The Healthy Farmland Diet:
How Growing Less Corn Would Improve Our Health and Help America's Heartland

Technical Appendices

Appendix A: Model Overview

We utilize a "general equilibrium" economic model to consider how U.S. cropland might change in response to changes in diet. Specific advantages of using a general equilibrium model are that we can: expand the scope of hypothetical dietary changes; analyze how changes in market prices in one sector affect the consumption of other goods and food products; use equations derived from economic theory (instead of making ad hoc assumptions) to examine the international implications of changing trade flows; and consider how farmland will substitute for the use of other resources—such as labor, capital, and intermediate inputs—in the production function of crop producers.

Our economic model was developed by the Global Trade Analysis Project (GTAP), which assembles and calibrates international input-output ("I-O") tables and trade data to create a database that represents the global economy (Brockmeier 2001; Hertel and Tsigas 1997). I-O tables are accounting relationships that show the final sales for each sector, the expenditures that each sector makes for intermediate inputs, and the "value-added" contribution that each sector makes to gross domestic product. The standard version of GTAP that we use in this report is static, which implies that it captures the global economy at one particular time. The reference year for data in GTAP 7 (the version of the model we use) is 2004. We selected GTAP because it is accessible, provides transparency and the capability to replicate and improve upon previous efforts, and has been used in land-use modeling in other contexts.

Because the computational and data requirements inherent to developing an accurate model of the global economy are considerable, GTAP aggregates regions and sectors. In particular, GTAP 7 contains 129 regions, each of which can either be a single country or collection of countries, and 57 sectors that each produces one good. Goods and intermediate inputs in GTAP are traded globally and are distinguished by country of origin. This implies that GTAP can be useful for evaluating the impacts of sectoral policy changes, such as tariffs, quotas, and subsidies, on global trade flows.

GTAP's structure is premised on the "circular flow model." This framework depicts the interdependence between the supply and demand for goods by tracking monetary value flows—GTAP's unit of measurement—through the economy. Households desire to consume goods that firms produce, but these consumers can purchase goods only with income. They can earn income by "selling" the services of factors of production—such as labor—to firms. Simultaneously, firms desire to sell goods, but they need inputs to produce them. In GTAP, firms can buy intermediate inputs from other firms and pay for primary factors of production from the "regional household." GTAP's primary factors of production include land, skilled labor, unskilled labor, natural resources, and capital. GTAP's "regional household" allocates this revenue among private household consumption, government consumption, and savings.

Regional governments can levy taxes on firms either within or outside their region. GTAP utilizes behavioral equations, derived from economic theory, that govern: how revenue is allocated among consumers, governments, and savings; consumer purchasing decisions; and firm production decisions. In GTAP, global savings are equal to global investment. There are adjustment costs in the model for global trade flows, based on the "Armington assumption," which implies that imports and exports don't respond perfectly to shocks.

GTAP is a "computable general equilibrium" (CGE) model, which has several implications. First, for a given set of market prices, goods will be consumed by households to achieve their greatest level of satisfaction, or "utility." Second, for a given set of market prices, producers will produce the quantity of goods that will maximize their profits. Because GTAP assumes competitive market conditions, firms earn zero profits in equilibrium. Third, market prices adjust so that the quantity supplied of a good will equal the quantity demanded for the good, and this condition will simultaneously occur for every product. This last implication is called a "market clearing" condition.

GTAP's production function reflects a nested series of actions. First, firms determine the relative percentage of primary factors of production and intermediate inputs purchased from other firms. Formally, GTAP's production function is structured such that there is a constant elasticity of substitution (CES) between these two types of aggregated inputs.[1] We utilize a CES value of

[1] The elasticity of substitution is the proportional change of the quantities of two inputs relative to the proportional change of their marginal products. An elasticity of substitution of zero implies that two inputs are perfect complements, or cannot be substituted, whereas a value of infinity implies that they are perfect substitutes. Specifying this ratio as "constant" implies that the ratio does not change with as a function of input quantity.

zero— the standard value used in GTAP—between primary production factors and intermediate inputs (Hertel et al. 2008b).

Second, firms select inputs within those categories. Firms in GTAP utilize intermediate inputs according to a constant returns-to-scale production function, which implies that increases in output require the same proportion of inputs needed for existing levels of production. Firms in GTAP select the relative mix of primary production factors, including land, according to a CES parameter value of 0.24 for crops (Hertel et al. 2008b). GTAP also distinguishes between the mobility of primary production factors. Labor and capital are perfectly mobile across sectors, whereas natural resources and agricultural land are "sluggish" to adjust. This implies that returns to labor and capital are the same across all sectors in the economy, whereas total agricultural land is fixed and farmland values can vary across sectors.

The basic GTAP production function does not incorporate many parameters that influence the amount of acreage required for crop production. We do not consider how variation in the agronomic and climatic conditions within different U.S. regions could influence the viability of fresh fruit and vegetable production. For example: pasture acreage may occur on marginal land without another suitable use; and the feasibility of expanding fruit and vegetable production can depend on the capability for irrigation. We also do not consider the land-use implications of alternate production methods, such as pasture-based and livestock-confinement systems.[2]

---

[2] GTAP has developed a land-use module—"GTAP-AEZ"—that derives acreage estimates by taking some of these factors into account. The most critical parameters in GTAP-AEZ include: the price-yield elasticity (i.e., the responsiveness of yield to changes in market prices); the variability of agro-ecological conditions within a region, including growing season length and climate zone; the crop-specific productivity of unused cropland relative to cropland being utilized; the rate at which land can be transformed among uses between agro-ecological zones; the relative substitutability of crops with other land-uses, such as pasture and forestry, within an agro-ecological zone; and the relative substitutability between crops within an agro-ecological zone. GTAP-AEZ has been used to examine the potential land-use impacts resulting from greenhouse gas regulations (Avetisyan et al. 2011; Golub et al. 2009) and biofuel regulations (Taheripour, Hertel, and Tyner 2011; Taheripour et al. 2010; Tyner et al. 2010). We don't use GTAP-AEZ in this study because of GTAP's coarse sector definitions—fruits and vegetables represent only one composite sector, even though many types of both crop categoriess are commercially grown. Also, the model's parameter values have not been validated for the fruit and vegetable sector.

Appendix B: Relationship between GTAP Sectors and Dietary Guidelines

GTAP's I-O accounts for each U.S. sector are developed from Bureau of Economic Analysis (BEA) I-O sectors and summarized in Table 5 (Tsigas 2008).[3] "Food Products," at $178 billion, is the largest GTAP food category when measured as the sum of domestic consumption and import expenditures. Food Products is a catchall category that aggregates a wide range of processed foods.[4] The second-largest GTAP food sector is "Beverages and Tobacco Products," wherein "beverages" include soft drinks, alcohol, and flavored syrup and concentrate.

"Cattle Meat," which represents nonpoultry meat consumption such as beef and pork, is the third-largest GTAP sector at $47 billion. "Milk" is the GTAP sector that contains fluid milk and manufactured dairy products such as cheese, butter, and ice cream. "Vegetables and Fruit" contains vegetable, fruit, and tree nut farm sales, which essentially represents the sale of fresh fruits and vegetables. These latter two sectors are each equal to $33 billion. "Other Meat," which constitutes $23 billion in consumer expenditures, represents processed poultry products. The next largest category is "Fishing."

The rest of the relevant categories represent crop sales, animal production sales, or other ingredients in processed foods. Direct purchases for final consumption are relatively modest for these categories. For example, the outputs from many GTAP crop sectors are predominately used as intermediate inputs in livestock or processed food products.

[3] The reported food expenditures in Table 5 are based on the most recent BEA benchmark I-O data as of May 29, 2013.

[4] These foods include bread and baked goods; processed fruits and vegetables; frozen foods; snack foods; cookies, crackers, and pasta; chocolate; pet food; seasonings and salad dressings; breakfast cereal; processed seafood; coffee and tea; and candy.

Table 5. U.S. Food Expenditures by GTAP Sector

GTAP Sector	I-O Bureau of Economic Analysis Industry Code	2002 Personal Consumption + Imports (millions USD)
Food Products	“Food Manufacturing” industries	178,266
Beverages and Tobacco Products	“Beverage Manufacturing”; “tobacco Manufacturing”	83,708
Cattle Meat	Animal (except poultry) slaughtering, rendering, and processing	47,172
Milk	“Food Manufacturing” dairy production industries	32,998
Vegetables and Fruit	Vegetable farming; fruit farming; tree nut farming	32,863
Other Meat	Poultry processing	23,005
Fishing	Fishing	11,299
Other Animal Products	Animal production, except cattle and poultry and eggs; poultry and egg production	6,663
Sugar	Sugarcane mills and refining; beet sugar manufacturing	2,481
Vegetable Oils	Soybean and other oilseed processing	1,698

Cattle	Cattle ranching and farming	1,521
Paddy Rice; Wheat; Cereal Grains	Grain farming	1,358
Oil Seeds	Oilseed farming	189
Raw Milk	Dairy cattle and milk production	83
Plant Fibers	Cotton farming	40
Cane and Beet	Sugarcane and sugar beet farming	1

Sources: BEA (2008); Tsigas 2008

Appendix C: Modeling Scenarios

We apply hypothetical taxes or subsidies to the U.S. private household demand both for domestic and imported food products so that final consumption of specific foods sectors is aligned with healthier diets. The scenarios we consider are summarized in Table 1 and the GTAP codes that correspond to the shocks we apply are presented as Appendix D. In GTAP, tax revenue on private households flows to the "regional household" described earlier. This implies that, in the case of a tax, the price that households pay for the taxed good is greater than that good's market price. The opposite conditions occur in the case of a subsidy. Because our focus is on the implications of changing U.S. food consumption patterns, we do not impose taxes or subsidies on the output of sectors.

We utilize the USDA Economic Research Service estimates of per capita food consumption as a basis for hypothetical dietary changes (USDA ERS 2013b). We use 2004 food consumption patterns so that they are consistent with the GTAP 7 benchmark year—U.S. per capita eating patterns have changed only trivially since that time. We use the most recent USDA NASS crop acreage data to calculate changes in U.S. crop acreage (USDA NASS 2013). These are 2012 data for all crops except fruits and vegetables, for which we use 2011 data (USDA ERS 2012a; USDA ERS 2012b). International crop acreage estimates were obtained from the 2004 GTAP 7 database (GTAP 2011).

We aggregate GTAP sectors along the same dimensions as Birur, Hertel, and Tyner (2008) to simplify modeling requirements—except for GTAP food sectors, for which we develop specific results. We also modify GTAP's default own-price elasticity[5] parameter values, as documented in Hertel et al. (2008b), using parameter values described below so that they are more representative of estimates in the empirical literature. A caveat for implementing shocks of as large a magnitude as ours is that the elasticity estimates are more accurate for smaller hypothetical changes.

We focus on dietary recommendations for food products and not ingredients, as ingredients do not vary within GTAP sectors. For example, GTAP has a sector for dairy products, but it does not have distinct food sectors for, say, whole milk and skim milk. Given the lack of consensus among dietary standards with regard to the consumption of dairy and protein foods, we consider two

[5] The "price elasticity" is the ratio of the percentage change in the quantity demanded of a good and the percentage change in price.

contrasting diet scenarios: the MyPlate guidelines and the Healthy Eating Plate developed by Harvard University. The Healthy Eating Plate recommends reduced consumption of red meat and dairy products relative to MyPlate. Of course, multiple combinations of domestically produced crops could support an improved diet. Interacting relationships include:

- Many combinations of food that could result in a healthy diet
- Different crops used to create similar ingredients in processed foods
- Changes in diet that impact crop yields because of productivity
- Reductions in food waste that mitigate the need for additional farmland for underconsumed food groups such as fruits and vegetables
- A farm's decision to produce crops or livestock that depends on the sale of byproducts
- Other factors, such as the market share of imported crops and food products, that depend on a variety of considerations, including: consumer preferences, tariffs, subsidies, quotas, interest rates, exchange rates, climate change and weather shocks, farm labor standards, environmental regulations, and transportation costs.

Fruits and Vegetables

We assume that fruit and vegetable consumption increases exclusively through GTAP's "Vegetables and Fruit" sector, which represents fresh fruits, vegetables, and nuts. We disregard any potential increase in the consumption of processed fruits and vegetables to rectify dietary deficiencies because, while some processed fruits and vegetables may have nutritional content reasonably similar to that of fresh fruits and vegetables, other products could have overconsumed ingredients, such as solid fats and added sugars, that negate the health benefits of eating more fruits and vegetables. One prominent example is French fries. A second reason we limit ourselves to fresh fruits and vegetables is that in the base GTAP model, processed fruits and vegetables cannot be separately modeled from other unrelated processed-food products. Nonetheless, given consumer preferences for fruits and vegetables, it might be difficult to grow the most preferred products during some parts of the year in many regions, particularly if they are fresh instead of processed.

MyPlate guidelines recommend consuming 2 cups of fruit, 2.5 cups of vegetables, and 0.6 ounces of nuts on an average daily per capita basis for a 2,000-calorie per day diet. However, per capita vegetable consumption for the year 2004 was 1.8 cups per day, with 55 percent consumed as fresh; while per capita fruit consumption was 0.8 cups per day, with 49 percent consumed as fresh. This implies that if the dietary shortfall in fruit and vegetable consumption were to be exclusively remedied by eating more fresh fruits and vegetables, then fresh fruit and vegetable consumption would have to increase by 296 percent and 72 percent, respectively. Per capita nut consumption in 2004 was 0.81 ounce-equivalent per day, implying that nut consumption would need to decrease by 26 percent to satisfy dietary guidelines.

We calculate the weighted average of these deficiencies, weighted by the sum of personal consumption expenditures and imports, to measure the percentage by which the GTAP "Vegetables and Fruits" consumption must increase to attain MyPlate recommended levels. We find this percentage to be 173. We modify the value of GTAP's default price elasticity parameter to -0.7 so that it is consistent with fruit and vegetable elasticity estimates reported in the literature (Lin et al. 2010).

Dairy Products

U.S. average daily per capita consumption of dairy products is 1.5 cups. We increase this value by 100 percent in the MyPlate scenario, because MyPlate recommends that three cups of dairy products be consumed on a per capita daily basis. By contrast, Harvard's Healthy Eating Plate recommends that the consumption of dairy products should be no more than one to two cups per day. We choose the lower bound of this recommended range—which corresponds to a hypothetical decrease of 33 percent in the consumption of dairy products—for the purpose of providing a greater contrast between the Healthy Eating Plate and the MyPlate standards. We modify the default GTAP dairy product own-price elasticity to -0.7, the mean estimate in USDA's Commodity and Food Elasticities database (USDA ERS 2013a).

Red Meat, Poultry, and Seafood Products (Protein)

In 2004, Americans consumed 3.58 ounces of red meat (consisting of beef, veal, pork, and lamb) on an average per capita daily basis. They also consumed 2.49 ounces of poultry (chicken and turkey) and 0.44 ounces of seafood. Of this seafood consumption, 0.28 ounces were consumed as fresh or frozen. MyPlate dietary guidelines, however, suggest that red meat consumption should be 1.8 ounces, poultry consumption at 1.5 ounces, and seafood consumption at 1.2 ounces. This implies a 50 percent reduction in red meat, 40 percent reduction in poultry, and 260 percent increase in seafood consumption.[6] We assume that any seafood dietary deficiencies are attained by increasing the consumption of fresh or frozen seafood, given that processed seafood is contained within GTAP's Food Products category.

Healthy Eating Plate recommends 112.5 grams of protein per day as a healthy level of protein consumption on a 2,000 calorie per day diet, which corresponds to 3.97 ounces per day. Using the mean of this standard's red meat consumption range of 3 ounces per week and its default recommended level of weekly seafood consumption (6 ounces), we derive a scenario in which poultry consumption is 2.68 ounces per day (an 8 percent increase), daily seafood consumption is 0.86 ounces (a 149 percent increase of fresh seafood), and daily red meat consumption is 0.43 ounces (an 88 percent reduction). We modify GTAP's default own-price elasticity parameter value to -0.56 for poultry, -0.29 for fish, and -0.7 for red meat (we use the elasticity for beef) by means of the corresponding mean estimates in the USDA's database (USDA ERS 2013a).

Evaluating the sustainability and land-use impacts of these increases in seafood consumption depends on the fish species consumed and whether the harvesting occurs from wild fisheries or aquaculture. But exploration of this issue in greater detail, while important, is beyond the scope of our report.

[6] This would actually require a 271 percent increase in seafood consumption. But we use 260 percent because no model solution occurs in GTAP with the Gragg solution method if there is a 271 percent increase.

Appendix D: Simulation

A simulation in GTAP involves a set of commands in conjunction with given database, equations, and parameters. This set of commands directs the model to calculate a new solution, or equilibrium. Variables in GTAP are either endogenous or exogenous. Endogenous variables are determined within the model, whereas exogenous variables are inputs to the model. Examples of exogenous variables in GTAP include population, tax rates, and tariff rates. Household demand is an example of an endogenous variable.

Fruit and Vegetable Scenario

The objective of this scenario is to examine the impact of a 173 percent increase (or, in GTAP terms, a "shock") in the U.S. private household demand for fresh fruits and vegetables (F&V), assuming no other changes in exogenous variables. Total F&V demand is comprised both of domestic and imported demand. However, household demand is an endogenous variable and cannot be directly shocked. Therefore we shock another variable that could affect the fresh fruit and vegetable demand. Given that a subsidy on fruit and vegetable consumption could increase consumer demand, we find this to be an appropriate variable. We determine the amount of subsidy in GTAP through the following commands:

swap qpm("vegfruit","USA") = tpm("vegfruit","USA");

swap qpd("vegfruit","USA") = tpd("vegfruit","USA");

Shock qpd(vegfruit","USA") = 173;

Shock qpm("vegfruit","USA") = 173;

In the first command, *qpm* and *tpm r*epresent the percentage changes in the U.S. private household demand for F&V imports and the subsidy rate on private consumption of imported F&V, respectively. In the second command, *qpd* and *tpd* represent the percentage change in the U.S. domestic private household demand for F&V and the subsidy rate on private household consumption of domestically produced F&V, respectively. The first two commands endogenize the subsidy rate on domestic and imported F&V in the United States and exogenize the U.S. domestic and import demand for F&V. That is, the variables *tpm* and *tpd* are now endogenous while *qpd* and *qpm* are exogenous and can therefore be shocked directly. The third and fourth commands shock the domestic and imported U.S. demand, respectively, for F&V. The model uses a simulation process by starting with an initial equilibrium and a given system of equations and increases the subsidy until the domestic and imported demand increase by 173 percent and a new equilibrium is attained.

Healthy Eating Plate Scenarios

In this scenario we analyze the impact of meeting the protein and dairy requirement of the Harvard Healthy Eating Plate diet. Specifically, the following commands exogenize U.S. domestic and imported demand for protein and dairy:

swap qpd("dairy","USA") = tpd("dairy","USA");

swap qpm("dairy","USA") = tpm("dairy","USA");

swap qpd("beef","USA") = tpd("beef","USA");

swap qpm("beef","USA") = tpm("beef","USA");

swap qpd("chicken","USA") = tpd("chicken","USA");

swap qpm("chicken","USA") = tpm("chicken","USA");

swap qpd("seafood","USA") = tpd("seafood","USA");

swap qpm("seafood","USA") = tpm("seafood","USA");

We shock the qpd and qpm to analyze the impacts.

To reduce the U.S. domestic and imported demand for beef and dairy:

Shock qpd("dairy","USA") = -33;

Shock qpm("dairy","USA") = -33;

Shock qpd("beef","USA") = -88;

Shock qpm("beef","USA") = -88;

To increase U.S. domestic and import demand for chicken and seafood:

Shock qpd("chicken","USA") = 8;

Shock qpm("chicken","USA") = 8;

```
Shock qpd("seafood","USA") = 149;

Shock qpm("seafood","USA") = 149;
```

MyPlate Scenario

In this scenario we analyze the impact of meeting the protein and dairy requirement specified in the federal government's MyPlate dietary guidelines. We use the following swaps and shocks:

```
swap qpd("dairy","USA") = tpd("dairy","USA");

swap qpm("dairy","USA") = tpm("dairy","USA");

swap qpd("beef","USA") = tpd("beef","USA");

swap qpm("beef","USA") = tpm("beef","USA");

swap qpd("chicken","USA") = tpd("chicken","USA");

swap qpm("chicken","USA") = tpm("chicken","USA");

swap qpd("seafood","USA") = tpd("seafood","USA");

swap qpm("seafood","USA") = tpm("seafood","USA");
```

To increase U.S. domestic and imported demand for dairy and seafood:

```
Shock qpd("dairy","USA") = 100;

Shock qpd("seafood","USA") = 260;

Shock qpm("dairy","USA") = 100;

Shock qpm("seafood","USA") = 260;
```

To reduce U.S. domestic and imported demand for beef and chicken:

```
Shock qpd("beef","USA") = -50;

Shock qpm("beef","USA") = -50;
```

```
Shock qpd("chicken","USA") = -40;

Shock qpm("chicken","USA") = -40;
```

Appendix E: “Harvard Protein and Dairy” (Scenario 6) and “MyPlate Protein and Dairy” (Scenario 7)

We ran two additional scenarios, one (Scenario 6) combining the Harvard shocks in Scenarios 2 and 4 and the other (Scenario 7) the MyPlate shocks in Scenarios 3 and 5. Table 6 shows the results. We see in both cases that the percentage changes in production both of the final product and intermediate product are similar to what they were when the dairy and protein shocks were implemented separately.

Cereal grain acreage is the crop sector for which these changes in protein and dairy consumption have the greatest direct impacts. In the Harvard scenario, U.S. cereal grain production falls by 13 percent. This corresponds to an 8 percent decline in cereal grain acreage, or almost 8 million acres. In the MyPlate scenario, U.S. cereal grain production increases by 2 percent, as the large increase in milk production is greater than the declines in cattle and poultry production. There are negligible impacts on cereal grain crop acreage in the MyPlate scenario.

We also find that U.S. production of other grains, oilseeds, and other crops do not significantly change for domestic consumption. Their increase in production for export markets is sufficiently large that they experience acreage increases. Similar to what occurred in Scenario 1, a reduced demand for cereal grain reduces land values and makes planting other crops destined for exports relatively more cost-competitive. In the Harvard scenario, land values for cereal grains decrease by 29 percent, oilseeds by 19 percent, sugarcane by 21 percent, other grains by 15 percent, and other crops by 17 percent. Under the MyPlate scenario, land values for cereal grains fall by 48 percent, oilseeds by 46 percent, sugarcane by 59 percent, other grains by 41 percent, and other crops by 45 percent.

Table 6. Results for "Harvard P&D" (Scenario 6) and "MyPlate P&D" (Scenario 7)*

	"Harvard P&D" (Scenario 6)	"MyPlate P&D" (Scenario 7)
% Change in U.S. Production of Final Product		
Beef	-54%	-38%
Chicken	5%	-30%
Dairy	-21%	64%
% Change in U.S. Production of Intermediate Product		
Cattle	-49%	-36%
Poultry	2%	-26%
Milk	-16%	47%
U.S. Crop Production Changes		
% Change in Cereal Grain Production	-13%	2%
% Change in Cereal Grain Acreage	-8%	0%
Initial Cereal Grain Acreage (million acres)	104.8	104.8
Change in Cereal Grain Acreage (million acres)	-7.9	-0.4

* P&D = protein and dairy

Appendix F: Sensitivity Analysis

We conducted sensitivity analysis with regard to the price elasticity to see how this variable influences our results. A smaller elasticity estimate, in absolute value, implies that consumer demand is less responsive to changes in prices, and vice versa. This implies in turn that a larger subsidy is needed to reduce demand by a fixed amount. Thus in the high-elasticity scenario with an elasticity value of -1, smaller domestic and import subsidies are needed to increase F&V demand by 173 percent. These subsidies are 76 percent and 66 percent, respectively. In contrast, in the low-elasticity scenario with a parameter value of -0.33, higher domestic (98 percent) and import subsidies (97 percent) are needed to increase F&V demand by 173 percent than in the base case. The changes in the quantity of production and farm acreage do not significantly vary under alternate demand elasticity estimates.

Appendix G: Aggregation of World Regions

We aggregate as follows the main crop-producing regions of the world from which the United States imports fruits and vegetables:

1. NAFTA (Canada and Mexico)
2. Southern hemisphere (Argentina, Australia, Brazil, Chile, New Zealand, South Africa, and Peru)
3. Banana-exporting equatorial countries (Columbia, Costa Rica, Ecuador, Guatemala, Honduras, and Panama)
4. All other countries

Appendix H: Comparison of Results with Other Studies

In comparing our results with prior studies, we find that our acreage estimates are lower. For example, Buzby, Wells, and Vocke (2006) found that U.S. fruit and vegetable acreage would increase by 12.9 million acres, whereas Young and Kantor (1999) concluded that 6.9 million additional acres of fruits and vegetable would be needed at a maximum. One methodological difference is that we do not hold the market share of imports fixed in our model—in fact, the U.S. F&V market share in Scenario 1 increases from 85 percent to 88 percent. However, also unlike previous studies, farmland does not increase proportionally to production, and the ability of farms to increase labor and capital by relatively greater percentages implies that less overall acreage may be needed.

We also find that the production of cereal grains, other grains, oilseeds, sugar, and other crops decreases as U.S. farmland becomes more expensive (due to increased rental rates caused by the growing demand for fruits and vegetables). For example, the land rental rate for cereal grains increases by 156 percent, oilseeds by 129 percent, sugarcane by 176 percent, other grains by 93 percent, and other crops by 131 percent. Because some of these crops are exported, the decrease in U.S. crop production is partially offset by an increase in crop production in the rest of the world. Such pronounced changes in U.S. crop acreage are occurring because the basic GTAP model does not allow variation in the extent to which different crop types are substitutes for each other.

Further efforts should evaluate the extent to which increases in fruit and vegetable land rents would affect land values for other crop types in the United States. Fruits and vegetables could substitute for other types of crops if their acreage were to significantly expand, though over the past decade fruit and vegetable acreage was relatively unchanged; meanwhile, corn and soybean acreage expanded at the expense of other crops due to greater biofuels mandates, rising developing-country incomes, and low interest rates. This suggests that fruit and vegetable crop acreage may have a lower degree of substitutability relative to grains, oilseeds, and other crops than these crops have with each other.

Appendices A–H References

Avetisyan, M., A. Golub, T. Hertel, S. Rose, and B. Henderson. 2011. Why a global carbon policy could have a dramatic impact on the pattern of the worldwide livestock production. *Applied Economic Perspectives and Policy* 33(4):584–605.

Birur, D.K., T.W. Hertel, and W.E. Tyner. 2008. *Impact of biofuel production on world agricultural markets: A computable general equilibrium analysis*, GTAP Working Paper No. 53. West Lafayette, IN: Center for Global Trade Analysis, Purdue University.

Brockmeier, M. 2001. *A Graphical Exposition of the GTAP Model*, GTAP Technical Paper No. 8. West Lafayette, IN: Center for Global Trade Analysis, Purdue University.

Bureau of Economic Analysis (BEA). 2008. Industry economic accounts. Online at *www.bea.gov/industry/*, accessed on August 15, 2013.

Buzby, J.C., H.F. Wells, and G. Vocke. 2006. *Possible implications for U.S. agriculture from adoption of select dietary guidelines*, Economic Research Report Number 31.Washington, DC: U.S. Department of Agriculture.

Global Trade Analysis Project (GTAP). 2011. *GTAP land use data—version 7, release 3.0.* West Lafayette, IN: Center for Global Trade Analysis, Purdue University.

Golub, A., T. Hertel, H.-L. Lee, S. Rose, and B. Sohngen. 2009. The opportunity cost of land use and the global potential for greenhouse gas mitigation in agriculture and forestry. *Resource and Energy Economics* 31(4):299–319.

Harvard School of Public Health. 2011. *Healthy eating plate: Harvard's new guide to healthy eating.* Online *at www.hsph.harvard.edu/nutritionsource/healthy-eating-plate/*, accessed on August 13, 2013.

Hertel, T.W., H.-L. Lee, S. Rose, and B. Sohngen. *2008a. Modeling land-use related greenhouse gas sources and sinks and their mitigation potential*, GTAP Working Paper No. 44. West Lafayette, IN: Center for Global Trade Analysis, Purdue University.

Hertel, T.W., R.A. McDougall, B.G. Narayanan, and A.H. Aguiar. 2008b. In *Global trade, assistance, and production: The GTAP 7 data base*, edited by Narayanan, B.G., and T.L. Walmsley. West Lafayette, IN: Center for Global Trade Analysis, Purdue University,14-1–14-18.

Hertel, T.W., and M.E. Tsigas. 1997. *Structure of GTAP*. West Lafayette, IN: Center for Global Trade Analysis, Purdue University.

Lin, B.-H., S.T. Yen, D. Dong, and D.M. Smallwood. 2010. Economic incentives for dietary improvement among food stamp recipients. *Contemporary Economic Policy* 28(4):524–536.

Lock, K., R.D. Smith, A.D. Dangour, M. Keogh-Brown, G. Pigatto, C. Hawkes, R.M. Fisberg, and Z. Chalabi. 2010. Health, agricultural, and economic effects of adoption of healthy diet recommendations. Lancet 376(9753):1699–1709.

Monfreda, C., N. Ramankutty, and T.W. Hertel. 2009. Global agricultural land use data for climate change analysis. In *Economic analysis of land use in global climate change policy*, edited by edited by T.W. Hertel, S.K. Rose, and R.S.J. Tol. Abingdon, UK: Routledge Press, 33–49.

Mukhopadhyay, K., and P.J. Thomassin. 2012. Economic impact of adopting healthy diet in Canada. *Journal of Public Health* 20(6):639–652.

Ribera, L.A., C. Yue, and R. Holcomb. 2012. Geographic impacts on U.S. agriculture of the 2010 dietary nutrition guidelines. *Choices: The Magazine of Food, Farm, and Resource Issues* 27(1).

Taheripour, F., T.W. Hertel, and W.E. Tyner. 2011. Implications of biofuels mandates for the global livestock industry: A computable general equilibrium analysis. *Agricultural Economics* 42(3):325–342.

Taheripour, F., T.W. Hertel, W.E. Tyner, J.F. Beckman, and D.K. Birur. 2010. Biofuels and their byproducts: Global economic and environmental implications. *Biomass and Bioenergy* 34(3): 278–289.

Tsigas, M. 2008. *GTAP 7 data base documentation,* Chapter 7, I-O table: United States. West Lafayette, IN: Center for Global Trade Analysis, Purdue University.

Tyner, W.E., F. Taheripour, Q. Zhuang, D. Birur, and U. Baldos. 2010. *Land use changes and consequent CO_2 emissions due to U.S. corn ethanol production: A comprehensive analysis*. West Lafayette, IN: Department of Agricultural Economics, Purdue University.

U.S. Department of Agriculture, Economic Research Service (USDA ERS). 2013a. Commodity and food elasticities. Online at *www.ers.usda.gov/data-products/commodity-and-food-elasticities.aspx#.UUeAa1d65pm*, accessed on August 15, 2013.

U.S. Department of Agriculture, Economic Research Service (USDA ERS). 2013b. Food availability (per capita) data system. Online at *www.ers.usda.gov/data-products/food-availability-(per-capita)-data-system.aspx*, accessed on August 15, 2013.

U.S. Department of Agriculture, Economic Research Service (USDA ERS). 2012a. Fruit and tree nut yearbook: Table A2. Fruit and tree nut bearing acreage, U.S., 1980 to date. Online at *usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1377*, accessed on August 15, 2013.

U.S. Department of Agriculture, Economic Research Service (USDA ERS). 2012b. *Vegetable and pulses outlook: Dry bean yields set record high*, VGS-352. Washington, DC: U.S. Department of Agriculture.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA NASS). 2013. *Crop production: 2012 summary*. Washington, DC: USDA.

U.S. Department of Agriculture and U.S. Department of Health and Human Services (USDA and HHS). 2010. *Dietary Guidelines for Americans 2010, 7th Edition*. Washington, DC: U.S. Government Printing Office.

Young, C.E., and L.S. Kantor. 1999. *Moving toward the food guide pyramid: Implications for U.S. agriculture*, Agricultural report number 779. Washington, DC: U.S. Department of Agriculture.