Modeling OECD Agricultural Programs in a Global Context

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1. Introduction

Until the Uruguay Round (1986-93) of the General Agreement on Tariffs and Trade (GATT), world agricultural domestic and trade policies were largely unconstrained by global trade rules. Taxes and subsidies on manufactures were gradually diminished through a series of multilateral GATT rounds, but agriculture was generally exempted. This treatment allowed GATT members to pursue farm policies that met their unique national objectives and fit their circumstances, and contributed to the wide diversity in program design and protection levels found in global farm programs today.

The effects of import tariffs and export subsidies on trade and production are straightforward, but the production impacts of different types of domestic agricultural support can differ in important ways. Recognizing this, the Uruguay Round Agreement on Agriculture's (AoA) disciplines on domestic support defined expenditure limits and exemptions according to the way that the subsidy is implemented. Output or input price subsidies were presumed to directly distort production decisions; policies such as these were placed in the "amber box" and face binding expenditure limits under the AoA. Policies such as decoupled income support payments were assumed to be minimally production and trade distorting, and are not subject to any expenditure limits. Tightening expenditure constraints on domestic support according to program type, and leveling protection and support levels across countries, are central issues of the global debate on agriculture in the Doha Development Agenda, the current multilateral round at the World Trade Organization (WTO).

Understanding the production and trade effects of agricultural programs is critical for policy formulation. The effects of import tariffs and export subsidies will generally depend on the responsiveness of consumer demand and production to the relative price distortions that they introduce. The supply effect of a farm program, however, depends on a number of factors. One is its implementation, or how it influences producer incentives. For example, a price subsidy per unit of production directly increases returns, drawing resources into the sector and leading to higher production, while still allowing the full transmission of market price shocks to producers. In contrast, a price support program insulates producers from market price signals for their product, which weakens their supply response to market price shocks. Supply effects of farm programs are also influenced by market conditions, such as the efficiency of domestic capital and insurance markets. These conditions differ among countries, particularly between developed and developing economies.

The challenge for the analysis of global agricultural policy reform is to capture the incentive effects of the complex and highly differentiated farm programs found in diverse national settings. This is not always straightforward, as neither economists nor policy makers have a consensus view of the incentives created by some programs such as household income transfers, or "decoupled payments," repeated and predictable disaster payments, or whole-farm subsidies that allow full planting flexibility.

In this paper, we offer some perspectives on agricultural policy analysis using a multi-country computable general equilibrium (CGE) model, a class of applied economic model that has become an important tool for providing analysis to U.S. policy makers on critical trade issues. This paper describes the CGE model used in Burfisher, Robinson and Thierfelder (2002), (BRT), which is an agriculture-focused, global CGE model based on data from the Global Trade Analysis Project (GTAP) database. The model is differentiated by its explicit modeling of agricultural programs, including fixed producer price floors, export subsidies that vary with changes in the relative prices of domestic and world prices, and fixed household income transfers. The model is used to analyze scenarios for agricultural policy reform in three developed countries: the United States, the European Union (EU), and Japan. We focus on those three countries because they are large actors in global markets, and they use a broad range of domestic support programs. In section 2, we describe the basic features of the BRT CGE model, including its data and its treatment of agricultural policies. In section 3, we report the results from the BRT model scenarios of unilateral versus joint agricultural policy reform in the three countries. We focus on the impacts on trade volume, prices, and program costs. In section 4, we describe the sensitivity of results to changes in factor substitution and trade elasticity parameters; these sensitivity results should be of interest to all users of GTAP-based CGE models. We also describe the sensitivity of results to how farm programs are modeled. We present conclusions in section 5.

2. Empirical Model

Basic Model

The BRT CGE model builds on the standard, neoclassical specification of trade-focused CGE models, and it is described in detail in Burfisher, Robinson and Thierfelder (2002).[1] There are 16 countries or regions and 18 sectors in the model. Developing countries are aggregated into regions based on measures of food security from a study using cluster analysis by Diaz-Bonilla et al. (2000). They identify groups of countries with common characteristics based on five different measures of food security. Since we focus on agricultural policies, we include 9 primary agriculture sectors and 6 processed food sectors; the other sectors in the economy are broadly defined as natural resources, manufacturing, and services. There are five primary factors: skilled labor, unskilled labor, land, capital, and natural resources. Unskilled labor and capital are mobile across all sectors while skilled labor, land, and natural resources are specific to different subsets of sectors. We include three broad types of agricultural policies: agricultural tariffs, agricultural export subsidies, and domestic subsidies of various types.

Data on Agricultural Tariffs

The model incorporates most-favored-nation (MFN) bound and applied agricultural tariffs from the Agriculture and Market Access Database (AMAD). These rates include the *ad valorem*

[1] The multi-country software is an update of the GAMS code used in Lewis, Robinson, and Thierfelder (2003). The data on trade, production, and consumption are from the GTAP database, version 5.1.

equivalents of tariff-rate quotas.[2] Many developing countries have agricultural bound rates that are substantially higher than their applied rates. We remove applied rates, since these are assumed to be binding on imports. Nonagricultural tariff data are from GTAP version 5.1.

Regional trade agreements and non-reciprocal preferences that reduce MFN tariffs for selected bilateral trade flows have become increasingly important in the global trading system, but the availability of preferential tariff data is uneven. Our model includes U.S. and Canadian agricultural trade preferences provided to the Western Hemisphere, including NAFTA and the non-reciprocal preferences offered to developing countries. Chilean bilateral trade agreements and MERCOSUR are modeled in a stylized way, with zero bilateral tariffs among members. EU preferential tariffs apply to about two-thirds of its agricultural imports (Hasha, 2001), but a comprehensive database on its preferences is not available. Table 1 shows the import-weighted, average agricultural tariffs in the model for the U.S., EU, and Japan, inclusive of available bilateral trade preference data.

Table 1-Import-weighted, agricultural tariff rates of the United States, EU and Japan, in the CGE model (%)

	United States	EU	Japan
Rice	4.1	64.9	325.0
Wheat	0.1	61.4	249.2
Other grains	0.2	38.6	20.2
Horticulture	0.9	14.5	44.9
Oilseeds	0.8	0.0	76.4
Sugar	0.0	251.6	0.0
Other crops	2.0	2.7	18.7
Livestock	0.3	9.3	28.2
Milk	0.0	0.0	0.0
Resources	0.3	0.1	-1.1
Meats	2.2	62.7	49.0
Oils and fats	2.2	11.4	6.6
Dairy products	36.9	87.7	287.0
Processed rice	2.4	87.4	325.0
Processed sugar	16.1	76.4	116.1
Other foods	5.5	24.7	33.9
Manufacturing	2.6	4.3	2.3
Services	0.9	0.8	2.4

Sources: Agricultural and Market Access Database (AMAD), Global Trade Analysis Project (GTAP) version. 5.1, Harmonized Tariff Schedule of the United States Annotated, 2000.

Data on Agricultural Export Subsidies

We incorporate *ad valorem* export subsidy rates for 1998 from USDA (2001) for the U.S. and the EU (table 2). Other countries that use export subsidies, including Korea, Switzerland, and Norway, have been aggregated into large regional groupings in our model, and their subsidies are

[2] We do not explicitly account for Japan's import mark-ups, which are a charge to domestic consumers for purchases from government importers, who import duty-free. Instead, we applied AMAD tariff equivalents to all imports.

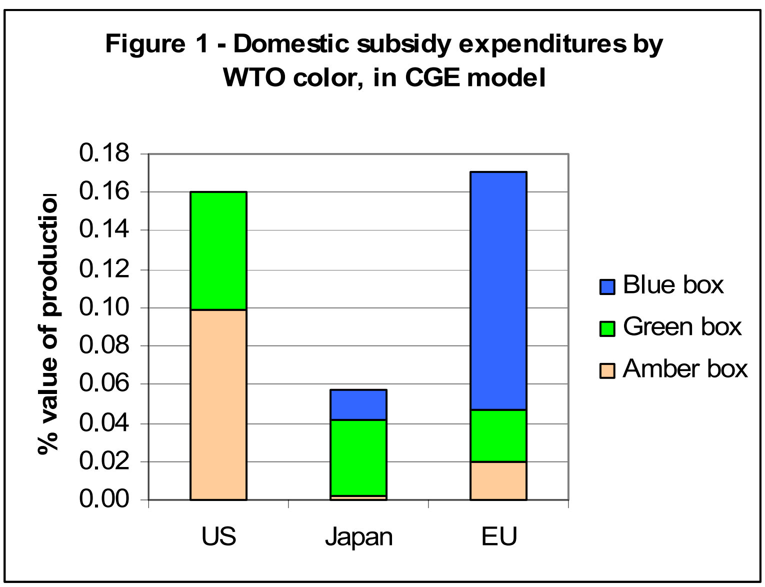
not accounted for. By 2000, subsidy expenditure outlays and subsidized quantities were below the allowed limits set by the AoA, with the exception of U.S. dairy subsidy volume, but the fill rates for the two elements of the subsidy constraints vary. For example, the EU filled only 8 percent of its wheat subsidy expenditure limit in 2000, but 71 percent of its volume limit. Leetmaa (2001) explains how the two constraints complement each other: when world prices are low, the volume limit becomes the binding export subsidy constraint; and when world prices are high, the value limit becomes the binding constraint. Depending on the scenario, it may be necessary to account for commitments and fill rates of export subsidies, and impose the WTO's limits. In BRT, policy reforms led to reduced or zero EU export subsidies, except for sugar. In 1998, EU sugar subsidies exceeded both value and volume commitments, but in 2000, these subsidies were under 70 percent of WTO limits.

Table 2 – Export subsidy rates in the CGE model, and 2000 outlays versus commitments

	Ad valorem export subsidy rate in CGE model	Actual outlay, 2000	Percent of 2000 outlay commitment filled	Actual export subsidy quantity, 2000	Percent of 2000 volume commitment filled
European Union	Percent	$US million	Percent	1000 metric tons	Percent
Rice	13.8	35.2	88	132.3	99
Wheat	9.1	118.1	8	10203.7	71
Other grains	34.2	208.7	18	7080.1	65
Horticulture	0.8	29.4	51	738.4	98
Meats	27.1	516.6	31	863.9	47
Dairy	24.2	1112.1	44	1581.7	77
Processed sugar	54.4	357.2	66	882.2	69
United States					
Poultry meat	0.0	6.8	47	11.5	41
Dairy	18.6	8.5	10	71.2	100

Sources: USDA (2001), and U.S. and EU export subsidy notifications to the WTO.

Data on Agricultural Domestic Support



We model the domestic agricultural support programs of the United States, EU, and Japan, using data from the 2000 Producer Support Estimate (PSE) database of the Organization for Economic Cooperation and Development (OECD) (2001). We do not use the market price support component of the PSE, and instead explicitly include agricultural tariffs and export subsidies. We use only the budgetary expenditure component of the PSE. Budget expenditures for the three countries totaled about $165 billion in 2000. About one-third of that amount was expenditures on input or output subsidies, or direct payments to producers; the remainder was general services expenditures on programs such as research and development, and on pest and disease control.

Following USDA (2001), we decompose PSE budget expenditures into WTO "colors" – the amber, green, and blue boxes that have different treatment under the AoA. We do this by linking farm expenditures in the PSE database to countries' most recent WTO notifications on their aggregate measures of support (AMS).[3] Different countries may notify similar programs under different WTO colors. For instance, many developing countries notify some input subsidies as green box because they are for development purposes, while other countries notify similar programs as amber. In the model, the policies have the same economic impact. We include de minimus expenditures, although the WTO AMS notification excludes support that does not exceed 5 percent of the member's total value of production (10 percent for developing countries). For example, we include U.S. irrigation subsidies, which are considered de minimus. Subsidy rates in the CGE model, by WTO color, are shown in fig. 1. In the BRT reform scenarios, we remove only the distorting amber and blue box support. We assume that green box programs are not included in reforms, although it is argued that some types of green box support can influence production levels.

Modeling Exogenous and Endogenous Types of Agricultural Programs

We model five generic types of agricultural programs. Three are exogenous: *per unit output subsidies, household income transfer payments*, and *other minimally distorting payments.* Two types are endogenous: *variable output subsidies* and *price support payments*. In table 3, we describe how the five policy types operate in the CGE model, and describe the programs in the United States, EU and Japan by policy type.

Table 3 – Mapping domestic subsidies from OECD PSE data into WTO "colors" and CGE model (Note, table prints at end of document)

O*utput subsidies* are fixed *ad valorem* subsidies per unit of output. They directly change relative prices and shift resources toward production of the subsidized goods. Since the production technology in the model uses fixed input-output coefficients for intermediate inputs, a subsidy to intermediate goods operates like an output subsidy, and we treat them identically. Fixed, per-unit output or input subsidies represent a relatively small share of subsidy expenditures. In 2000, about one-third of EU subsidies in our database, excluding general services, were output or input subsidies; 9 percent of U.S. subsidies were in this category, and no expenditures by Japan were modeled in this way.

Household income transfer payments are fixed, lump-sum payments that are not linked to the current level of production or current prices. Income transfers in the model include U.S. production flexibility contracts and EU set-aside payments. We link the EU set-aside payments to a 10-percent set-aside of grains and oilseeds land area.

[3] The WTO AMS notifications of the five countries used for this component of the database were from these years: Canada (1998), U.S. (1998), EU (1998/1999), Mexico (1998), and Japan (1998).

The effect of income transfers on agricultural production is a controversial issue for policy makers and economists. The growing body of theoretical literature on these decoupled payments has described a number of market features that could lead households to respond to transfers in ways that have direct effects on farm production. Rude (2000) describes the roles of risk aversion, increasing returns to scale, and debt constraints in creating links between transfers and production decisions. Vercammen (2001, 2003) describes several potential links: rural labor market rigidities, bequest motives, a rising marginal tax rate, a wedge between borrowing and savings rates, and initial debt to asset ratios. OECD (2001) describes the possible insurance and wealth effects of decoupled payments, and their possible effects on exit, expectations and responsiveness. Decoupled payments can also lead to a wealth effect on the rural labor supply (Findeis, 2002).

The emerging empirical literature relevant to decoupled income transfers in the U.S. suggests that they are unlikely to have significant production effects given the efficiency of U.S. agricultural markets for land, labor, and capital, and for managing risk (Gardner, 1992; Collender, 1999; Harwood et al., 1999). An analysis of the U.S. experience with decoupled payments under the 1996 farm legislation found no evidence at the aggregate level that receipt of income transfers affected investment rates in machinery and equipment, although some households are probably credit constrained (USDA, 2003). However, the payments may affect production indirectly, by changing household choices about work, consumption, savings and investment. USDA (2003) found that farm households that received the payments had higher rates of consumption out of income than nonrecipient farm households of comparable incomes. Dewbre and Mishra (2002) found that U.S. households receiving decoupled payments reduced their on-farm hours, consistent with the expectation that changes in households' wealth will lead to adjustments in their labor-leisure choices. However, the effect is small. Roe, Somwaru and Diao (2002) showed that if U.S. agricultural capital markets are complete, direct payments have long run effects on land asset values and rental rates, but no effect on agricultural production. Lin (2003) reports that U.S. countercyclical payments, which are a hybrid program in which payments on a fixed historical base area move inversely with market prices, have generated a "swap" market. Financial institutions purchase the farmer's right to the payment, absorbing the risk of payment reduction or loss. Alternatively, some farmers are ensuring a level of CCP benefit by participating in futures markets. Anecdotes such as this reinforce the view that U.S. markets for rural capital and risk management are efficient, and that links between household income transfers and production decisions are likely to be weak.[4]

In our CGE model, we assume that factor markets in developed countries are efficient, so that income transfers have no direct incentive effects on production. Our model structure does not allow us to address other issues related to income transfers: The model has a single aggregate household; we do not incorporate a labor-leisure choice in the model; and we do not model

[4] Market inefficiencies in developing countries may create stronger links between income transfers and farm production. For example, decoupled PROCAMPO agricultural income transfers in Mexico were found to lead to increased farm income, which was attributed to their role in relieving farmer credit constraints and stimulating farm investment and output (Cord and Woton, 1998; Sadoulet, de Janvry and Davis, 2001).

intertemporal savings and consumption choices.[5] These are areas of model development that are likely to become increasingly important for agricultural policy analysis.

Other minimally distorting payments are fixed budget expenditures that have minimal links to production decisions and which satisfy WTO green box criteria. These programs include payments for land conservation and management, pest and disease control, infrastructure, and some disaster assistance. We account for these fiscal expenditures but assume they have no production effects.

We allow for endogenous farm programs, where applicable. Our approach follows a literature of endogenous policies in CGE models that began with a single-country model of U.S. farm programs by Kilkenny and Robinson (1990) and Kilkenny (1991). Burfisher, Robinson and Thierfelder (1992) extended that analysis to a two-country CGE model with farm programs in the U.S. and Mexico. Weyerbrock (2001) modeled intervention prices and endogenous export subsidies in a multi-country CGE model of the EU with farm programs.

In our CGE model, we consider the EU compensatory payments (blue box) to be a *variable output subsidy*. These subsidies are paid directly to producers of grains, oilseeds, protein crops, and some animals. Introduced in 1993, the compensatory payments were designed to compensate EU producers for declining guaranteed producer price levels (Hasha, 1999; Walter-Jorgensen and Jensen, 2001). They influence production decisions because payment eligibility requires current production of supported products. Since the total payment is fixed, the rate per unit of output contracts (expands) when output expands (contracts).

We allow endogenous *price support payments* to insulate producers from falling output prices by providing guaranteed floor prices. The domestic policies in the U.S., EU, and Japan offer different levels of insulation, and face different AoA disciplines. The U.S. marketing loan rates are an amber box policy that provides payments to farmers that increase as market prices decline below the loan rates. Japan's income stabilization program provides guaranteed producer prices for rice and other commodities (Japan, 2000). Their deficiency payments adjust with changes in market prices. Japan's rice program requires a reduction of rice acreage, which can be diverted into other uses and is eligible for other commodity program benefits. Japan's rice program is a blue box expenditure, while other income stabilization payments have been notified as amber box support. In the EU, export subsidies are used to clear excess domestic supplies resulting from the EU's fixed intervention prices for grain, oilseeds, livestock, dairy, and processed sugar.

An implication of modeling programs endogenously is that there can be strong interaction effects when simulating the separate removal of each type of agricultural policy – tariffs, domestic support, and export subsidies. In our model, removing tariffs alone while price support programs remain in place can lead to larger world price swings, since demand will increase but supply response within certain price ranges may be limited. Similarly, the removal of export subsidies in our model would imply the dismantling of some domestic price supports. The separate reforms are not additive. Nevertheless, many analyses of agricultural policy reform describe policies as fixed *ad valorem* price wedges, decomposing their separate effects, and

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[5] See Roe, et al. (2002), for an analysis of the effects of U.S. decoupled payments on farm consumption and savings decisions, using an intertemporal, economy-wide general equilibrium model.

generally finding that tariffs are the most distorting policy (e.g., Diao, et al., 2001; Hoekman, et al., 2002, Tokarick, 2003). We argue that our model captures these policies more realistically, by depicting them as linked elements of an integrated support system.

3. Results of Agricultural Policy Reform Scenarios

Scenarios and results

We use the CGE model to analyze two experiments: (1) full removal of all agricultural import barriers, amber and blue domestic subsidies, and export subsidies by the U.S., EU, and Japan; and (2) full global reform of agricultural tariffs and subsidies. We decompose the first experiment by imposing unilateral reforms by the U.S., the EU and Japan. Our main conclusions are:

- *Insulating producers from market prices weakens a country's production response to partners' reform.* When producers receive support through deficiency payments or intervention price programs, adjustments to reforms in non-reforming partner countries occur primarily through changes in subsidy payments, rather than through production (table 4). For example, when the EU (Japan) eliminates its domestic support and trade restrictions in agriculture, U.S. price support payments decline by 85% (74%) as agricultural supply and demand from the EU (Japan) changes, but total U.S. agricultural output changes slightly, by less than one percent in both scenarios.

- *Domestic agricultural policies are, to some extent, a response to market conditions created by distorting policies of other countries.* One country's farm program costs are affected dramatically by another's unilateral reform.[6] The effects of trade partners' reforms in reducing U.S. program costs are especially pronounced. Japan's farm program costs increase when the U.S. and EU reform mainly because their reforms cause Japan's import price of rice to decline.

- *Multilateralism leads to a "softer landing" for production than unilateralism.* In all three countries, domestic agricultural production contracts with unilateral reform. The adjustment is smaller when all three countries reform multilaterally, reflecting that each country's domestic policies are partly a response to subsidies in other countries. For example, the contractionary effects of U.S. unilateral reform on U.S. farm production are partially offset by the effects of EU and Japan reforms on U.S. production. This suggests that undertaking domestic reform in a multilateral context can reduce both the allocative inefficiencies due to a country's own policies as well as the world market distortions that provide a credible rationale for those domestic subsidies.

- *Domestic price supports partially neutralize a county's reforms of its other "pillars."* Market access has been argued to be the key element in global reform because domestic subsidy rates are relatively low and because open borders raise the costs of domestic price supports, creating pressures for their reform. However, continued expenditure on programs

[6] Farm program costs include agricultural production subsidies and export subsidies, but do not include offsetting agricultural tariff revenue, following standard reporting practice.

that insulate producers from price signals suggest that the benefits of market access reforms may be relatively limited in the context of a partial or gradual reform process for domestic support.

- *Complete liberalization of world agricultural tariffs and the elimination of farm support in OECD countries has a dramatic impact on world trade.* We find that total world agricultural trade increases by 33.3 percent and the world agricultural price increases by 12.5 percent (table 7).

Table 4 – Effects of agricultural policy reform by the EU, U.S. and Japan
Note: table prints at end of document

4. Sensitivity Experiments

CGE models simulate an economy in equilibrium. The structure of the model imposes an accounting framework that balances the circular flow of income and expenditure, and savings and investment, within an economy typically characterized by a fixed supply of primary resources. The impacts of a shock are primarily structural, as resources and demand shift among sectors in response to changes in relative prices. Economic responses in the model reflect the structural parameters in the model base, including the base shares of factors in value added, and shares of trade in production and consumption. The range of response to shocks can vary significantly under different values for elasticity parameters, which describe the responsiveness of producers and consumers to relative price changes. In this section, we test the sensitivity of our model to different values of factor substitution and trade elasticities.[7] In addition, we show the impacts of our endogenous modeling of agricultural subsidies on supply response, fiscal costs of farm programs costs, and agricultural trade volumes and prices, compared to a specification with exogenous programs. We show the importance of explicit modeling of farm programs.

Sensitivity of Supply Response to Factor Substitution Elasticity Parameters

There is a long-standing debate in the agricultural profession on the supply responsiveness of agriculture to price changes. Reduced form econometric models in which economists estimate the relationship between supply and producer price often find relatively low aggregate agricultural elasticities of supply (less than one), and somewhat larger cross-price elasticities. One problem with these estimates is that in many countries, price or market rigidities introduced by farm programs influence the supply response. Flex-acres in the U.S. during the early 1990's, on which production did not receive payments nor affect payments on program acres, provided an opportunity to analyze market-driven U.S. supply response. A study of supply on flex-acre land by Lin et al. (2001) still found a low aggregate supply elasticity, but somewhat increased cross-price elasticities relative to supply response during 1986-90.

The production function approach to estimating supply elasticities accounts for input costs as well as producer prices and generally results in a larger estimated supply response. Supply elasticities in a general equilibrium model are closer to the production function approach, but they are structural, rather than estimated, although they can be calibrated to replicate estimated

[7] We test sensitivity to parameter values, not the sensitivity to functional form.

supply responses. In a CGE model, producers respond to the costs of intermediate and factor inputs (inclusive of input taxes and subsidies) and revenue from market prices, and any taxes and subsidies on output. General equilibrium supply elasticities are therefore sensitive to the specification of functional forms and to parameter values that influence either input costs or market demand.

In a CGE model, supply response is most directly linked to parameters that describe production technologies and factor supply. In the BRT model, we assume fixed aggregate supplies of agricultural land, capital, and labor, with factors fully mobile across sectors. Intermediate input substitution elasticities are zero, reflecting the Leontief (fixed coefficient) production technology in the model, and we assume a constant elasticity of substitution in agricultural value added among land, labor types, and capital inputs of 1.2 for all countries and sectors. The elasticity parameters in our CGE model are reported in table 5.

Table 5 – Elasticity parameters in the CGE model
Note: table prints at end of document

When all factors are mobile and sectors are a small share of GDP (as is the case of agricultural sectors in OECD countries), long run supply curves are almost horizontal and supply elasticities are quite high. The only reason the supply elasticities are not essentially infinite is that land is specific to agriculture and sectors compete for it.

We test for the long-run agricultural supply responsiveness in the U.S. and the EU that are implied by the structure and parameters in the BRT model. Our experiment is a one-percent increase in government stock demand for wheat, in a version of the model with no farm programs. To show the sensitivity of the calibrated supply response in our model to our parameters, we show how our supply response changes across a reasonable range of factor substitution elasticities:

- Base model: Factor substitution elasticity of 1.2 and all factors inter-sectorally mobile;
- Low factor substitutability: Factor substitution of .3 (one-quarter of the base parameter of 1.2);
- High factor substitutability: Factor substitution of 4.8 (four times the base parameter of 1.2).

We find that the own-price supply elasticity of wheat in the U.S. is very sensitive to factor substitution assumptions, with an elasticity that ranges between 20.2 and 93.1. U.S. supply response in our multi-country model is similar to the levels and range of response found in the single country U.S.-CGE model developed by Hanson *et al.* (1996).[8] U.S. wheat output increases by 1.3 percent in both the high and low substitution models, but the price effects are much larger in the low elasticity case. U.S. output must expand by more than the 1 percent increase in inventory demand because of the large spill-over effects on world markets, where almost 50 percent of base output is sold. Wheat supply in the EU is quite sensitive to factor market substitution assumptions, with own-price supply elasticities ranging from 26.6 to 242.2.

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[8] The supply response in CGE models tends to be much higher than the supply elasticities reported in the econometric literature, indicating that importance of general equilibrium effects.

In the U.S. and the EU, other agricultural sectors such as other grains and oilseeds, which compete for primary factors, contract as wheat output expands. All cross-price elasticities with respect to the price of wheat are negative. In both countries, factor shares of value added in wheat, other grains, and oilseeds are nearly identical. Their supply response is therefore not significantly influenced by sectoral differences in factor intensities.

Table 6 – Sensitivity of own and cross-price long-run supply elasticities for wheat in BRT CGE model to different factor substitution elasticities

	United States			EU		
Base model	Wheat own-price	Other grain Cross-price	Oilseed cross-price	Wheat own-price	Coarse grain cross-price	Oilseed cross-price
Base	47.3	-0.3	-0.6	83.8	-0.2	-0.9
Low factor substitutability	20.2	-0.3	-0.7	26.6	- 0.3	-0.7
High factor substitutability	93.1	-0.3	-0.5	242.2	0.0	-1.3

Notes: Supply response is calculated with respect to an exogenous, 1-percent inventory demand shock for wheat. Cross-price elasticities are with respect to changes in the price of wheat, with all factors mobile.
Source: Author calculations.

Sensitivity of Trade Results to Trade Elasticity Parameters

In the model, there is joint production of commodities for domestic and export sales, where the allocation of output between domestic and export markets is described by a nested, constant elasticity of transformation (CET) function between domestic sales and exports, and among exports to each trade partner. Export supply is a function of relative prices, the transformation elasticity, and the export share of output. The export share and the elasticity of export transformation are two key parameters. Since the producer price is a weighted aggregation of the export and domestic sales prices, a large export share raises the pass-through of increased world prices to the domestic market. A high elasticity of transformation reduces the domestic production effects of export growth.

Similarly, consumers allocate their expenditures between imported and domestic varieties of a composite good. We use the Almost Ideal Demand System (AIDS) specification in which the expenditure shares are a function of total expenditure on the composite commodity and relative prices, and domestic good and imports by region are imperfect substitutes. When consumers can shift easily from domestic to imported varieties, the effects of a relative price shock on domestic supply are stronger. Similar to the CET share parameter, the import share of consumption influences the transmission of world prices to the domestic market. The consumer price of the composite good is a weighted average of the domestic and import prices, and the larger the share of imports in consumption, the greater is the transmission of world price shocks to the domestic market.

Our elasticities differ by sector, with import substitution parameters for primary and processed agricultural sectors ranging between 1.8 and 2.5, and CET elasticities ranging between 1.5 and 3. We draw on the growing body of empirical literature to provide a general range for the elasticities in our model. Roland-Holst et al. (1994) report an estimated import substitution parameter for agriculture of 1.5 for the U.S. and a CET elasticity of 3.8. They report similar elasticities for food processing as 0.9 and 0.8. Hummels (1999) estimated import substitution elasticities for animals, cereal, and a large number of processed food sectors, which are generally quite large - over 8 for some processed food products. Galloway et al. (2000) estimated short and long-run Armington elasticities for a large number of processed foods industries, generally finding parameter values that were close to one.

Our sensitivity experiments explore a reasonable range in trade elasticity parameter values, in which we set both the CET and import elasticities at one-half and two times larger than the parameters in our base CGE model. We compare the trade impacts of a full agricultural liberalization scenario in which we remove global domestic agricultural support and tariffs. As would be expected, we find that world agricultural trade and agricultural prices are more responsive to a trade policy shock when there is high tradability among domestic and traded varieties (table 7). The large range in trade and price outcomes across the elasticities underscores the importance of the underlying econometric estimations relied on in a CGE model.

Table 7 – Sensitivity of global agricultural trade and price effects of global agricultural tariff and farm program removal to trade elasticities (% change from base)

Base model	World agricultural price	World agricultural trade
Base tradability	12.5	33.3
Low tradability	8.5	20.3
High tradability	14.9	46.1

Note: World agricultural price is the trade-weighted aggregate agricultural export price. Trade is reported in volume terms.
Source: Author calculations.

Sensitivity of Supply Response, Fiscal Costs to Endogenous Farm Program Modeling

We analyze the sensitivity of supply response and farm programs costs to the way in which farm price support programs are modeled. We use a short-run version of the model with sector-specific land and base values for factor substitution and trade elasticity parameters. When a factor, such as land, is sector-specific, the short run supply elasticities are comparable to econometric partial equilibrium estimates. Our experiments are separate, one-percent inventory demand shocks for two sectors each in the United States and the EU, under two types of farm program modeling. In one model, we assume that price support/export subsidy programs operate endogenously, insulating producer supply response. In the second model, we assume that these programs operate as fixed, *ad valorem* output and export subsidies. We find that endogenous farm programs significantly impact the supply response and program costs.

When farm programs maintain a fixed market price, there is no longer a direct effect of the sector's market price change on its output. However, there are indirect effects that operate through the sector's cost structure and through its competition with other program and non-program sectors for primary resources. To the extent that an agricultural sector uses itself as an input, often for seed, its input cost changes as the market price changes. Intermediate input costs for commodities that use the supported commodity also change. As output adjusts in other agricultural sectors, output in the supported commodity is affected through linked factor markets.

In the endogenous model, U.S. deficiency payments adjust to support the producer price whenever the market price falls below it.[9] Producers do not respond to the market price when the market price is below the fixed price floor. The U.S. own-price elasticity for wheat, grains and oilseeds is significantly lower with endogenous price support compared to a model with fixed *ad valorem* subsidies (table 8). Wheat and oilseeds production actually decline following an exogenous increase in demand which raises the market price, and the supply elasticity is negative. In this case the indirect effects generate negative supply elasticities.

Table 8 – Short-run supply response to U.S. stock demand shocks under different modeling assumptions about marketing loan program

	Endogenous price support		Fixed, *ad valorem* price support	
	Own-price supply elasticity	Percent change in price support costs for commodity	Own-price supply elasticity	Percent change in farm price support costs
Wheat	-0.2	-27.3	3.8	0.2
Oilseeds	-0.3	-23.4	3.5	0.2

Notes: Demand shocks result from separate, exogenous one-percent increases in government stock demand for each commodity. Land is sector-specific.
Source: Author calculations.

Consider the changes in wheat. Increased inventory demand increases its relative market price. Intermediate users, including livestock and processed foods, face increasing input costs, and their supply contracts. The processed foods sector has strong intermediate demands for fruits and vegetables which do not receive price support, reducing demand for this sector. As the fruits and vegetable sector contracts, its demand for land and other factors of production declines, which lowers value-added costs for wheat, and contributes to its expansion. However, rising own-use intermediate input costs for wheat creates pressure for wheat output to contract. In the short-run, the own-use effect on cost dominates. In the long-run, with greater factor mobility, the effect of an increased supply of land dominates. The own price supply elasticity is 7.1, and wheat output expands.

These results suggest that econometric estimates of own-price supply responses in the presence of farm price support programs may not even get the correct sign, and they miss important general equilibrium effects related to changing factor returns and intermediate demand. These results also underscore the importance of specifying the correct structural model, especially regarding how agricultural support programs operate, although this issue typically receives less attention than elasticity parameters.

In the EU, export subsidies support a fixed intervention price facing both producers and consumers. Export subsidies and trade absorb most of the domestic demand shock when endogenous subsidies are in effect (table 9). In the case of wheat, the upward domestic price pressure due to inventory build-up is large enough to result in the elimination of wheat export subsidies, and total export subsidy program costs decline. For dairy, increased domestic supply increases export supply as a result of the large share of exports in base production in these sectors. The very large role of the EU in the world dairy market trade, in which it accounts for

[9] For a detailed description of how U.S. farm programs operate, see Westcott, Young and Price (2002).

nearly one-half of global trade, leads to spillover effects on world markets. The expansion in EU export sales drives down the world price and increases the need for export subsidies; driving up unit subsidy costs and total export subsidy expenditures. In contrast, when the export subsidy program is modeled as fixed *ad valorem* price wedges, production responds to market prices and there is a smaller role for exports in equilibrating the domestic market.

Table 9 – Short-run supply and trade response to EU demand shocks under different modeling assumptions about export subsidies						
	Endogenous export subsidies and intervention prices			Fixed, *ad valorem* export subsidies		
		Percent change from base		Percent change from base		
	Own-price supply elasticity	Export program costs for commodity	Exports	Own-price supply elasticity	Export program costs for commodity	Exports
Wheat	1.2	-100.0	-9.0	6.7	0.3	0.5
Dairy	-	503.5	40.8	49.6	0.2	0.5

Notes: Demand shocks result from separate, one-percent exogenous increases in government stock demand for commodity. Supply elasticities are calculated with respect to the domestic market price; there is no change in the domestic market price for dairy when the export subsidy program is endogenous. Land is sector-specific. Exports are reported in volume terms.
Source: Author calculations.

Sensitivity of Trade and World Prices to Endogenous Farm Program Modeling

Finally, we explore the sensitivity of results for world agricultural trade and prices, and fiscal costs, to our modeling of farm programs. We use base elasticity parameters and allow full factor mobility. Our scenario is a 50 percent reduction in global agricultural tariffs. We compare results from our model with a model in which all farm programs are described as fixed*, ad valorem* wedges.

Alternative modeling of farm program modeling does not result in significant differences in aggregate trade flows, however, there are important differences relating to commodity-level trade, farm program costs, bilateral trade flows, and world prices (table 10). When programs insulate producers in the U.S., they do not respond to the expanding market opportunities created by tariff reform. U.S. wheat and other grains grain exports actually decline, while the world market shares of other suppliers, including Canada and Argentina, increase. The policy implication from this model – that subsidies weaken the ability of competitive sectors to respond to growing demand – is not found in the model in which subsidies are modeled as fixed *ad valorem* rates. With smaller supply response in the model with price support programs, the resulting change in world prices is 20 percent higher than in the model with fixed price wedges. In a model with endogenous price support, this lowers farm program costs in the case of the U.S., while in the fixed price wedge model, subsidy expenditure are found to increase with growth in production and exports. In the case of the EU, farm program costs grow faster when subsidies are endogenous rather than fixed price wedges, reflecting compositional changes in demand and supply that lead to falling world prices for commodities that receive EU export subsidies.

Table 10 – Sensitivity of agricultural trade and price effects of 50% cut in global agricultural tariffs to farm program modeling assumptions (% change from base)		
	Base model	Model with fixed *ad valorem* domestic and export subsidies
World agricultural trade	12.6	12.3
World agricultural price	4.6	3.8
U.S. agricultural exports	8.9	10.6
U.S. farm program costs	-26.7	1.9
EU agricultural exports	19.3	18.1
EU farm program costs	5.7	1.6
U.S. wheat exports	-2.9	8.4
U.S. other grain exports	-12.9	4.7
Canada wheat exports	24.8	20.3
Canada other grain exports	27.5	7.4
Argentina wheat exports	4.8	4.5
Argentina other grain exports	11.8	7.5
Note: The world agricultural price is the trade-weighted aggregate agricultural export price. Trade is reported in volume terms. Source: Author calculations.		

5. Conclusions

Policy makers have increasingly relied on computable general equilibrium models to analyze global agricultural policies. The strength of these models is their comprehensive perspective on the ways in which commodity taxes and subsidies influence not only producer incentives, but also intermediate demand, factor markets, the non-farm economy, national income and welfare, and trade partners. At the same time, the complexity of these models can generate some skepticism about their results. One critique is that these models typically incorporate ad hoc assumptions about elasticities of supply and demand. Another is that, because of their complexity, the key elements that are driving the results of a scenario are not always transparent.

In this paper, we deconstruct a CGE model that was recently used to analyze farm programs in the U.S., EU, and Japan. The model incorporates the base GTAP data on production, trade, and structural parameters that are found in most global CGE models in use today. We calculate the agricultural supply response in that model, and show its sensitivity to a reasonable range of assumptions about factor market elasticities. We also show the sensitivity of world agricultural trade and price results in the model to a range of values for import demand and export supply elasticities. We find that the size of these parameters matter to the magnitude of trade results, but there is a growing body of empirical literature that can guide the choice of appropriate trade parameter estimates.

Finally, we show the sensitivity of supply, fiscal program costs, and world agricultural trade and prices to the way in which farm subsidies are modeled. We find that modeling assumptions about farm programs matter significantly to the results of agricultural policy analysis. The three countries in our study use domestic price support and export subsidies that vary with market prices, absorbing market price shocks and lowering agricultural supply response. When fixed *ad valorem* wedges are used to represent these programs, policy analysis is incorrect and, in some cases, such as in the analysis of short-run supply response, farm program costs, and trade, the sign is wrong.

Since the Uruguay Round concluded, farm programs in developed countries have become more complex and their links to production more ambiguous. In part, these policy changes result from the principles of the Agreement on Agriculture, which imposed different disciplines on policies depending on their implementation and their presumed impacts on production and trade. While some aspects of new farm programs will require more research, as we accumulate experience with their effects on supply, we argue that it is critical that the differentiated incentive structures of OECD farm support be incorporated into modeling frameworks in order to provide realistic and useful insights to policy makers.

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Table 3 – Mapping agricultural subsidies from OECD PSE data into WTO "colors" and CGE model

	Output subsidy		Input subsidy		Variable output subsidy	Farm household income transfer			Price support payment			Other
Policy type in in CGE model	Output subsidy, fixed per unit of output		Input subsidy, fixed per unit of input		Variable per unit of output	Direct payment to household, fixed			Price subsidy, endogenous, fixed producer price			Minimally distorting
WTO treatment	Amber	Blue	Amber	Green	Blue	Green	Blue	Amber	Amber	Blue	Export subsidy	Green
EU programs	Prod. Aid and subsidies to crops and livestock, interest subsidies	Prod-uction aid for peas, beans	Production aid and payments per ha. for crops, production aid for lvstk., fodder, silage		Compensatory payments and lvstk. Premiums	Transitional payments to Sweden, payments for cessations, conservation, income aid	Set-aside payments				Intervention prices and export subsidies	Land mgmt, organic farming, pest and disease control, conservation, farm improvement, agro-tourism, sub-national payments
Japan programs	Interest and insurance subsidies								Price stabilization for eggs, horticulture	Price stabilization with supply controls for rice, soybeans, milk		Extension, pest and disease control, infrastructure, rice diversion/environment al payments
U.S. programs			Crop insurance	Input credit subsidy		PFC, Credit on assets, income tax concessions		Market loss assist-ance	Loan deficiency payments and marketing loan gains			Extension, conservation, irrigation, farmland protection, crop disaster
Production effects in CGE model	Increase marginal returns by raising revenue or lowering input costs, resulting in increased output. Increased supply reduces market prices, offsetting some of the benefit.				Increase market returns but per unit return varies with output, eliminating marginal incentives.	Income transfers to household, with no links to production decisions or prices.			Provides price floor for producers. When market prices are below floor, producers are insulated from market prices. When market prices rise above floor, farmers respond to market prices.		Provides domestic intervention price floor for producers/consu mers. Export subsidies maintain intervention price if world price falls below it.	No production or price effects.
Program costs in CGE model	Subsidy costs increase(decrease) when output increases(decreases).					Subsidy costs fixed.			Subsidy costs increase (decrease) when market prices fall (rise), if market price is below floor price.		Subsidy costs increase (decrease) when world prices fall (rise) relative to intervention price.	Subsidy costs fixed.

Source: Authors' calculations using approach described in USDA (2000), data from OECD (2001), country notifications on domestic support to the WTO, Japan (2000), Walter-Jorgensen and Jensen (2001), Hasha (1999), Dyck (2000).

Table 4 – Effects of agricultural policy reform by the United States, EU and Japan (% change from base)							
Effects on countries:	Total farm program costs[1]	Variable program costs [2]	Total agricultural output	Farm output	Processed agriculture output	Total agricultural exports	Total agricultural imports
U.S.							
All three reform	-40.70	-100.00	-1.59	-2.08	-1.38	11.16	7.31
U.S. reforms	-40.70	-100.00	-2.88	-4.08	-2.34	-1.14	8.12
Japan reforms	-19.83	-73.62	-0.60	-0.90	-0.46	5.87	0.66
EU reforms	-22.95	-85.38	-0.96	-1.01	-0.90	5.33	0.39
EU							
All three reform	-85.25	-100.00	-6.01	-7.68	-5.27	4.03	31.07
U.S. reforms	-2.25	-36.14	-0.11	-0.04	-0.14	2.00	0.09
Japan reforms	-2.21	-36.01	0.11	0.13	0.10	3.48	-0.89
EU reforms	-85.25	-100.00	-6.53	-8.34	-5.73	-1.80	31.43
Japan							
All three reform	-72.19	-100.00	-2.31	-6.21	-1.21	7.83	42.45
U.S. reforms	4.86	13.96	-0.06	0.42	-0.20	2.53	1.53
Japan reforms	-72.17	-100.00	-2.38	-6.68	-1.17	1.64	42.18
EU reforms	4.06	11.22	0.06	0.67	-0.11	3.86	0.29

1/ Farm program costs include domestic subsidies and the EU's export subsidy expenditures for the agricultural sectors. We do not include agricultural tariff revenue.
2/ Variable program costs refer to U.S. and Japan price support payments and EU export subsidies.
n.a. means not applicable.
Source: Burfisher, Robinson and Thierfelder (2002).

Table 5 – Elasticity parameters in the CGE model									
	Rice	Wheat	Other grains	Horticulture	Oilseeds	Sugar	Other crops	Livestock	Milk
Import substitution	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Export supply transformation (nested)	3	3	2	2	2	3	3	2	2
Factor substitution in production function	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Meat	Oils and fats	Dairy	Processed rice	Processed sugar	Other foods	Natural Resources	Manufacturing	Services
Import substitution	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0.7
Export supply transformation (nested)	2	2	2	2	1.5	2	2	2	2
Factor substitution in production function	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.5