Case Study

Applied Economic Models of Commodity and Input Markets to Assess Prices, Quantities, Farm and Other Input Supplier Impacts, and Consumer and Taxpayer Costs

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Abstract
The impacts of exogenous market and policy developments reverberate up and down the farm to the retail marketing chain, affecting consumer prices, farm input prices, and the economic well-being of many people. Applied economists have developed analytical tools that trace how developments at one point in the supply chain may affect prices and quantities at other points. The particular analytical tools proposed here aim to provide students with hands-on experience in using market models and real data to simulate relevant policy and market scenarios. We start with a simple model representing only the supply and demand for corn and end with a vertically integrated model that links corn, hog, and pork markets. Each phase of model development gives a chance to build and test economic intuition about how price effects come about and their impacts on various market participants: who benefits and who pays—the winners and losers.

1 Introduction

Many people follow agricultural commodity markets: farmers and ranchers, firms that sell farm inputs and marketing services, livestock feeding operations, grain and meat processors, food processors and wholesalers, and futures market analysts. All these agents can be impacted by market developments induced by changes in agricultural policies, crop yields, animal productivity, and trade. Monthly commodity market outlooks in the World Agricultural Supply and Demand Estimates, otherwise known as WASDE (U.S. Department of Agriculture, Office of the Chief Economist 2023), are closely observed to see how changes in supply and demand factors affect price outlook. Yet, analysis can be complicated as shocks in one part of the agriculture sector spill up and down the supply chain and across borders. Often such effects defy simple explanation. Theoretically, possible outcomes may seem paradoxical as when, for example, increased productivity transforming agricultural inputs into consumer goods cause lower farm commodity prices and reduce farm income or when prices at wholesale or retail levels in the marketing chain may rise at the same time as farm prices fall.

Economists use supply and demand models to study market interactions, yet these tools are not always made accessible in agricultural economics classes or business education. Such omissions are failures: skills to define winners and losers are of broad use to farmers, the agri-food industry, and government. Agribusiness decision making can be improved if supported by an intuitive understanding of how a shock in one commodity or input market can affect outcomes in other markets.

The next section provides the background and motivation for the proposed approach. Section 3 describes the general features of the particular economic model we chose and our motivation for choosing it. In section 4 we present the empirical versions of the models and hands-on simulation experiments using them. We begin with a simple supply and demand model of the U.S. corn market and then progressively move to more complete models and simulation experiments to show applicability to real-life market developments and policies. The final section summarizes the value of these lessons to various potential audiences.

2 Background and Motivation

The models that economists use to represent agricultural commodity and input markets enable them to study how policies or market shocks may impact farm prices, taxpayer costs, and trade. Results illustrate how the impacts of higher output prices may be distributed unequally among input suppliers and how the negative impacts of higher input prices are distributed unequally among output markets. Policy simulation experiments can reveal how the impacts of government policies critically depend on the nature of the associated policy intervention.

We think that it is possible to equip students with the tools they need for doing this type of analysis using readily accessible economic models and the means to employ them in applied economic analysis. The applications of the model we propose evolve in stages, commodity by commodity, to facilitate learning. At each stage, the model presented is an incremental step forward and yet remains appropriate for analysis focused on certain questions. The final model explicitly represents U.S. markets for corn, hog, and pork and their input markets. Models are based on actual market and production cost data. Parameters are drawn from applied models in use today or relevant articles. Guided hands-on experiments reveal how a shock or policy causes vertical and horizontal interactions throughout these markets, the sensitivities of these shocks to parameter assumptions and market structure, and the benefits and costs to various agents in the farm to retail marketing chain. These lessons have both narrow and broad applications. The scenarios we develop relate directly to the particular case study presented, yet the intuition can be applied to other cases.

3 Equilibrium Displacement Model

A wide variety of economic models exist for agricultural market and policy analysis. The range of options extend from simple, one-commodity supply-demand graphical analysis to general equilibrium analysis wherein markets of all goods and services are explicitly represented, for example, the Global Trade Analysis Project (2023) model. Another popular option is multi-market, partial equilibrium (PE) models used to track year-by-year dynamics of crop and livestock markets (Westhoff et al. 2022). Such models are used in developing the baseline projections for the U.S. Department of Agriculture (USDA); Organization for Economic Cooperation and Development (OECD); Food and Agriculture Organization (FAO) of the United Nations; and Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI-MU). There is no one best model for any let alone for all purposes, but some models are more appropriate for addressing a problem than others.

The type of economic model chosen for our purposes sits in the range of alternative specifications just somewhat above the simple supply-demand graphical model found in introductory economics textbooks and somewhat below multi-market partial equilibrium models. It is most often referred to as the Equilibrium Displacement Model (EDM). The Policy Evaluation Model (PEM) was a version developed and maintained by the OECD (Organization for Economic Cooperation and Development 2001, 2005, 2021). An important precedent to its application in agricultural policy analysis was in an analysis of housing and urban land economics by Muth (1964). The development of the model more specifically for analysis of agricultural markets is generally credited to Floyd (1965), with important further elaborations by Gardner (1987), Hertel (1989), and Wohlgenant (2011). Piggott (1992) used his presidential address to the annual conference of the Australian Agricultural Economics Society to promote the use of equilibrium displacement modelling , or comparative static analyses of general function models, as a research tool in agricultural price and policy analyses. He emphasizes that despite its shortcomings, equilibrium displacement modelling is a research tool that can provide useful qualitative and quantitative insights with few assumptions. Brester, Atwood, and Boland (2023) contains a comprehensive review of the conceptual basis for the model and its implementation in analyzing policy.

An EDM typically represents supply and demand in a relatively small number of interconnected input and output markets. The system of output supply and factor demand relationships are derived explicitly from first order conditions of a profit or cost function and a generalized production function. Following precedents established in prior work using these types of models, we adopt a constant elasticity of substitution (CES) production function for these purposes. Students might find it helpful to review how to derive factor demand equations for a CES production function in Chapter IV, pages 89–93, of Gardner's textbook (Gardner 1987). For our purposes, we adopt his derived equations almost exactly.

Commodity demand equations relate the quantity demanded for each use to prices via demand elasticities. All behavioral equations in the models are in log-log, percentage change form with elasticities and factor shares as explicit parameters. Supply and demand parameter values, including factor shares, factor substitution elasticities, and demand elasticities, are drawn from published studies. Subsidy or tax wedges in price equations constitute the main ways for implementing market or policy simulation experiments. Initial values of producer subsidies for corn output and some categories of inputs were taken from the OECD (2022). Impacts of exogenous developments in policy or markets are modeled as changes in those wedges. Model results estimate changes in prices and quantities in all markets that arise when the system's equilibrium is displaced due to these exogenous shifts. The resulting impacts on producer and consumer surplus estimate welfare changes to agents. This approach has proven popular in academic work and to help decision makers understand market impacts of policies or other factors. See Table 1 for some examples showing the diversity of applications of the model in published analyses.

Table 1: Selected Studies that Use Equilibrium Displacement Models

Study	Topic
Salhofer and Sinabell 1999	Market effects of the EU countryside stewardship policies
Zhao et al. 2000	Public research and development effects on Australia beef
Dewbre, Anton, and Thompson 2001	Estimate and rank order the transfer efficiency and trade effects of various forms of farm support
Brester, Marsh, and Atwood 2004	Impact of country-of-origin labeling on U.S. beef, pork, and chicken markets
Martini 2011	Long Term Trends in Agricultural Policy Impacts
USDA, Office of the Chief Economist 2015	Economic effects of U.S. country-of-origin labeling
Lee, Sumner, and Champetier 2018	Pollination services and honey in a multiple input, multiple output, two season model
Hahn, Sydow, and Preston 2019	Estimation of damages to Mexico and Canada's livestock market associated with country-of-origin labeling
Lusk, Tonsor, and Shultz 2020	COVID-19 effects on U.S. beef and pork marketing margins
OECD 2021	Market impacts of agricultural and food policies in Norway

4 Empirical Models and Their Applications

There are eight files supplementing the information provided in this section. The one labeled "Overview of Models" compares the equation structure of each of the EDMs and provides data and parameter definitions. Five are devoted to documentation of each of the models individually, Model 1 to Model 5. The one labeled "Model Instructions" explains how to execute model simulations. Finally, the one labeled "Database" documents raw data sources used to construct the models.

The supplemental file, Overview of Models, contains an Excel workbook with two sheets. One of the sheets presents, in column-wise sequence, the equations comprising each one of the five models showing the progression from Model 1, representing interaction of just the aggregate supply and demand for corn, through to Model 5, a representation of the vertically related corn, hog, and pork markets together with their associated input markets. The other sheet contains the variable and parameter names, and their definitions.

The supplemental files "Model 1" to "Model 5" each contain: (a) model descriptions, (b) the empirical versions of each of the market models formatted for solution using the Excel Solver application, and (c) a worksheet for tabulating simulation results for producer, consumer, and taxpayer welfare. The supply and demand for corn in Model 1 implicitly contains the details that are given explicitly in subsequent model versions. Model 2 relates output quantity to inputs used, replacing the first model's supply function with a system of input demands, supplies, and prices. Similarly, where in Model 2, aggregate corn demand *implicitly* includes corn exports, food use, and feed uses, these are made explicit in Model 3. Model 4 distinguishes that part of feed use that goes to hogs and includes equations representing the demand and supply of hogs and the associated non-feed inputs of hog production. This theme continues in Model 5, which represents how the demand for hogs is derived from the interaction of retail demand and supply of pork. While some of these models are simpler than others, none are inherently wrong—it would be incorrect to assume that a model with more equations is always more accurate or more useful.

The overall structure of the following sections corresponds to model versions and experiments. Each section begins with a flow chart illustrating a model followed by a general description of that model and the motivation behind it. The sub-sections contain the simulation motivations and lessons. Each subsequent section provides a version of the model with more details of up- and down-stream markets.

The discussions of scenarios in the following sections will refer to numerical results of model simulations to be undertaken by students. Detailed instructions to implement each of the scenarios for each model version are made available in the supplemental Model Instructions file. In each exercise, students are invited to shock the model out of its initial equilibrium, usually by changing a wedge or gap between buyer and seller prices of an output or input, and then solve the model to find the new equilibrium. The students can see how the shock they implement affects all explicitly modeled prices and quantities of inputs and outputs, as well as the welfare impacts on consumer, producer, and taxpayer surplus. Key lessons from these experiments are summarized in each of the various sub-sections below.

4.1 Model 1: Corn Supply and Demand

This first and most elemental model of corn supply and demand corresponds closely to comparative static graphical analysis taught in introductory economics classes. It aims to explain and analyze prices and quantities traded in a single competitive market. The market behavior is represented in total market supply and demand equations (to the left and right in Figure 1). The supply-inducing price is the market price adjusted for any producer price support or wedge, and the demand-side price can also be adjusted to reflect any subsidy or tax to consumers. The market price (in the middle of Figure 1) will adjust to clear the market, with equal quantities of supply and demand.

Figure 1: Interaction of Aggregate Corn Supply, Demand, and Market-Clearing Prices

Model 1 thus comprises five equations. The key parameters are the elasticities of supply and demand.

4.1.1 Model 1 Scenario: Corn Producer Subsidy

Here the model is used to simulate the effects of a new 10 percent output subsidy to corn producers. (We say "new" because base data we used already has some support for corn producers.) The output subsidy is based on producer support estimate (PSE) data and includes support that is tied to income or revenue.[1] The time frame of simulated results in this and all subsequent scenarios is intended to reflect the outcome after a medium-term adjustment process, so we ignore changes in stock levels and gradual adjustments in behavior. Results of the policy shock are measured by the induced changes in market prices and quantity outcomes, and producer and consumer welfare.

This scenario is a good starting point for those who are not familiar with structural economic models. Figure 2 traces the changes in supply, demand, and market price induced by the output subsidy.[2] The supplemental file, Model 1, presents the numerical version of that process. Market equilibrium before the hypothetical increase in the output subsidy is depicted in Figure 2a. The key requirement is that the quantity supplied, $Qs = f_s(Ps)$, at the supply-inducing price, $Pd\_ / (1 - op\_)$, must equal quantity

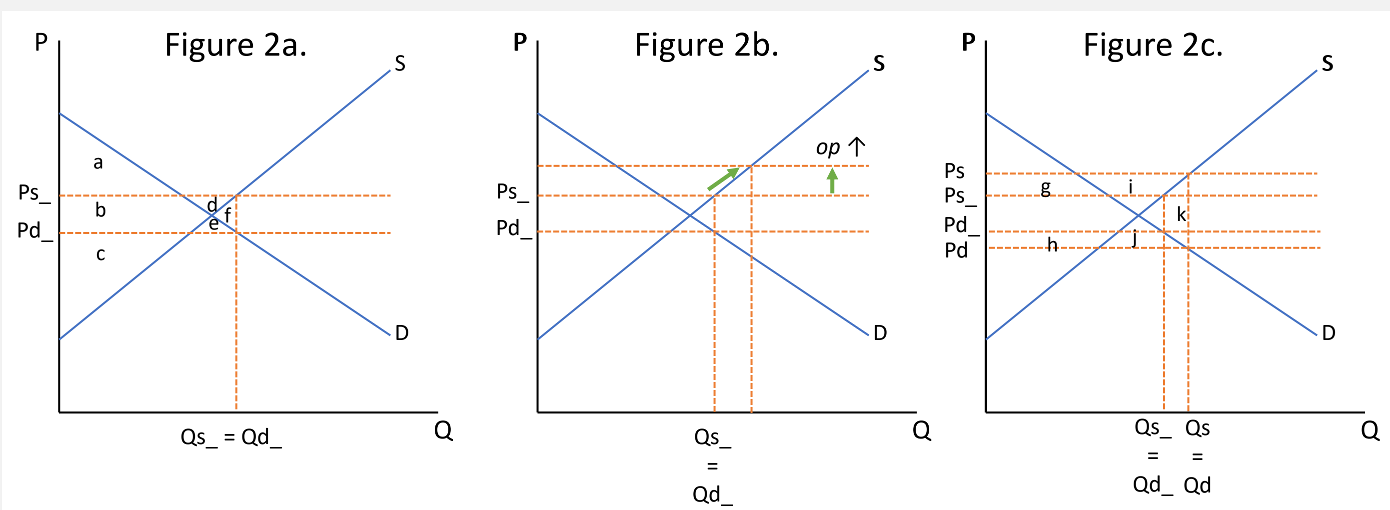

Figure 2: Market Diagram and Model Simulations

[1] Later, U.S. programs that pay on a historical base area will be included in these models. The methods used here are introductory and set aside findings of a vast literature about the production impacts of payments not tied to output (or decoupled). Before doing serious analysis of U.S. payments not tied to output, particularly payments tied to a historical base area, it is useful to look at this so-called decoupling literature. Although that step is important for being precise about the sizes of impacts, the directional and distributional effects presented here should be reliable.

[2] The simplicity of Model 1 lends itself to straightforward graphical analysis. Other versions, not so much. We use that graphical analysis here to illustrate key concepts that apply generally for all the models.

demanded, $Qd\_ = f_d(Pd)$, at the market-clearing price $Pd\_$. (The naming convention we adopted utilizes an underscore '_' at the end of all initial values of variable names. To designate solved values, we omit that underscore.) The model allows for consumer prices to differ from market prices, such as in the presence of consumer subsidies or taxes, but this complication is omitted from the figure. The diagram relates initial consumer surplus ($a + b + e$), producer surplus ($b + c + d$), taxpayer costs ($b + d + e + f$), and deadweight loss (f).

Figure 2b depicts the situation after the increased subsidy (op - $op\_$) is introduced but before a new market equilibrium is established. The numerical counterpart to this situation can be seen by comparing price and quantity outcomes shown in Model 1, after the introduction of the subsidy but before the model is solved (using Excel Solver).

In Figure 2b, the subsidy is shown to cause movement along the supply curve—producers are willing to supply a larger quantity as the subsidy pushes the supply price higher. However, quantity demanded by consumers has not yet changed; $Qd\_$ remains the same until the new equilibrium is found, thus creating a situation wherein the market-clearing requirement that the quantity supplied must equal the quantity demanded is not met ($Qs > Qd\_$ in Model 1). This imbalance is something which a competitive market will not put up with! Nor is this the case in reality: the additional quantities produced cannot just vanish rather than being sold, used, stored, or accounted for in any way. Something has to give. That something is the market-clearing price.

This fundamental role the market price plays in clearing the market is made evident when the model is solved for the new price with the new subsidy, depicted graphically in Figure 2c and numerically in Model 1. The solved model will give the new, lower market-clearing price (Pd) with greater quantities supplied and demanded. The new price plus producer subsidy will map to higher effective producer price (Ps) than before the new policy was introduced. However, that increase will be somewhat less than the initial producer price plus subsidy due to the induced reduction in the market-clearing price.

The Results sheet in Model 1 tabulates gains and losses caused by the subsidy. Higher effective prices for producers lead to higher producer surplus (Figure 2c, $g + i$). Lower market-clearing prices increase consumer surplus (Figure 2c, $h + j$). The final incidence will depend on the relative supply and demand elasticities—a point we do not explore here, but more advanced students could implement the same scenario with different elasticities to compare price and surplus impacts. The subsidy creates a tax burden (Figure 2c, $g + h + i + j + k$) greater than the sum of producer and consumer surplus gains, leading to an overall deadweight loss (Figure 2c, k).

4.2 Model 2: Corn Model with Inputs

Simulation results obtained with the basic corn supply and demand model discussed above confirm intuition regarding the directional effects of output subsidies on prices and welfare, and provide "back of the envelope" insights into quantitative magnitudes of those changes, but not much else. More importantly, that model permits us to only measure consumer and producer surplus at a highly aggregated level. The estimated change in consumer surplus is an aggregate of the changes for domestic buyers of corn for food, feed, and other uses. Moreover, that aggregate incorporates the consumer surplus accruing to agents who buy corn for export. Similarly, the estimated change in producer surplus implicitly adds together changes in surplus accruing to all the agents that supply factors of production to farmers. One question that dominates discussions of farm policy and market developments is, "What will this or that change do to farm income?" However, farm income accrues only to those factors owned and supplied by farmers, principally farm-owned land and labor.

To answer the question about what happens to farm income one needs to know how returns to non-farm-owned inputs change due to the market or policy development of interest. Answering such questions requires a model in which supply and demand for production factors are explicit. We start with such a model, deferring for the moment the disaggregation on the demand side. The demand-side model structure is consequently identical to the previous case and the relationship of corn producer and buyer prices to the market-clearing price is also the same. However, the corn supply quantity is replaced by explicitly representing input markets that were implicitly part of the supply equation before (lower left part of Figure 3). Corn is produced using a multitude of individual human, land, chemical, and mechanical inputs. For our purposes and without much sacrifice in precision relative to our objectives, we create just three aggregate categories: land, other farm-owned (mainly own labor), and purchased inputs. In making farm income calculations, we further distinguish between land owned by farmers and that which we assume is rented from non-farmers. There are three inputs and consequently three input demands as functions of target output level and the relative input prices. We end with three market-clearing change variables: the domestic market price of corn and the demand prices for two factors of production—farm-owned inputs and purchased inputs. Notice that the model will actually calculate not three but *four* prices (the yellow price boxes of Figure 3). To obtain the fourth—the demand price of land in our case,[3] we exploit the condition implied by profit maximization in a competitive market that in equilibrium the sum of factor payments must equal total revenue—the zero-profit condition. That is to say, factor payments to any one of the factors of production can be obtained as the difference between total revenue and the sum of factor payments made to the other two factors.

The elasticity of demand remains a key parameter, but also important are the supply elasticities of cropland, farm-owned inputs, and purchased inputs, and factor demand own- and cross-price elasticities. The market context is important in terms of the cost shares of land, farm-owned inputs, and purchased inputs. The policy context includes the initial input support for purchased inputs, and land planted to a specific crop, or land planted tied to historical base, as well as support to all output and consumer price policies.

There are other steps that have proven useful in applied economic analysis of this type. First, we calculate initial factor payments to each input as the product of that input's factor share and output

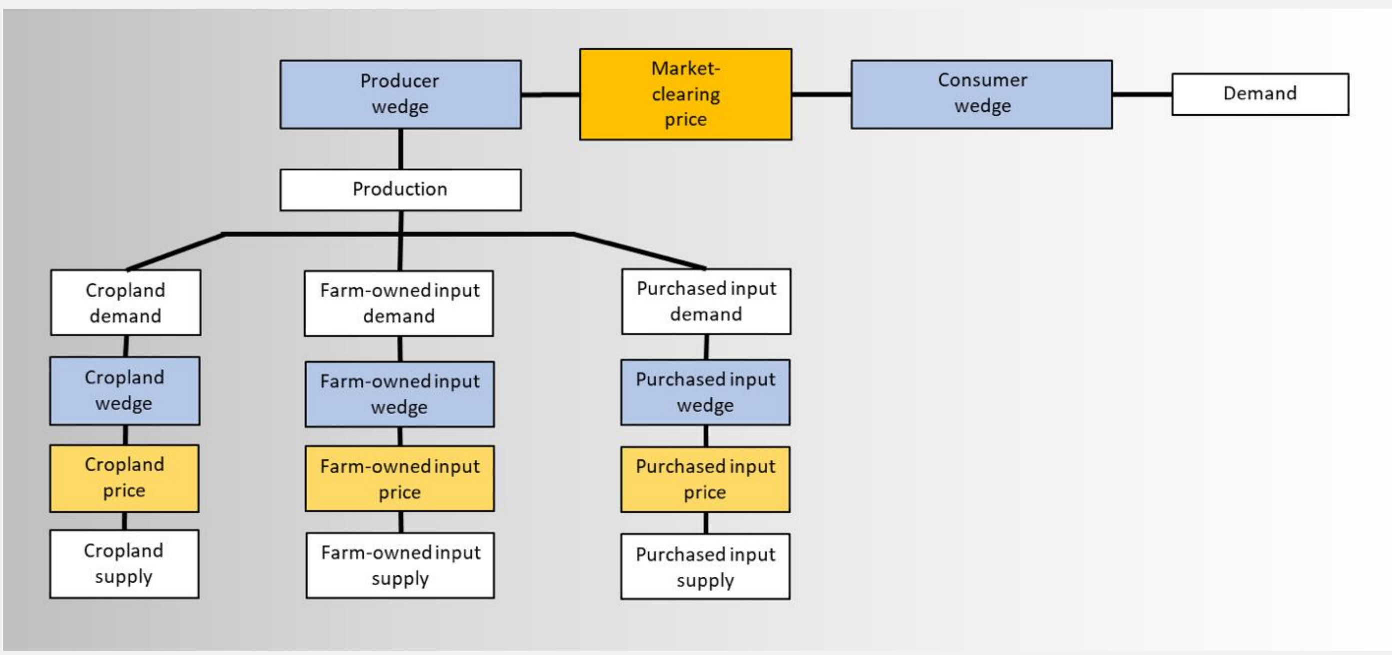

Figure 3: Interaction of Corn and Associated Input Markets and Market-Clearing Prices

[3] The choice of which one of the input categories to be determined residually is arbitrary.

market revenue. For example, initial factor payments to, say, land is equal the input share of land times that market revenue. Second, the focus on percent changes allows us to abstract from numerical input quantity and price levels. That is, since all behavioral equations are in percent change form, we need percent change in factor prices, not actual factor prices. Indeed, it can be difficult to obtain prices for these factors, not least because they are aggregates of many different inputs. Instead, we create an index for each factor quantity equal to the expenditures on the input in the base period. That way we can set initial demand prices at unity (or equal to 1). The model data are consistent with the market data we collect and respects the requirement that factor payments equal the product of their quantities and prices. We reproduce these steps in all subsequent models.

4.2.1 Model 2 Scenario: Corn Producer Subsidy

The decomposition of commodity supply into its input demands, supplies, and markets is critical to applied price analysis. This exercise helps to clarify that producer surplus associated with crop supply is not the same thing as farm income or farmer well-being. Results presented here will show how the output price, quantity impacts, and the commodity producer surplus effect are related to input market and input supplier outcomes. Net farm income is calculated along with aggregate producer surplus, so the implications of a crop supply subsidy for farm income can be highlighted. Comparing taxpayer costs to farm income impacts might be a way to highlight, for some audiences, the importance of understanding what part of the producer surplus goes to different input suppliers. More advanced exercises could be envisioned with different assumptions about input supply elasticities that link these key parameters to producer surplus decomposition as well as to crop output supply.

4.3 Model 3: Corn Model with Inputs, Food, Feed, and Export Demand

This is the last model that focuses exclusively on corn and corn inputs. It differs from the last version in only one respect. Here, we separate aggregate demand for corn into export, feed, and food demand categories (at right of Figure 4). This is accomplished by adding simple own-price demand equations for each one of those aggregates. The food demand category combines domestic buyer demand for corn to be used in food products, for ethanol production, and seed uses. We will return to a more detailed look at the feed demand category when we move to the corn-hog version of the model next. As mentioned above, the demand for corn to be sold to corn importing countries can be thought of as sort of excess demand combining the residual between domestic production and consumption in all countries importing U.S. corn.

This model can be used to assess the impacts of policies on different buyers and also the effects of policies that affect buyer prices differently. Some experiments might seem unconnected to current U.S. corn policies, but being able to test the relative impacts of policies that affect domestic and foreign buyers of a commodity can give important insights into how trade policies affect markets, producers, and consumers (see supplemental material).

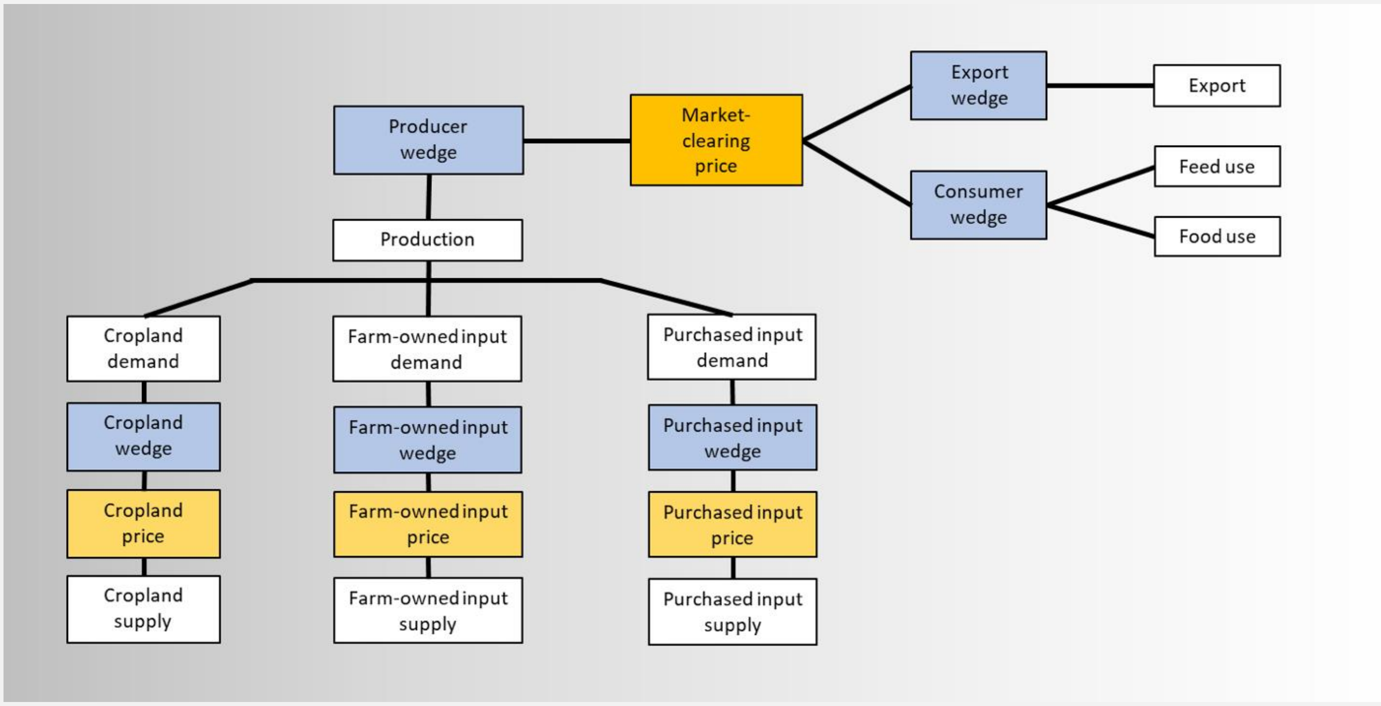

Figure 4: Corn Model with Inputs and Demand Disaggregation

4.3.1 Model 3 Scenario: Corn Producer Subsidy

The impacts of an output payment on consumer prices and surplus are assessed explicitly here. The decomposition of consumer surplus among domestic users and export buyers alone can be an important aid to understanding how supply-side policies affect key constituencies. Advanced students can go farther to assess the role elasticities of demand play on market price outcomes, quantity impacts, and producer and consumer surplus. Moreover, the impact of changing the elasticity of one demand on outcomes for the other two demands can be used to highlight their interactions and the implications for consumer surplus by demand type.

4.4 Model 4: Corn and Hog Model

In order to create the corn-hog model, we append a model representing equilibrium in the U.S. hog market (Figure 5, right hand side). As for the corn model with inputs, hog supply is represented by a system of supply equations corresponding to the first order conditions obtained by maximizing profit given a hog production function. Key parameter estimates were obtained from MacDonald and Ollinger (2000). We distinguished four input categories: (1) farm-owned labor, (2) feed grain, (3) feed protein, and (4) purchased inputs (supplemental Overview of Models file). The corn and hog components are tied together via two linkages: (1) the price of feed grain used in the hog production module equals the market price of corn from the corn module, and (2) the demand for corn for use in hog rations is determined in the hog module. To achieve the latter, we further distinguished corn feed demand in the corn module between that used for hog production and that used for other animals.

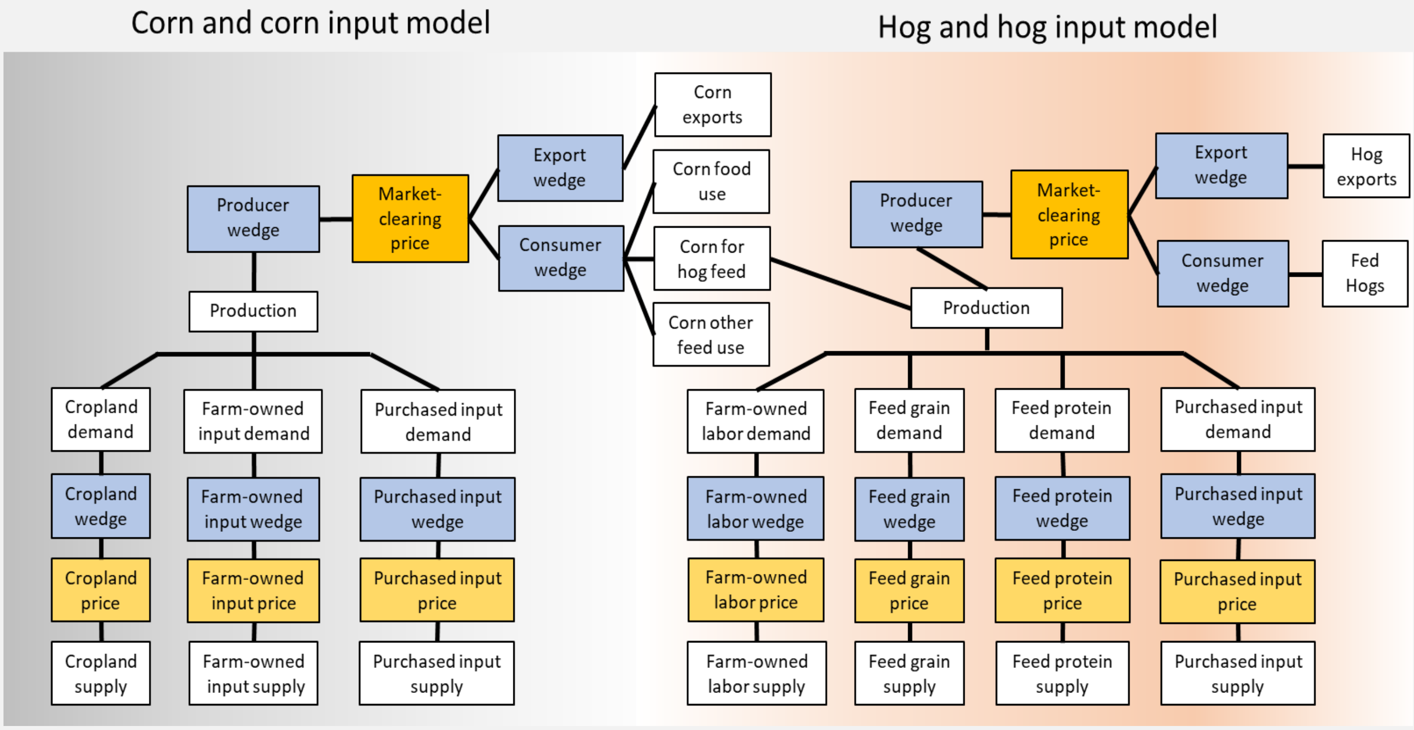

Figure 5: Corn and Hog Model

4.4.1 Model 4 Scenario: Corn Producer Subsidy

The layering of corn and hog models with their respective input markets makes explicit a variety of interactions. The corn output subsidy scenario continues to generate the preceding results for corn input suppliers and other corn buyers, domestic and export, yet the model now elaborates how the hog sector is affected. The subsidy to the production of corn, one input of hog production, can be seen to shift out the supply of hogs with a lower feed price. The hog price is reduced, and other input prices are bid higher given the elasticities used here. Further experiments with the same shock and different elasticities for hog input demands or other hog input supplies can illustrate these interactions further.

4.5 Model 5: Corn, Hog, and Pork Model

In similar fashion as when creating the corn-hog model, we append a model representing equilibrium in the U.S. pork market (Figure 6, right hand side). Following the procedure employed in the two previous versions, pork supply is represented by a system of supply equations corresponding to the first order conditions obtained by maximizing profit given a pork production function. Key parameter estimates were obtained from the USDA Economic Research Service (2011). We distinguished four input categories: (1) hired labor, (2) capital services, (3) hired labor, and (4) purchased inputs. The hog and pork components are tied together via two linkages: (1) the price of hogs used in the pork production module equals the market price for hogs from the hog module, and (2) the demand for hogs for slaughter in the hog module is determined in the pork module.

4.5.1 Model 5 Scenario (1): Corn Producer Subsidy

The first application of this model repeats the ongoing exercise of a corn output subsidy in order to track the impacts up- and down-stream, including explicitly the impacts on markets of different inputs to corn, hog, and pork production. The implications for corn and hog commodity and input market prices and quantities are unchanged. Outcomes for pork and pork input markets are now explicitly represented in

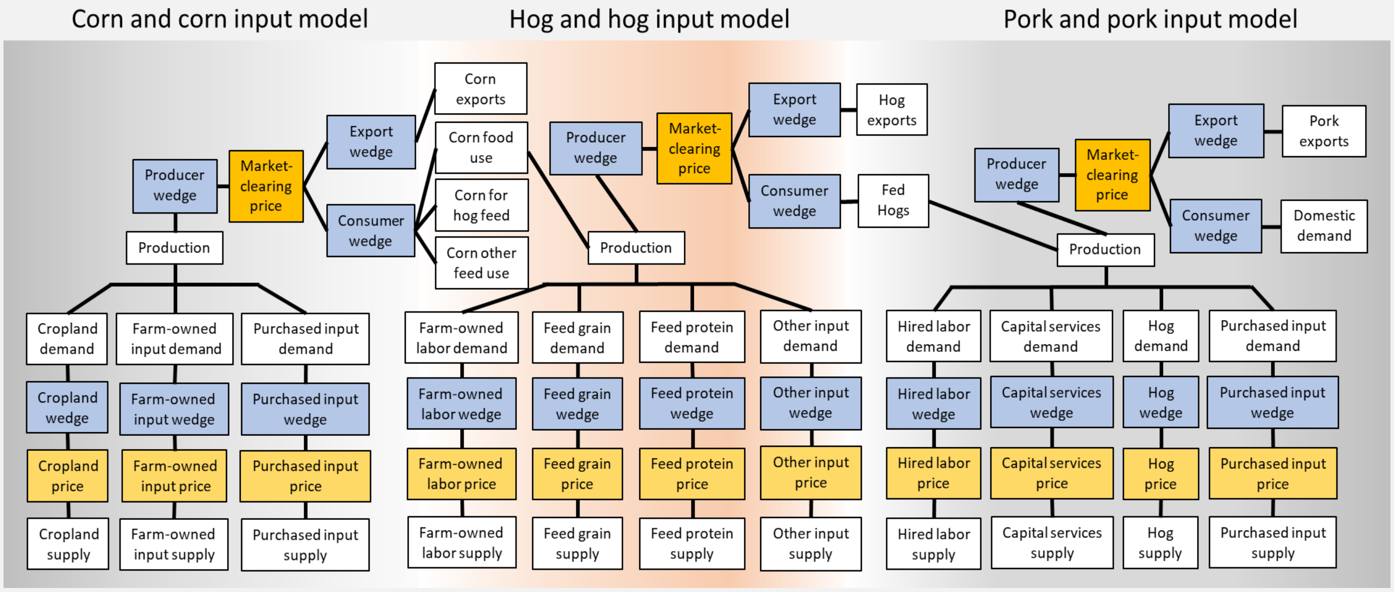

Figure 6: Corn, Hog, and Pork Model

the model, not implicit in the hog demand. The corn output subsidy shifts out hog supply, and the hog market impacts shift out pork supply. The hog price falls, driving up purchases of this input to produce more pork. Other input demands are determined by the combination of expansion effects (as pork production rises) and substitution effects (when comparing the prices of other inputs, including less expensive hogs). An important consideration is the high share of hog costs in total pork production costs according to our source data (see factor shares data in Model 5). The demand quantity effects seen in the results are not the initial demand shifts alone, but instead a combined result of the demand shifts and the changes in equilibrium prices. The final impacts on other pork inputs, like labor, and pork price might be compared to the initial subsidy to corn production.

4.5.2 Model 5 Scenario (2): Hog Export Tax

This scenario tests what would happen if a policy targets hog exports. This scenario might represent the implications of a hypothetical subsidy, but it also could be used as a step toward analyzing the impacts of a trade deal or dispute, an animal disease, or a regulatory change. These alternatives would not have the same taxpayer impacts or welfare impacts more broadly if the policy relates to animal or human well-being that cannot be included in the market analysis provided here. Nevertheless, the directional impacts on market quantities and prices, consumers, producers, and input suppliers are likely the same.

The export tax leads to lower hog exports with the exact effect depending on the size of the tax, the equilibrium price change, and export demand elasticity. The overall impact is less hog demand in aggregate and a falling hog price. That reduction in hog demand causes a movement along the hog supply curve, which takes the form of falling hog input demands, as seen in their falling prices and quantities. The corn market details can also be seen: less demand for hog feed means less overall demand, so there is also a movement along the corn supply curve with consequently lower corn input prices and quantities.

The lost hog feed demand is partly offset by price-induced increases in other corn uses. Likewise, the hog export tax effect is mitigated by responses of other hog demands, including for domestic pork production. The effect of lower hog price is made clear in the pork market representation and, in fact, these pork market effects can be seen as perfectly analogous to the impacts of the corn output supply impact. In both these scenarios, the driving force that causes pork market response is a lower hog price, so the directional impacts of the pork and pork input prices and quantities—and even magnitudes in this case—are mostly quite similar in these two scenarios.

This scenario can be used to illustrate how an intermediate product trade policy, whether tax or other measure, has up- and down-stream impacts. In this case, the implications of such a trade policy for farm (corn) income and food (pork) consumer can be estimated.

4.5.3 Model 5 Scenario (3): Pork Purchased Input Price

This scenario tests the impact of something that causes the costs pork processors pay for inputs to rise. The policy used here is a tax, but the same scenario for market outcomes might relate to a variety of shocks to productivity, regulations, or other factors—although the assessment of distributional impacts on well-being might be different if the motivation is not a tax.

The directional impacts of an increase in other purchased input prices on pork, hog, and corn sectors should be mostly predictable. The effects on input markets throughout the system will tend to be dominated by expansion—or, in this case, contraction—effects at most levels given the cross-price elasticities of factor demands. The sizes of impacts might appear small relative to the outcomes of earlier scenarios or even to preliminary expectations. However, the share of these purchased inputs in pork production costs is small (as seen in the value of *Sbpk*), so the tax impacts will tend to be modest. Pork and hog market interactions tend to be strong, but the role of hog feed in total corn demand is similar in magnitude to the share of other purchased inputs in pork production costs, so the corn market impacts are further diminished in terms of magnitude. More advanced students might embark on a sequence of variations in this scenario. As ever, input supply elasticities could be changed. Going farther, however, initial pork cost shares could be artificially changed (as long as the shares sum correctly) or the tax could be applied to other pork inputs, like labor, or to more than one class of pork inputs. Each additional permutation will explore how a different set of market conditions or tax implementation will affect the product market and then spill upward to the intermediate good market and crop market.

5 Discussion

Economic models such as those employed here are useful, not because they provide perfect descriptions of reality—no model can. Rather, they are useful because they force analysts to formalize their views about how agricultural commodity markets work and to think through first order and knock-on effects of market developments systematically. They are meant to augment, not replace, intuition for thinking about how exogenous shifts in supply and demand play out in prices, and the economic costs and benefits to various agents. When confronted with a policy change, new demand or use, or supply shortfall, economic models may provide useful insights into how impacts may show up along the marketing chain from farm gate to consumer plate. As revealed in the results from simulation experiments discussed above, the effect of a subsidy or tax in market equilibrium will almost never equal the impact on the price first affected. For example, simulation analysis with even the simplest of our models could show, somewhat counterintuitively, that producers lose more from a consumer tax than consumers do, all depending on the relative elasticities. In similar vein, students can see that final supply-side benefits or costs of a commodity market policy or change go to the input suppliers who are least responsive to price (so most inelastic) and the smallest share often goes to the input suppliers whose response is most responsive to price (most elastic). Cropland supply in the United States evolves slowly over time with only limited response to price, such that developments in corn, soybean, and other crop markets will tend to have their largest impacts on land prices.

Do these lessons matter to students? If their career or passion leads them to consider market implications of proposed real changes in agricultural policy in the United States or elsewhere, technological innovations, new demands for agricultural products, long-run drivers of weather patterns and income, or any other market shock, then developing their ability to formalize analysis of responses can be valuable. When they read the news about a disruption in wheat markets on the other side of the world, trade negotiations between countries, or biofuel policy changes, the concepts they covered here might be key tools for thinking about what that news means for them as voters and consumers, for their communities or countries, and their employers or business decisions.

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References

Brester, G., J. Atwood, and M. Boland. 2023. *Equilibrium Displacement Models: Theory, Applications, and Policy Analysis.* Minneapolis: University of Minnesota Libraries Publishing.

Brester, G., J. Marsh, and J. Atwood. 2004. "Distributional Impact of Country-of-Origin Labeling in the U.S. Meat Industry." *Journal of Agricultural and Resource Economics* 29(2):206–277.

Dewbre, J., J. Anton, and W. Thompson. 2001. "Direct Payments, Safety Nets and Supply Response: The Transfer Efficiency and Trade Effects of Direct Payments." *American Journal of Agricultural Economics* 83(5):1204–1214.

Floyd, J.E. 1965. "The Effects of Farm Price Supports on the Return to Land and Labour in Agriculture." *Journal of Political Economy* 3:148–158.

Gardner, B. 1987. *The Economics of Agricultural Policies.* New York: Macmillan.

Global Trade Analysis Project. 2023. "GTAP Models: Current Model." www.gtap.agecon.purdue.edu/models/current.asp.

Hahn, W., S. Sydow, and W. Preston. 2019. "Revisiting U.S. Country of Origin Labeling Trade Damage Estimates: How Does an Equilibrium Displacement Model Perform Under Different Scenarios." *Canadian Journal of Agricultural Economics* 67:349–361.

Hertel, T.W. 1989. "Negotiating Reductions in Agricultural Support: Implications of Technology and Factor Mobility." *American Journal of Agricultural Economics* 71:559–573.

Lee, H., D. Sumner, and A. Champetier. 2018. "Pollination Markets and the Coupled Futures of Almonds and Honey Bees: Simulating Impacts of Shifts in Demands and Costs." *American Journal of Agricultural Economics* 101(1):230–249.

Lusk, J., G.T. Tonsor, and L.L. Shultz. 2020. "Beef and Pork Marketing Margins and Price Spreads During COVID-19." *Applied Economic Perspectives and Policy* 43(1):4–23.

MacDonald, J.M., and M.E. Ollinger. 2000. "Scale Economies and Consolidation in Hog Slaughter." *American Journal of Agricultural Economics* 82(2): 334-346.

Martini, R. 2011. "Long Term Trends in Agricultural Policy Impacts." *OECD Food, Agriculture and Fisheries Papers* 45. Paris, France.

Muth, R.F. 1964. "The Derived Demand for a Productive Factor and the Industry Supply Curve." *Oxford Economic Papers* 16:221–234.

Organization for Economic Cooperation and Development. 2001. *Market Effects of Crop Support Measures.* Paris, France.

Organization for Economic Cooperation and Development. 2005. *The Six-Commodity PEM Model: Preliminary Results.* Paris, France.

Organization for Economic Cooperation and Development. 2021. *Policies for the Future of Farming and Food in Norway.* Paris, France.

Organization for Economic Cooperation and Development. 2022. *Agricultural Policy Monitoring and Evaluation 2022.* Paris, France. www.oecd.org/publications/agricultural-policy-monitoring-and-evaluation-22217371.htm.

Piggott, R. 1992. "Some Old Truths Revisited." Presidential address, 36th Annual Conference of the Australian Agricultural Economics Society, Department of Agricultural Economics & Business Management, The University of New England, Armidale NSW 2351, Canberra, 10–12 February.

Salhofer, K., and F. Sinabell. 1999. "Utilising Equilibrium-Displacement Models to Evaluate the Market Effects of Countryside Stewardship Policies: Method and Application." *Die Bodenkultur [Austrian Journal of Agricultural Research]* 50(2):143–153.

U.S. Department of Agriculture, Economic Research Service. 2011. "U.S. Feeder Pig-to-Finish Production Cash Costs and Returns." Washington DC. Accessed at www.ers.usda.gov/data-products/commodity-costs-and-returns/commodity-costs-and-returns/#Historical%20Costs%20and%20Returns:%20Hogs,%20farrow-finish.

U.S. Department of Agriculture, Office of the Chief Economist. 2015. *Economic Analysis of Country of Origin Labeling (COOL). Report to Congress.* Washington DC, April.

U.S. Department of Agriculture, Office of the Chief Economist. 2023. "World Agricultural Supply and Demand Estimates." Available at www.usda.gov/oce/commodity/wasde.

Westhoff, P., M. Rosenbohm, J. Whistance, J. Binfield, S. Chiuchiarelli, B. Maltsbarger, W. Thompson, and F. Malakhail. 2022. "Baseline Update for U.S. Agricultural Markets." FAPRI-MU Report 4-22.

Wohlgenant, M.K. 2011. "Consumer Demand and Welfare in Equilibrium Displacement Models." In J.L. Lusk, J. Roosen, and J.F. Shogren, ed. *Oxford Handbook of The Economics of Food Consumption and Policy*. Oxford UK: Oxford University Press, pp. 292–319.

Zhao, X., J.D. Mullen, G.R. Griffith, W.E. Griffiths, and R.R. Piggott. 2000. "An Equilibrium Displacement Model of the Australian Beef Industry." *Economic Research Report* No. 4, NSW Agriculture, Orange.