33 billion bushels, which is the sum of domestic demand and net exports (U.S. Department of Agriculture, Economic Research Service, 2014b). Instead of estimating input prices, we normalize units for inputs so that all input prices initially equal one. We then calibrate input expenditure shares—α_1, α_2, and α_3—to match data from Foreman (2014). We categorize costs as follows. Capital expenditure consists of capital recovery, machinery, and equipment; interest on operating capital; and repairs. Labor expenditure consists of hired labor and the opportunity cost of unpaid labor. Intermediate input expenditure consists of seed, fertilizer, soil conditioners, manure, chemicals, custom operations, and fuel, lube, and electricity. Land expenditure is the opportunity cost of land. Input expenditure shares are then 0.207 for capital, 0.050 for labor, 0.501 for intermediates, and 0.243 for land.

Now we discuss the calibration of the policy parameters, σ_y and σ_d. According to the U.S. Department of Agriculture, Farm Service Agency (2014), various price-support policies for FY 2003–2007—certificate gains of \$0.14 billion, loan deficiency payments of \$7.03 billion, and marketing loan write-offs of \$0.45 billion—totaled \$7.62 billion, or an average of \$1.52 billion per year. Since the average value of production is \$31.09 billion, the price support σ_y is 4.89% (100 $\times$ 1.52/31.09). For FY 2003–2007, decoupled subsidies—direct payments of \$10.46 billion and countercyclical payments of \$5.39 billion—totaled \$15.85 billion, or an average of \$3.17 billion per year. Assuming that 90% of entrants (discussed in the next paragraph) chose to operate (implying that $\bar{m} = 0.9$), $\sigma_d = \$3.17/0.9 = \$3.52$ billion.

The parameters f_o, ψ, and ω are calibrated to match three pieces of information from the data and to normalize the initial measure of farms to 1. First, we calibrate the shape parameter of the Pareto distribution so that the most productive 25% of farms produce 39% of output (Foreman, 2014), which yields $\psi = 3.77$. Second, since we do not have direct data on fixed costs of operating, we choose the fixed cost of operating $f_o = 7.82$ so that 90% of entrants choose to operate (our results

Table 1. Effect on Output Decomposition

Variable	Elimination of Price Supports	Elimination of Direct Payments	Elimination of Both Policies
$d\log Y$	−1.82%	−6.30%	−8.08%
$d\log Z$	0.00%	2.69%	2.69%
$\nu\alpha_1 d\log K$	−0.51%	0.32%	−0.17%
$\nu\alpha_2 d\log L$	−0.04%	0.03%	−0.02%
$\nu\alpha_3 d\log X$	−0.38%	0.24%	−0.13%
$\nu(1-\alpha_1-\alpha_2-\alpha_3)d\log H$	−0.07%	0.05%	−0.02%
$(1-\nu)d\log\bar{m}$	−0.82%	−9.62%	−10.43%

Table 2. Effects on Output and Input Prices, Total Farms, and Percentage of Operating Farms

Variable	Baseline Values	Elimination of Price Supports	Elimination of Direct Payments	Elimination of Both Policies
p	2.74	2.63%	9.41%	12.24%
r	1.00	−2.94%	1.93%	−1.01%
w	1.00	−1.02%	0.66%	−0.35%
q	1.00	−3.09%	2.03%	−1.07%
s	1.00	−3.64%	2.40%	−1.26%
m	1.00	−4.00%	2.65%	−1.39%
$1-G(\bar{z})$	90%	0.90%	0.54%	0.54%

Table 3. Welfare Impacts in $ Billion

Variable	Elimination of Price Supports	Elimination of Direct Payments	Elimination of Both Policies
ΔPS	−0.26	0.17	−0.09
ΔCS	−0.81	−2.83	−3.65
ΔGC	−1.67	−3.16	−4.72
NW	0.60	0.50	0.98

are not sensitive to this assumption, which is needed for the cutoff productivity for operating farms to bind). Third, we calibrate the scale parameter ω to 29.73 to match the average total corn production of 11.33 billion bushels.

Based on average corn price and quantity and the elasticity of demand, we calibrate the scale parameter of the demand function $A = 13.86$. With input prices normalized to one, the input supply scale parameters can be calibrated using revenue shares $B_i = \nu\alpha_i(1+\sigma_y)pY$, which gives $B_k = 5.58$, $B_l = 1.35$, $B_x = 13.50$, and $B_h = 6.52$. Given the above values, we set $f_e = [(1-\nu)(1+\sigma_y)pY - \bar{m}(f_o - \sigma_d)]/m = 1.78$ so that the no-arbitrage condition holds.

Elimination of Subsidies

This section presents the results of three policy experiments: elimination of price supports, direct payments, and both subsidies together. Table 1 reports the decomposition of the change in output based on equation (49). Table 2 presents the percentage changes in output and input prices, the total measure of farms, and the percentage of operating corn farms. Table 3 reports the welfare results.

Removal of Price Supports

Elimination of price supports causes farmers to cut their corn production by 1.82% (table 1). This decline in production is attributed to the fall in the measure of operating corn farms by 0.82%

and all input uses by a total of 1.00%, because TFP remains unchanged. Input use declines by 0.51% for capital, 0.04% for labor, 0.38% for intermediate inputs, and 0.07% for land. The fall in output supply causes the price of corn to rise by 2.63% (table 2). As demand for inputs falls, the capital rental rate, wage rate, intermediate input prices, and land rental rate decline by 2.94%, 1.02%, 3.09%, and 3.64%, respectively. For price support removal, the effect of the change in output price is transmitted to input prices, leaving profits unchanged for the marginal corn farm. Consequently, the cutoff productivity is not impacted, which has two key implications. First, as the cutoff-level productivity remains the same but aggregate output declines, both the total measure of farms and measure of operating corn farms decline (refer to equation 35). Also, as $\bar{z}$ does not change, the percentage of operating farms $(1 - G(\bar{z}))$ is also constant (see equation 14) at 90%, which implies that the percentage decline in the total measure of farms and measure of operating corn farms is equal to 4.00%. Second, since $\bar{z}$ is unchanged, TFP (Z) remains constant (see table 1).

Removal of price supports decreases producer price and production, which causes producer surplus to fall by \$260 million (table 3). A higher market price coupled with a reduction in consumption causes consumer surplus to decline by \$810 million. Elimination of price supports results in a savings of \$1.67 billion. Net welfare—which is the sum of changes in producer surplus, consumer surplus, and government cost savings—rises by \$600 million. This result underscores the efficiency gain from the elimination of distortive price-support policies.

Removal of Direct Payments

Since corn demand is inelastic (see the calibration subsection), the results presented below correspond to $\phi < 1$ in the comparative static analysis of direct payments. As corn farmers receive fewer government subsidies due to the elimination of decoupled payments, they respond by reducing output by 6.30% (see table 1). This reduction in production is attributed to a decline in the measure of operating farms by 9.62% as inefficient farms exit corn production. As only the more efficient corn farms remain in production, TFP increases by 2.69%. Input use increases because—as corn demand is inelastic—lower output and a higher corn price (see table 2) increase total revenues, which augments input demand. Consequently, input use positively contributes to output. However, the negative effect on operating corn farms outweighs the positive effects of TFP and input uses.

The decline in corn supply causes the output price to increase by 9.41%. As input use rises, the capital rental rate, wage rate, intermediate input price, and land rental rate increase by 1.93%, 0.66%, 2.03%, and 2.40%, respectively. Moreover, in response to higher revenues, the total measure of farms expands by 2.65%. However, marginal farms find it unprofitable to operate and thus exit corn production, which causes the cutoff-productivity level to increase, leading to a decrease in the share of corn farms that choose to operate $(1 - G(\bar{z}))$ from 90% to 54%. This result highlights the fact that decoupled subsidies keep inefficient corn farms in business.

Our findings of a gain in TFP and a decline in the percentage of corn farms that choose to operate are new insights in the farm policy literature. The main reasons for these results are that our model allows for productivity differences across farms and endogenous entry and exit decisions. Chau and de Gorter (2005) note that the effect of decoupled subsidies on output could be minimal if the output of exiting marginal farms is small, but their result only captures the effect of marginal farm exits and not the effects of resource reallocations across and within farms.

Elimination of direct payments has substantial welfare effects. The increase in the corn price is larger than the decrease in supply, leading to a producer surplus gain of \$170 million. With a higher corn price and a decrease in consumption, consumer surplus declines by \$2.83 billion. Elimination of decoupled subsidies results in government savings of \$3.16 billion. Net welfare rises by \$500 million, indicating an efficiency gain from the elimination of direct payments.

Table 4. Effects on Output Decomposition

Variable	Elimination of Equal Subsidies of Price Supports	Direct Payments
$d\log Y$	−3.56%	−5.94%
$d\log Z$	0.00%	2.55%
$\nu\alpha_1 d\log K$	−0.99%	0.32%
$\nu\alpha_2 d\log L$	−0.09%	0.03%
$\nu\alpha_3 d\log X$	−0.74%	0.24%
$\nu(1-\alpha_1-\alpha_2-\alpha_3)\, d\log H$	−0.14%	0.04%
$(1-\nu)d\log\bar{m}$	−1.60%	−9.12%

Table 5. Effects on Output and Input Prices, Total Farms, and Percentage of Operating Farms

Variable	Baseline Values	Elimination of Equal Subsidies of Price Supports	Direct Payments
p	2.74	5.22%	8.86%
r	1.00	−5.68%	1.88%
w	1.00	−1.98%	0.64%
q	1.00	−5.97%	1.98%
s	1.00	−7.02%	2.34%
m	1.00	−7.69%	2.58%
$1-G(\bar{z})$	90%	90%	56%

Removal of Both Subsidies

This subsection presents the results of a free-market policy aimed toward removing both price supports and direct payments. The effects of elimination of both policies reinforce each other in reducing corn supply by 8.08% (table 1) and increasing corn price by 12.24% (table 2). The fall in output is attributed to a decline of 10.43% in the measure of operating corn farms, which offsets the productivity increase of 2.69% and higher input use. The decrease in demand for all inputs causes input prices to fall. The effects of price supports on the total measure of farms outweigh those of direct payments, leading to a 1.39% decrease in the total measure of farms. Since price support changes do not impact the cutoff-productivity level, the decrease in the share of operating corn farms from 90% to 54% is due to the elimination of direct payments. The loss of producer surplus arising from the removal of price supports is greater than the gain in producer surplus from the elimination of decoupled subsidies, resulting in a loss of \$90 million. Since the elimination of both policies increases the corn price and reduces consumption, consumer surplus falls by \$3.65 billion. Removal of both policies leads to a saving of government expenditure of \$4.72 billion. The net welfare gain from moving to a free-market regime is \$980 million.

Equal-Size Subsidies

Are price supports or direct payments more distortive? To address this question, we consider equal subsidies on price supports and direct payments (i.e., expenditures on each policy equal 10% of the value of production, which is achieved with $\sigma_y = 10\%$ and $\sigma_d = \$3.45$ billion). In the baseline scenario, both subsidies are in place. In the first scenario, we remove the output subsidy but maintain the direct payments. In the second scenario, we eliminate the direct payments but retain the price supports. Table 4 reports the decomposition of the change in output based on equation (49). Table 5 presents the percentage changes in output and input prices, the total measure of farms, and the percentage of corn farms that choose to operate. Table 6 reports the welfare results.

From the comparison of the effects of the two scenarios, it is clearly evident that direct payments have larger impacts than price supports on output, productivity, output price, measure of operating

Table 6. Welfare Impacts in $ Billion

Variable	Elimination of Price Supports	Elimination of Direct Payments
ΔPS	−0.53	2.15
ΔCS	−1.59	−2.67
ΔGC	−3.35	−3.03
NW	1.23	2.50

corn farms, and welfare, indicating that decoupled subsidies are more distortive than price supports. Direct payments cause larger distortions than price subsidies because direct payments enter the profit function additively and thus implicitly lower the fixed cost. These findings highlight the result that marginal corn farms are helped more by decoupled subsidies than price supports. Furthermore, elimination of direct payments, in addition to reducing the output of inefficient marginal farms, also leads to resource reallocation from inefficient farms to more efficient farms. This augments aggregate productivity and also results in a producer surplus gain, in contrast to producer surplus loss from price support elimination. These findings underscore the fact that decoupled subsidies are more distortive than coupled subsidies. This is a key result that differs from that found in the farm policy literature, which concluded that, while direct payments do influence production decisions, the effects are often small (Bhaskar and Beghin, 2009) and price supports have larger production distortions than direct payments (Roe et al., 2003). Our findings are consistent with Gibson and Luckstead (2016), who used a dynamic general equilibrium model to show that direct payments have larger production distortions than price supports.

Finally, we conducted sensitivity analyses for different forms of the production function and input supply and output demand functions. The qualitative results do not change, and the quantitative results change only marginally in response to these sensitivity analyses. Thus, our results are robust to various functional forms, which are available in the online supplemental appendix.

Conclusion

In the 1980s and early 1990s, policy makers in the United States and European Union justified the introduction of direct payments by claiming that they do not impact output and prices. However, many studies have since shown that direct payments influence farmers' production decisions through several channels—risk and wealth, credit constraints, labor-leisure allocation, land value capitalization, and farmers' expectations. One other important channel that had not been explored in the farm policy literature is productivity differences among farms and endogenous entry and exit decisions. This study provides an in-depth theoretical analysis of the effects of both price supports and direct payments on output supply and price, input use and price, productivity, and the measure of farms by incorporating the heterogeneous nature of farm productivity and allowing for free entry and exit of farms. Modeling endogenous entry and exit allows us to capture the real-world phenomena of farms switching between corn and other crop production as well as farmers leaving production altogether. We use data for the U.S. corn market to quantify these effects. The numerical results corroborate the theoretical findings.

Our analytical results show that elimination of coupled payments curtails aggregate output; increases output price; and reduces input use, input prices, and the measure of operating corn farms. However, coupled payments do not impact the cutoff-productivity level and, as a result, TFP does not change. The removal of direct payments also reduces aggregate corn production, raises the corn price and total revenues, and leads to fewer operating corn farms. Higher total revenues causes the demand for aggregate input, input prices, and the measure of total farms to increase. Without decoupled payments, marginal farms find corn production to be unprofitable and exit corn farming. This increases the cutoff productivity, leading to a reallocation of resources from low- to high-productivity farms and augmenting aggregate TFP. This reflects the increase in farm size over the past several decades, with small and marginal farms exiting the industry and more productive and larger farms thriving. Specifically, the decline in direct payments (in 1997–2002 and again in 2003–2011) coincides with a decline in the number of small farms and an increase in the number of large farms (U.S. Department of Agriculture, Farm Service Agency, 2014). Thus, our study explains some of the patterns in farm exit and entry and the shifting of resources from small to large farms.

Our results show that direct income payments not only influence production decisions but also highlight the condition under which they can be more distortive than price supports. Given the importance of farm-level heterogeneity in productivity and endogenous entry and exit for both coupled and decoupled policies, a worthwhile extension could be to analyze the crop insurance program implemented by the 2014 Farm Bill in the context of this model.

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Appendix A

Γ_1 through Γ_7 and Θ are:

$$\Gamma_1 = \left(\frac{B}{A\nu}\right)^{\frac{\nu}{\nu(1-\phi)-(1+\theta)}} \left(\frac{\omega\left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)}{((\psi-1)f_e)^{\frac{1}{\psi}}}\right)^{\frac{(1+\theta)(1-\nu)}{\nu(1-\phi)-(1+\theta)}} > 0$$

$$\Gamma_2 = \frac{1}{\psi}\left(\frac{B^{\nu(1-\phi)}}{A^{1+\theta}\nu^{-\frac{\nu(\theta+\phi)}{1-\nu}}}\right)^{\frac{1}{\nu(1-\phi)-(1+\theta)}} \left(\frac{\omega^{\psi}}{\psi-1}\right)^{\frac{(1+\theta)(1-\nu)(1-\phi)}{\psi(\nu(1-\phi)-(1+\theta))}}$$
$$\times \left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)^{\frac{-(\phi+\theta(\phi+\nu(1-\phi)))}{\nu(1-\phi)-(1+\theta)}} f_e^{\frac{-((1-\phi)((1+\nu(\psi-1))+\theta(1-\nu))-\psi(1+\theta))}{\psi(\nu(1-\phi)-(1+\theta))}} > 0$$

$$\Gamma_3 = \left(\frac{B}{A\nu}\right)^{\frac{1}{\nu(1-\phi)-(1+\theta)}} \left(\frac{\omega\left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)}{((\psi-1)f_e)^{\frac{1}{\psi}}}\right)^{\frac{(1-\phi)(1-\nu)}{\nu(1-\phi)-(1+\theta)}} > 0$$

$$\Gamma_4 = \left(\frac{B^{\nu(1-\phi)-1}}{(A\nu)^{\theta}}\right)^{\frac{1}{\nu(1-\phi)-(1+\theta)}} \left(\frac{\left(\omega\left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)\right)^{\psi}}{f_e(\psi-1)}\right)^{\frac{\theta(1-\nu)(1-\phi)}{\psi(\nu(1-\phi)-(1+\theta))}} > 0$$

$$\Gamma_5 = \left(\frac{B^{-\nu\phi}}{A^{1+\theta-\nu}\nu^{\frac{-\nu(1+\theta-\nu+\phi)}{1-\nu}}}\right)^{\frac{1}{\nu(1-\phi)-(1+\theta)}} \left(\frac{f_e(\psi-1)}{\omega^{\psi}}\right)^{\frac{(1+\theta)(1-\nu)\phi}{\psi(\nu(1-\phi)-(1+\theta))}}$$
$$\times \left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)^{-\frac{1-\nu+\phi+\theta(1+(1-\nu)\phi)}{\nu(1-\phi)-(1+\theta)}} \left(\frac{1}{1-\nu}\right) > 0$$

$$\Gamma_6 = \omega^{\frac{(1+\theta)(1-\nu)(1-\phi)}{\nu(1-\phi)-(1+\theta)}} \left(\frac{B^{\nu(1-\phi)}\nu^{\frac{\nu(\theta+\phi)}{(1-\nu)}}}{f_e^{\frac{(1+\theta)(1-\nu)(1-\phi)}{\psi}}A^{(1+\theta)}}\right)^{\frac{1}{\nu(1-\phi)-(1+\theta)}}$$
$$\times \left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)^{\frac{-(\phi+\theta(\phi+\nu(1-\phi)))}{\nu(1-\phi)-(1+\theta)}} \frac{(\psi-1)^{1-\frac{(1+\theta)(1-\nu)(1-\phi)}{\psi(\nu(1-\phi)-(1+\theta))}}}{\psi} > 0$$

$$\Gamma_7 = \frac{B}{1-\nu}\frac{\omega^{\psi}}{(\psi-1)f_e}^{\frac{(1+\theta)(1-\nu)}{\nu\psi}} \nu^{\frac{-1}{1-\nu}} \left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)^{\frac{1+\theta(1-\nu)}{\nu}} > 0$$

$$\Theta = \frac{\phi\left(\nu^{\frac{\nu}{1-\nu}} - \nu^{\frac{1}{1-\nu}}\right)^{-\frac{(\theta+1)(\nu-1)}{\theta+\nu(\phi-1)+1}} \frac{B}{A}^{\frac{\nu}{\theta+\nu(\phi-1)+1}} (\psi-1)^{\frac{(\theta+1)(\nu-1)}{\psi(\theta+\nu(\phi-1)+1)}} \omega^{\frac{-2\theta\nu+\theta-\nu+1}{\theta+\nu(\phi-1)+1}}}{f_e^{\frac{(\theta+1)\nu}{\theta+\nu(\phi-1)+1}} \nu^{\frac{\nu}{\theta+\nu(\phi-1)+1}} (\nu(1-\phi)-\theta-1)} > 0$$

Supplemental Appendix

For the sensitivity analysis, we use the CES production function to study the impact of price supports versus decoupling:

$$y(z) = z^{1-v}\left(\alpha_1 k(z)^{\rho} + \alpha_2 l(z)^{\rho} + \alpha_3 x(z)^{\rho} + (1-\alpha_1-\alpha_2-\alpha_3)h(z)^{\rho}\right)^{\frac{v}{\rho}}. \tag{S1}$$

For this CES production function, $\rho = \dfrac{s-1}{s}$, where s is the elasticity of substitution. To differentiate this production function from the Cobb-Douglas production function with $s = 1$, we doubled the elasticity of substitution from 1 to 2.

We also consider linear functional forms for the input supply and output demand functions:

- Capital supply: $B_1^k + B_2^k r$,
- Labor supply: $B_1^l + B_2^l w$,
- Intermediate input supply: $B_1^x + B_2^x q$,
- Land supply: $B_1^s + B_2^s h$,
- Output demand: $A_1 + A_2 p$.

Based on these functional forms, we reran the simulation and report the results in tables S1 and S2. The directional impacts are not sensitive to these new functional forms. Furthermore, the magnitude of the impacts are comparable to those reported in the manuscript for the Cobb-Douglas production function and constant-elasticity input supply and output demand functions.

Table S1. Effect on Output Decomposition

Variable	Price Supports	Elimination of Direct Payments	Both Policies
$d\log Y$	−1.77%	−6.08%	−7.69%
$d\log Z$	0.00%	2.69%	2.69%
$v\alpha_1 d\log K$	−0.70%	0.35%	−0.39%
$v\alpha_2 d\log L$	−0.04%	0.02%	−0.03%
$v\alpha_3 d\log X$	−0.37%	0.18%	−0.21%
$v(1-\alpha_1-\alpha_2-\alpha_3)d\log H$	−0.07%	0.03%	−0.04%
$(1-v)d\log\tilde{m}$	−0.83%	−9.74%	−10.61%

Table S2. Effects on Output and Input Prices, Total Farms, and Percentage of Operating Farms

Variable	Baseline	Price Supports	Elimination of Direct Payments	Both Policies
p	2.74	2.55%	9.08%	11.62%
r	1.00	−2.94%	1.47%	−1.67%
w	1.00	−1.39%	0.70%	−0.79%
q	1.00	−3.03%	1.52%	−1.72%
s	1.00	−3.31%	1.67%	−1.89%
m	1.00	−4.06%	2.06%	−2.32%
$1-G(\bar{z})$	90%	0.90%	0.54%	0.54%