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# PRIVATE STRATEGIES, PUBLIC POLICIES & FOOD SYSTEM PERFORMANCE

**IMPACTS OF GROWTH STIMULANTS  
IN THE DOMESTIC LIVESTOCK SECTOR**

by

Everett B. Peterson, Paul V. Preckel,  
Thomas W. Hertel, and Anya M. McGuirk\*

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## ABSTRACT

Many individuals are predicting a "second green revolution" in agriculture from the introduction of growth stimulants into the livestock industries. An economy-wide approach is used to determine the affects on prices and quantities of introducing growth stimulants in the domestic dairy and pork industries. In general, the impacts are found to be much smaller than previous research focused at the sectoral level has suggested. Increases in the amount of lean meat per hog, which reduces processor demand, may actually lead to a reduction in pork production at the farm-level.

Key Words: biotechnology, general equilibrium, pork and dairy

## Impacts of Growth Stimulants in the Domestic Livestock Sector

Many individuals are predicting that agriculture is on the verge of a "second green revolution." Recombinant DNA and other technologies are being developed that may provide, at low cost, products to improve the efficiency of raising plants and animals. Growth stimulants, notably bovine somatotropin (bST or bovine growth hormone), porcine somatotropin (pST or porcine growth hormone), and ractopamine (a swine growth repartitioning agent) are likely to be early applications of biotechnology and other growth stimulant research. Several studies evaluating the effects of bST have indicated large potential increases in feed efficiency and milk production.<sup>1-6</sup> Similarly, large potential increases in feed efficiency and reductions in time on feed have been projected for pST and ractopamine.<sup>7,8</sup>

These significant potential effects have led to several studies on the impact of bST adoption on milk prices and production,<sup>9,10</sup> pST on pork production and prices<sup>7</sup> and the impact of bST and pST jointly.<sup>11</sup> Except for Kuchler and McClland,<sup>11</sup> these studies did not consider the impacts that livestock growth stimulants may have on the domestic crop sector through changes in feed demand. The pork and dairy industries are major users of feed grains, especially corn, and soybean meal. In 1985, feed usage in the dairy and pork industries accounted for over one third of the domestic demand for corn and soybean meal.<sup>12</sup> Thus, the potential impacts on prices and product mix in the domestic crop sector may also be very large.

The use of growth stimulants in the domestic livestock sector can also affect domestic food processors. Changes in relative agricultural prices will either increase or decrease input costs for processors, thereby directly affecting their profitability. In addition, meat packers in particular, may be affected by changes in input quality. pST and ractopamine have both been estimated to increase the amount of lean pork in a hog carcass by at least 10%.<sup>1,8</sup> This will allow pork processors to obtain more meat per animal with possibly larger prime cuts. None of the earlier studies on bST and pST have considered these potential impacts on food processors.

Finally, adoption of the growth stimulants are likely to affect consumer demand for dairy and pork products. In the case of pork, producing a leaner product may increase consumer demand at constant prices and income. Lemieux and Wohlgenant<sup>7</sup> have estimated that consumers would increase their demand for pork by 4.3% if it were 10% leaner. However, previous surveys<sup>13,14</sup> have shown that consumers may react adversely to the use of bST. Respondents to these surveys who had heard of bST (one third of the sample) indicated that

they would decrease their purchases of fluid milk by 15-18% if bST were introduced (and the price of milk remained unchanged). Assuming that the two thirds who had not heard of bST would not change their demand, the demand for fluid milk could decrease by 2% to 6%.

In sum, the effects of introducing livestock growth stimulants may extend from producers (of both livestock and crops), through the processing and wholesale/retail sectors, to the final consumer. Most studies have focused on a particular portion of a given livestock sector, ignoring adjustments elsewhere in the economy. This paper provides an overall analysis of the potential impacts of the use of growth stimulants in the domestic livestock sector. Our approach is of a general equilibrium nature, and extends the work in previous studies by: (a) determining the potential impacts on the domestic crop sector through changes in feed demand, (b) considering the impacts on domestic food processors, (c) considering the consequences of potential changes in retail demand, and (d) examining the trade effects. The analysis is based on an *ex ante*<sup>15</sup> evaluation of the introduction of growth stimulants in the livestock sector.

#### MODEL SPECIFICATION

An economy-wide general equilibrium model is used to analyze the impacts of the introduction of new growth stimulants in the domestic livestock sector. The scope of the model goes from farm-level production through consumption of final goods. The linkages within the food marketing channels as well as linkages to the rest of the domestic economy and the rest of the world are explicitly included. The model is a natural extension of the traditional marketing models of Gardner<sup>16</sup> and Holloway<sup>17</sup> with a complete specification of the "rest of the economy," the disaggregation of the farm production and food processing sectors, and a complete treatment of imports and exports. By explicitly modeling the linkages between sectors and the food marketing system one can trace the impacts of new technologies in the domestic livestock sector throughout the economy.

#### General Structure

The model is aggregated into two regions, the United States and the rest of the world, with all domestic and foreign goods assumed to be tradable. The model is static. We assume that the length of run is sufficient to permit full adjustment of sectoral capital stocks to the particular shock in question. All agents have complete information. Financial markets are not included in the model. The model is neoclassical in its treatment of

producer and consumer behavior. Hence, producers maximize profits, and consumers maximize their utility of consumption subject to a budget constraint. Due to an assumption of perfectly competitive markets, all profits are absorbed by payments to factors. As the owners of the primary factors, consumers' income is equal to factor payments. Finally, all markets clear in equilibrium.

The domestic economy is broken into four broad sectors (agriculture, food manufacturing, nonfood manufacturing and wholesale/retail activities) producing 27 goods. (Appendix table A.1 lists each commodity and the corresponding input/output sector identifier.) Each of these goods can be an intermediate and/or consumer good. There are ten agricultural goods, 15 manufactured food products and four nonfood goods in the model. Also, there are three primary factors of production: land, labor, and capital services. Labor and capital are mobile between all domestic sectors, while land is specific to the agricultural sector.

The rest of the world has an analogous structure, with three exceptions which are due to a lack of data. The exceptions are: wholesale/retail activities and intermediate demands are not explicitly modeled, and there is only one aggregate primary factor of production.

#### Structure of the Dairy and Pork Production/Marketing System

Figure 1 provides a broad overview of the domestic food marketing system with special focus on dairy and pork sectors. At the farm level, production of both dairy and pork is accomplished using primary factors of production (labor, land, and capital services), grains, proteins, and nonagricultural inputs. At the next level in the production/marketing system, raw dairy and pork products are transformed into processed dairy (both fluid and manufactured) products and processed pork products using inputs of nonagricultural goods (*e.g.*, packaging materials) and primary factors. These processed goods are then either exported to the rest of world region or they are passed on to the wholesale/retail sector.

At the wholesale/retail level, processed dairy and pork products (either domestic or imported) are transformed into retail goods for domestic consumption by combining each of them with labor and capital services. At the retail level, consumer choices are based on the concept of a utility tree<sup>18-21</sup> permitting household behavior to be viewed as a multi-stage process. Specifically, the consumer allocates alternative income shares to food versus other commodities. Then, at a lower level in the hierarchy, expenditures are allocated between

dairy (an aggregate between retail fluids and retail manufactured dairy products), meats (an aggregate between pork and other red meats), and other foods.

#### Data

In order to complete the model, numerical values for elasticities and share parameters must be specified. Empirical estimates of own-price and income elasticities of demand were obtained from the SWOPSIM model.<sup>22</sup> In cases where the elasticities were not available from SWOPSIM, other estimates from the literature were employed. Elasticities of substitution in the domestic livestock industry were taken from Hertel and Tsigas;<sup>23</sup> elasticities of substitution between intermediate inputs for domestic food processors and wholesale/retail firms were based on estimates from Wohlgenant;<sup>24</sup> and capital/labor substitution elasticities for domestic firms were taken from Harrison *et al.*<sup>25</sup>

A benchmark "snapshot" of the economy is used to obtain share parameters for the model. This benchmark data set is assumed to represent an initial equilibrium in the economy. For the domestic economy, a social accounting matrix (SAM) for a 1982 base year is employed.<sup>26</sup> Figure 1 lists the initial expenditures for selected components of the pork and dairy marketing channels. For the rest of the world, the initial benchmark data set was obtained from Peterson.<sup>27</sup> (A more complete model description may be found in Peterson, Preckel, and Hertel.<sup>28</sup>)

### MODELING THE IMPACTS OF TECHNOLOGY CHANGES IN LIVESTOCK PRODUCTION

The introduction of bST in the dairy industry, and pST or ractopamine in the swine industry, will affect the supply of these products at the farm-level, the supply and potentially input demand at the processor level, and possibly demand at the retail level. We will begin by focusing on the farm-level impacts.

#### Farm-Level Impacts

The introduction of a new technology that reduces marginal cost will shift the partial equilibrium supply curve out and to the right. A constant returns to scale, nested CES production function is assumed to represent technology in the domestic livestock industries. The industry marginal cost function that is derived from this production function is:

$$(1) MC_i = A ( a_1 P_{NF}^\alpha + a_2 ( b_1 P_P^\beta + b_2 P_G^\beta )^{\frac{\alpha}{\beta}} )^{\frac{1}{\alpha}}$$

- where:
- $MC_i$  = marginal cost of i-th livestock industry;
  - $P_{NF}$  = price of nonfeed aggregate;  
 $= \sum c_j \times P_{OIj} + c_n \times P_{PF}$ ;
  - $P_{OI}$  = price of other inputs
  - $P_{PF}$  = price of primary factor
  - $P_P$  = price of protein aggregate input;  
 $= \{ \sum d_j \times (P_{pj})^\epsilon \}^{1/\epsilon}$ ;
  - $P_{pj}$  = price of protein input j;
  - $P_G$  = price of grain aggregate input;  
 $= \{ \sum e_j \times (P_{Gj})^\delta \}^{1/\delta}$ ; and
  - $P_{Gj}$  = price of grain input j.

The parameters  $\alpha$ ,  $\beta$ ,  $\epsilon$ , and  $\delta$  denote elasticities of substitution and the  $a_i$ 's,  $b_i$ 's,  $c_i$ 's,  $d_i$ 's, and  $e_i$ 's are the cost shares of the corresponding inputs in the initial equilibrium. For example,  $a_1$  is the initial equilibrium share of nonfeed inputs in marginal (or unit) cost. Note that the shares must satisfy  $a_1 + a_2 = 1$ ,  $b_1 + b_2 = 1$ ,  $\sum c_j = 1$ ,  $\sum d_j = 1$ , and  $\sum e_j = 1$  because the cost function is linear homogeneous in prices.

Previous research has shown that introducing growth stimulants will increase feed efficiency and possibly increase protein requirements. This leads to both neutral and biased changes in the dairy and pork technologies<sup>7</sup>. The neutral change results from the decrease in overall marginal cost due to the increase in feed efficiency. This effect is captured by a decrease in the value of the parameter A. There are two biased components of the technical change. The first arises due to the increased protein content of the feed rations. This implies that the relative magnitudes of  $b_1$  and  $b_2$  change (although they will still sum to one). Second, the increase in feed efficiency reduces the share of feed inputs ( $a_2$ ) relative to nonfeed inputs ( $a_1$ ). Therefore, one needs to determine how the parameters  $a_1$ ,  $a_2$ ,  $b_1$ ,  $b_2$ , and A will change after the growth stimulants have been introduced. The following subsections describe the adjustments to these parameters.

### *Dairy*

For dairy, changes in the cost shares were determined by comparing balanced rations for an average cow in the DHIA program, with and without bST. This average cow was assumed to weigh 1350 pounds, and produce 57 pounds of milk per day without bST and 64 pounds of milk per day using bST. (The implied production increase of 12.25% from using bST is within the range of the experimental studies cited earlier.) The feed rations also differ. A ration employing 15% protein and 70.1% TDN was used without bST. To reflect the higher protein requirements, a ration employing 15.3% protein and 71.1% TDN was used with bST. (See table 1.) Feed efficiency increased by 8.25% in the cows using bST, compared to those not using bST. By multiplying the price of the feedstuffs<sup>29</sup> by the quantity used in the ration, and dividing by milk production, one can determine the per unit feed cost with and without using bST. From table 1, unit costs decrease by 2.73% when bST is introduced. The cost share of nonfeed inputs increases by 0.83% relative to the feed cost share (*i.e.*,  $a_1$  increased relative to  $a_2$  in equation 1). Also, the cost of grains increased relative to the cost share of proteins by 0.89% (distillers grain, cottonseed meal and soybean meal were considered proteins; corn and corn silage were considered grains).

It is interesting to note that even though the bST treated cows increase production by 12.25% and increase feed efficiency 8.25%, relative to non-bST treated cows, unit cost only decreases by 2.73%. This is due to the fact that feed costs comprise approximately 35% of the total cost of producing a pound of milk. Even with our assumed 100% rate of adoption, these results indicate that this relatively small decrease in unit cost will yield much smaller changes in national milk production than predicted by previous studies. (These earlier studies used a much higher increase in productivity and feed efficiency, partly due to less experimental information being available.)

### *Pork*

The impacts of ractopamine are taken to be representative of the impacts of introducing growth stimulants in the pork industry. The impacts on costs were obtained from Millar<sup>8</sup> (see table 2). Unit costs decrease by 1.28%, due to a 6.35% increase in feed efficiency. However, a higher protein (16% protein versus 14% protein) ration is recommended by animal scientists.<sup>8</sup> This leads to an increase in the amount of soybean

meal consumed per animal, while corn usage decreases. Thus, the grain feed cost share decreases by 13.65% relative to the protein feed cost share. In addition, the animals take less time to reach market weight due to an increase in average daily gain. Thus, the nonfeed cost share decreases by 0.29% relative to the feed cost share. As with bST, we assume 100% adoption of ractopamine by hog producers.

Note that the introduction of ractopamine has a different impact on the share of nonfeed costs relative to feed costs than does bST. This is because using ractopamine will decrease the feeding period for hogs, while using bST will not reduce the lactation period for dairy cows. Thus, the per unit requirements for labor and facilities (*i.e.*, the primary factor) will decrease by more for pork than for dairy. Note that due to a lack of information, no adjustments have been made to unit costs to reflect potential increases in management required by the use of growth stimulants.

#### Processor Level Impacts

At the processor level, the introduction of growth stimulants in the dairy and pork industries may have two effects. First, if the price of raw milk and hogs decreases, this will reduce the unit costs of the dairy and pork processors. This reduction in costs will encourage the processors to expand production. Second, in the case of pork, input quality will improve with leaner hogs because there will be less waste. Thus, the pork processors will get more salable meat from each hog slaughtered, or conversely, it will take fewer live hogs to produce one unit of processed pork product. Technology in the pork processing sector is represented by a nested CES production function which combines live hogs with a composite non-agricultural input in order to produce a product which can be sold to the wholesale/retail sector. We have assumed that a 10% leaner hog will reduce the per unit requirements of pork processors by 7.5%. (Not all of the improvement in lean will occur in the muscle, there will also be a reduction in organ fat.) Thus, the share of live hog inputs relative to nonagricultural inputs, will decrease and change the parameters in the industry marginal cost function for processed pork in the same manner as the changes in feed shares in the dairy and pork industries. It should also be noted that bST will not change the input quality of raw milk for the dairy processors.

### Retail Level Impacts

We mentioned earlier that leaner pork may increase the demand for pork products, while the use of bST may adversely affect the demand for dairy products. These hypothesized changes are modeled as follows. Leaner cuts of pork will make pork products more attractive to consumers relative to other red meats. It is assumed that the overall consumption of red meats, at constant prices, will not increase due to health concerns and any increase in pork consumption will come at the expense of other red meats. Specifically, we assume that at constant prices, consumers will increase their purchases of pork products by 4.3% relative to other red meats.<sup>7</sup> (Red meats and poultry products are considered separately in the hierarchical ordering of preferences. If leaner pork does displace demand for poultry in the future, then the results reported here would need reassessment.)

On the other hand, the negative perceptions of bST will affect the total consumption of dairy products as milk from bST treated cows will not only be consumed as fluid milk, but also as cheeses, ice cream and other processed dairy products. Thus, we assume that the retail demand for both fluid milk and other processed dairy products will decrease by 2%.<sup>13</sup>

## RESULTS

This section focuses on the analysis of the results from three different scenarios. The first considers the introduction of growth stimulants in the dairy and pork industries with no changes in processor or consumer demand. This is the "base case" scenario. In the second scenario, the introduction of growth stimulants is considered along with changes in input demand by pork processors and changes in the final demand for pork by consumers. Finally, the last scenario analyzes the impact of growth stimulants allowing for changes in input demand by pork processors and changes in the retail demand for both pork and dairy products.

### Base Case

In this scenario, only the introduction of growth stimulants in the dairy and pork livestock industries is analyzed. This allows for the isolation of growth stimulant impacts, without any of the potential demand side changes. Table 3 reports the percentage changes in prices and quantities for selected industries in the domestic economy.

Begin by considering the impacts of growth stimulants in the dairy and pork industries themselves. Recall that the use of the growth stimulants decreases unit (and marginal) costs in both industries. This reduction of costs, at the initial price levels, causes positive economic profits to occur and encourages expansion in both industries. As seen in table 3, farm-level dairy production increases by 1.75% and farm-level pork production increases by 1.55%.

The biased changes in the technologies that occur, along with the expansion of production, affect the demand for inputs in these industries. Use of primary factor inputs (labor, facilities, etc.) decreases in both industries. For pork, this decrease is due to greater rates of gain induced by the growth stimulants and therefore, a greater rate of throughput of animals through facilities. For dairy, even though using growth stimulants requires more nonfeed inputs relative to feed inputs, the level of both nonfeed and feed inputs per unit of output is reduced. Further, the increase in dairy production does not offset the reduction in input requirements.

The demand for grains also decreases in both industries. For pork, grain use decreases by 12.89% because of the shift in the feed ration towards more protein. For dairy, grain use declines by 1.11% due to the dominance of the reduction in feed requirements per unit of output over the output increase. Finally, protein use in pork production increases by 50.23%, due to the increase in protein requirements, while protein use decreases by 11.82% for dairy. The decrease in protein use in the dairy industry comes about through a change in feed mix induced by an increase in the price of proteins relative to grains (*e.g.*, the price of fats and oils, and feed grains in table 3).

The increase in farm-level dairy and pork production increases the amount of both of those products that require further processing. Thus, the production of processed dairy and pork products increases (see table 3). Also, because more processed products are being produced, more dairy and pork products are reaching the retail level. In order to induce consumers to purchase larger quantities of pork and dairy products, the retail prices of both must decrease. The retail prices of fluid milk, other dairy products and processed pork decline by 1.52%, 1.29% and 1.06%, respectively. (Note, that the retail prices of unprocessed milk, listed as dairy farm product, and home slaughtered pork, listed as pork farm products also decrease by 3.67% and 2.09%, respectively.) This reduction in retail prices is transmitted to the processors, and in turn to the livestock

producers. Note that the farm-level prices experience the largest decreases. This is due to the declining share of dairy and pork inputs in the processed and retail products. Thus, to achieve a 1% decrease in retail price requires the farm-level price to experience a much larger decline.

The change in feed use by the dairy and pork industries also affects the production of feedstuffs, both on and off-farm. Due to a 6.16% reduction in grains use by dairy and pork industries (a 2.78% decrease by all livestock industries), the production of feed grains declines by 1.39% at the farm-level. However, the increase in use of proteins in the feed rations causes a 3.48% increase in the production of fats and oils (*e.g.*, soybean meal) and a 1.52% increase in wet-corn milling (*e.g.*, corn gluten meal). Also, at the farm-level, the production of oil bearing crops (*e.g.*, soybeans) increases by 0.80%, due to an increase in demand by the fats and oils industry. The producer prices of feedstuffs also change. The farm-level price of feed grains decreases by 1.51%, while the farm-level price of oil crops increases by 2.35%. The producer price of fats and oils increases by 1.28% while the producer price of wet-corn products decreases by 0.57%. (The price of wet-corn products decreases because feed grains, an important input to wet-corn production, have decreased in price.)

Introducing growth stimulants in the dairy and pork industries also affects the other domestic livestock industries. Farm-level production of other meat animals (*e.g.*, beef, sheep) increases by 0.49%. The other meat animal industries use feed rations that are relatively more intensive in grains than in proteins. So, the decrease in the price of feed grains lowers the cost of producing other red meats, encouraging expansion. Note that the farm-level price of other meat animals declines by 0.46% and the retail price of other red meats decreases by 0.24%. The decrease in the price of feed grains has virtually no impact on the poultry livestock industry. This is because poultry feed rations contain relatively more protein than grain. Even though poultry producers can substitute between protein and grain when relative prices change, the small price change does not allow them to economically vary the mix of the feed ration by a significant amount.

Finally, the change in crop production affects factor demand by the domestic farm sector. Because the increase in production of oil crops did not offset the reduction in feed grain production, domestic agriculture reduced its usage of chemicals and fertilizers, labor, and capital services by 0.89%, 0.44%, and 0.43% respectively.

By using less of each of these inputs, farmland (which is specific to agriculture) becomes less productive, causing the farmland rental rate to decline by 1.69%.

#### Changes in the Demand for Pork Products

In this scenario, growth stimulants are introduced into the dairy and pork livestock industries and the changes in input demand by pork processors and retail pork demand by consumers are considered. The possible effects of bST on dairy retail demand are ignored in this scenario as there are some doubts about how long such an adverse effect on demand would last.

Because consumers now prefer pork to other red meats, consumption of processed pork products increases by 4.95% while the consumption of other red meats falls by 2.20%. This increase in retail demand spurs production by the pork processors by 4.87%. However, the increase in (processor) production does not offset the initial 7.5% decrease in the per unit requirement of live hogs. Thus, farm-level pork production decreases by 1.65%.

The seemingly paradoxical result that farm-level pork production decreases after introducing a growth stimulant occurs because the increase in retail demand is smaller than the decrease in input demand by pork processors. If the reverse were true, then pork production would expand. This illustrates the importance of acknowledging changes in input quality and its impact at the processing level. This aspect has been ignored in previous studies.<sup>7,11</sup> Given that the results of this scenario depend crucially on the relative magnitudes of the changes in retail and processor demands and that there is little empirical evidence on these potential changes, the importance of future research in this area is highlighted.

At the farm-level, the decrease in pork production further dampens the demand for grains, along with proteins. Total usage of grains by the livestock industries declines by 4.05%, compared with 2.78% in the base case and protein usage in the feed ration increases by 11.03%, compared with 13.66% in the base case. Thus, this scenario leads to a larger reduction in feed grain production, and a smaller increase in oil crop production when compared to the base case. The use of labor, capital services, and chemicals and fertilizers also declines in this scenario due to a greater reduction in crop production when compared to the base case. Finally, due to

the shift in preferences away from other red meats, the production of other meat animals at the farm-level declines by 1.61%.

#### Changes in Pork and Dairy Demand

This scenario incorporates not only changes in the retail and processor demand for pork, but also includes a 2% decrease (at constant prices) in the retail demand for all dairy products. One can think of this scenario as containing all of the potential changes in supply and demand from introducing growth stimulants in the dairy and pork industries.

As expected, when consumers reduce their demand for all dairy products, consumption of fluid milk and other dairy products falls (by approximately 1.65%). Note that the initial decrease in demand has been dampened by decreases in retail prices for fluid milk and other dairy products. Thus, relatively cheaper dairy products help to overcome some of the initial negative affects at the retail level.

This modest decrease in retail demand for dairy products did not cause the production of milk at the farm-level to decline. (A larger decline in retail demand could easily cause farm-level production to decrease.) However, the increase in milk production is much smaller than in the previous two scenarios. Because of this small increase and the decrease in farm-level pork production, this scenario projects the largest impact on the domestic crop industries. Grain usage by all livestock industries declined (compared to the initial equilibrium) by 4.47% while protein usage increased by 10.61%. Compared to the base case, the reduction in grain use is much larger and the increase in protein use is much smaller. Thus, this scenario leads to the largest reduction in feed grain production and price, and the smallest increase in oil crop production, when compared to the other two cases. This also gives the largest decline in the employment of labor, capital services, and chemicals and fertilizers in domestic agriculture.

#### Implications for International Trade

As noted in the introduction, an important aspect of the framework that we have employed in this paper is the explicit treatment of international trade. Technological change is a phenomenon with potentially global implications. This section addresses the implications of the introduction of growth stimulants for international trade. In the simulations conducted above, we have assumed no change in production technology and consumer

preferences in the rest of the world. This is not because we think this is a realistic assumption, but rather due to a lack of information. A consequence of this assumption is that introducing growth stimulants in the U.S. dairy and pork industries improves their relative competitiveness, thus exports expand while imports contract.

Estimates of the trade changes are reported in table 4, in both percentage and volume (*i.e.*, constant dollar) terms, for each of the three scenarios. Note that the percentage changes in table 4 are calculated from a relatively small base. Thus, even though fluid milk exports increase by 7.52%, this represents only a \$2.25 million increase in foreign sales. As a result of the relatively small share of trade in these sectors' total output, changes in the level of exports and imports do not play a major role in the domestic outcomes predicted by the model. Indeed, even doubling the trade elasticities has a negligible effect on domestic prices following the introduction of growth stimulants.

Despite the relatively small role of trade, it is still instructive to examine the trade pattern changes in table 4. In the case of dairy exports, it is clear that when U.S. consumers reduce their demand for dairy products, more of the increase in dairy production is exported. Also, imports fall with the decline in total consumption. This brings up an interesting point. While we have assumed that U.S. consumers reduce their consumption of all dairy products, it is conceivable that they might shift their demand towards imports, provided the imported items have not been produced with growth stimulants. Thus, how the commodity has been produced may provide an important method of product differentiation, and thereby affect the pattern of trade.

For pork, we see the same pattern of increasing exports and decreasing imports. When the gains in processing efficiency are considered (scenarios 2 and 3), exports increase by almost 50% compared to the base case. However, the increase in retail demand for pork products, domestic and foreign, also helps lessen the drop in foreign pork imports. In this case, we might expect U.S. consumers to discriminate against imports, which would have relatively more fat, in favor of domestic pork products.

In sum, there is considerable potential for changes in the pattern of international trade following the introduction of growth stimulants. The importance of such changes for the domestic economy depends on the extent to which these products are traded internationally. Also, the assumptions made about changes in technology and preferences in other countries will be crucial to the outcome of any simulation. To the extent

that there are differential rates of adoption and differential effects on consumer attitudes, it will be important for future studies in this area to disaggregate the rest of the world into early and late adopters (and perhaps non-adopters).

#### SUMMARY AND CONCLUSIONS

This paper has examined the potential impacts which the introduction of growth stimulants into the domestic dairy and pork industries might have on the U.S. economy. The use of recombinant DNA and other technologies to increase productivity in the livestock sectors have, particularly in the case of bST, led to much debate on the impact of these products. In this paper, we have taken a broad, economy-wide view of the impacts of livestock growth stimulants. This approach has extended previous research in this area by determining the impacts of introducing growth stimulants on the domestic crop sector and the domestic food processors, and by considering the consequences of changes in retail demand for pork and dairy products. We believe that by taking a broader view, a more consistent assessment of the impacts of using growth stimulants in the dairy and pork industries can be obtained.

Three different scenarios were analyzed: the introduction of growth stimulants with no changes in processor or retail demand, the introduction of growth stimulants with changes in processor and retail demand for pork, and the introduction of growth stimulants with changes in processor and retail demand for pork plus a change in retail demand for dairy products. As a whole, the results in this paper show a much more modest impact on prices and quantities than have previous studies. These differences may arise from several sources. First, most previous research has assumed much larger impacts on productivity and feed efficiency. Their assumptions were based on earlier experimental research that did indeed suggest that such effects might be quite large. However, recently more experimental information has become available, and it points to much smaller increases in feed efficiency. Second, using an economy-wide approach also helps to dampen the impacts on prices and quantities. Because previous research has focused only on a particular sector, all of the adjustments of introducing the growth stimulants are forced upon that sector leading to large changes in prices and quantities. However, in the face of such large changes, it is likely that other sectors of the economy will also adjust.

Allowing other segments of the economy to respond to changes in the livestock sector serves to dampen the impact of introducing growth stimulants.

The second major finding is when potential changes in input quality to pork processors are taken into account, pork production at the farm-level may actually fall, even in the face of improved technology and strengthened consumer demand. This paradox can occur because leaner live hogs yield a larger amount of salable meat to processors. Therefore, the processors need fewer animals to produce the same amount of processed pork products. If the increase in the retail demand for the leaner pork products does not offset the decline in processor demand, then farm-level pork production will decrease. None of the previous studies have acknowledged the implications on processor demand of improving swine product quality.

There are several limitations of this study that should be acknowledged. The analysis is limited to the effects of bST and ractopamine. Thus, care should be employed in generalizing these results to other growth stimulants and biotechnology products. Government programs for dairy and feed grains have been ignored in the analysis presented here. If the dairy price supports remain constant, then the farm-level price of milk will remain constant, milk production will expand more than shown here, and government expenditures will increase. However, due to the federal budget situation, it seems unlikely that the price supports would remain constant. Incorporating the feed grains program would likely lessen the impacts of the reduction in feed demand by the livestock industries through support payments to producers. This would also discourage the substitution between feed grains and oil crops. Again, by maintaining the current set of target prices and loan rates, government expenditures would increase, and place budgetary pressure to reduce these rates. Finally, because we take an aggregate, economy-wide, static perspective of the introduction of growth stimulants, we have ignored the potential impacts on the structure of the dairy and pork industries and the dynamics of how they will change over time.

This study has identified several areas for future research. First, better estimates of how productivity will improve in on-farm use of growth stimulants are needed. Specifically, additional information on productivity gains, improvements in feed efficiency, changes in the ration mix, and impacts on non-feed expenses are required.

Second, better estimates of how retail and processor demands will change are needed. Finally, more information is needed on the impacts of biotechnology in other countries.

In spite of these limitations, this study provides a consistent and comprehensive assessment of the implications of what is currently known about the impact of introducing growth stimulants in the livestock sector. The importance of taking a broad view of the economy to avoid overstating the effects of technological change and the importance of tracing products from the producer to the consumer with substantial detail in the marketing system have been identified. In sum, this research provides a useful guide for updating projections of the impacts of biotechnology, for agriculture, the domestic economy, and the rest of the world, as more refined estimates of the farm and processor level effects become available.

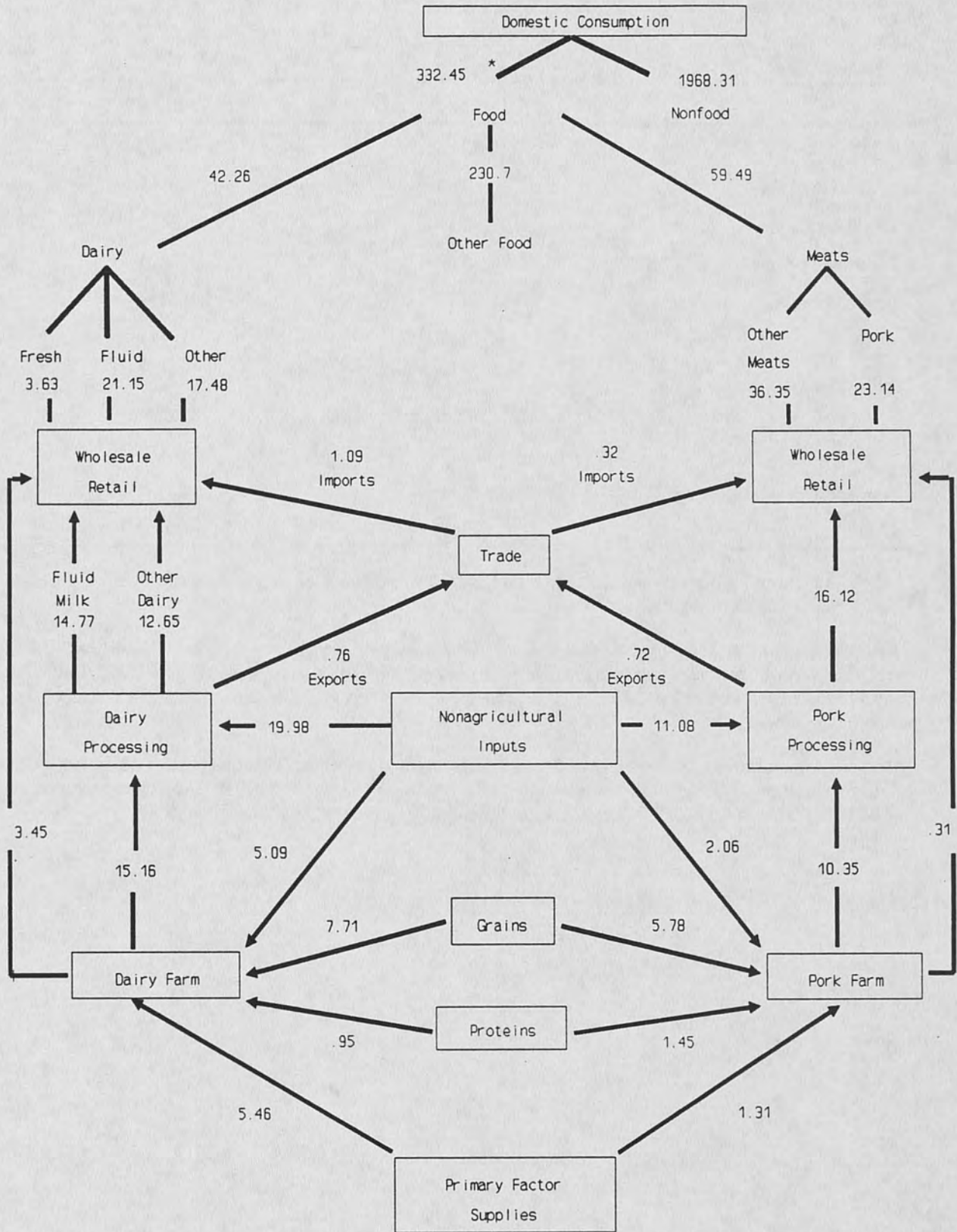


Figure 1. Domestic Dairy and Pork Marketing Channels

\* Numbers are value of product flows for initial equilibrium in billions of 1982 dollars.

Table 1 Milk Unit Costs<sup>a</sup>

	Without bST	With bST
Alfalfa Hay	\$0.7275 <sup>b</sup>	\$0.7275
Mixed Hay	0.0865	0.0865
Distiller's Grain	0.1453	0.1453
Cottonseed Meal	0.6800	0.6800
Soybean Meal	0.1485	0.2430
Corn	0.6604	0.7944
Corn Silage	<u>0.3639</u>	<u>0.3499</u>
Total	\$2.8121	\$3.0266
Production (lb./day)	57.	64.
Nonfeed Costs	\$0.0866	\$0.0850 <sup>c</sup>
Unit Cost/lb.	\$0.1360	\$0.1323

<sup>a</sup> Based on balanced rations obtained from Gerald M. Jones, professor of Dairy Science, Virginia Polytechnic Institute and State University.

<sup>b</sup> The prices for these feedstuffs and raw milk are 1982 average prices. They are: corn \$2.68/bu.; soybean meal \$13.50/cwt.; cottonseed meal \$13.60/cwt.; distillers grain \$145.30/ton; corn silage \$23.325/ton; alfalfa hay \$72.75/ton; and other hay \$57.65/ton. The year 1982 was chosen because the Social Accounting Matrix used in the model is based on 1982 data.

<sup>c</sup> Nonfeed expenditures ( $\$0.08666 \times 57 = \$4.9396$ ) are assumed to remain constant when bST is introduced. Thus, per unit nonfeed expenditures, excluding bST, equals  $(\$4.9396/64) \$0.07718$ . Adding the assume cost of bST of  $\$.50/\text{cow}/\text{day}$  ( $.50/64$ ) gives the total nonfeed per unit expenditures of  $\$0.08499$ .

Table 2 Hog Production Costs<sup>a</sup>

Cost Category	Without Ractopamine	With Ractopamine
Fixed <sup>b</sup>	\$36.080	\$36.080
Feed <sup>c</sup>		
Corn	19.806	17.242
Soybean Meal	11.368	14.170
Other	<u>4.836</u>	<u>4.278</u>
Total	36.010	35.690
Facilities <sup>d</sup>	11.240	10.600
Labor <sup>e</sup>	<u>2.610</u>	<u>2.460</u>
Total (per head)	\$85.93	\$84.83

<sup>a</sup> This is the cost of feeding a 44 lb. feeder pig out to a 235 lb. market weight, assuming average genetic potential.

<sup>b</sup> Fixed costs include: \$31.90 cost of feeder pig, one time medication charge of \$1.30, a marketing charge of \$1.00, and miscellaneous charges of \$1.88 (this includes a \$1.02 charge for an average 3% death loss).

<sup>c</sup> Feed costs are based on a ration containing 8.5% crude protein corn, 44% crude protein soybean meal and a base mix with the vitamins and minerals. The prices used for the feed ration were: \$2.60/bu. for corn; \$250/ton for soybean meal and \$17.75/cwt. for the base mix. Total cost per pound of feed is \$0.0661 for the 14% protein ration, and \$0.0705 for the 16% protein ration. The cost of ractopamine is assumed to be \$0.48/lb. of feed.

<sup>d</sup> Facilities charges include: fuel, electricity, and equipment repair charge of \$0.0152/head/day; equipment charge of \$0.0441/head/day; building charge of \$0.0272/head/day; and an inventory charge of \$0.0195/head/day. Thus, the total facilities charge is \$0.106/head/day.

<sup>e</sup> Labor costs is assumed to be \$0.0246/head/day.

Source: Millar<sup>8</sup>, 1990.

Table 3 Experiment Results<sup>a</sup>

	Base Case (Livestock Growth Stimulant Introduction)	Increased Pork Demand	Changes in Pork and Dairy Demand
	% Change		
<b>Production</b>			
Pork	1.55	-1.65	-1.64
Dairy	1.75	1.71	0.34
Fluid Milk	0.69	0.69	-1.08
Other Processed Dairy	1.09	1.07	-0.53
Processed Pork	0.77	4.87	4.90
Feed Grains	-1.39	-2.07	-2.32
Oil Crops	0.80	0.44	0.31
Wet-Corn Milling	1.52	1.40	1.38
Fats and Oils	3.48	2.72	2.54
Other Meat Animals	0.35	-1.61	-1.61
Other Red Meats	0.49	-1.69	-1.66
<b>Consumption</b>			
Fluid Milk	0.30	0.30	-1.64
Other Processed Dairy	0.27	0.27	-1.66
Processed Pork	0.46	4.95	4.99
Other Red Meats	0.38	-2.20	-2.17
<b>Producer Prices</b>			
Pork	-2.62	-3.30	-3.32
Dairy	-3.86	-3.96	-4.73
Fluid Milk	-2.18	-2.26	-2.71
Other Processed Dairy	-1.87	-1.95	-2.33
Processed Pork	-1.53	-1.84	-1.85
Feed Grains	-1.51	-2.07	-2.18
Oil Crops	2.35	2.21	2.35
Wet-Corn Milling	-0.57	-0.82	-0.86
Fats and Oils	1.28	1.16	1.24
Other Meat Animals	-0.46	-1.05	-1.07
Other Red Meats	-0.35	-0.82	-0.84
<b>Retail Prices</b>			
Fluid Milk	-1.52	-1.60	-1.91
Other Processed Dairy	-1.29	-1.37	-1.65
Processed Pork	-1.06	-1.29	-1.30
Other Red Meats	-0.24	-0.58	-0.59
<b>Agricultural Factor Use</b>			
Labor	-0.44	-0.90	-1.11
Capital Services	-0.43	-0.88	-1.08
Chemicals & Fertilizers	-0.89	-1.82	-2.24

<sup>a</sup> The complete set of experiment results are available from the authors upon request.

Table 4 Impacts on International Trade of Introducing Growth Stimulants in U.S.

Product	Base Case (Livestock Growth Stimulant Introduction)		Increased Pork Demand		Changes in Pork and Dairy Demand	
	Imports <sup>a</sup>	Exports <sup>b</sup>	Imports	Exports	Imports	Exports
	% Changes (\$ millions in parentheses)					
Fluid Milk	-6.13 (-1.84)	7.52 (2.25)	-6.45 (-1.93)	7.90 (2.73)	-9.64 (-2.89)	9.69 (2.91)
Other Dairy	-2.00 (-21.20)	3.11 (22.70)	-2.14 (-22.68)	3.27 (23.87)	-3.92 (-41.55)	3.29 (24.02)
Processed Pork	-2.19 (-9.31)	3.82 (27.05)	-0.13 (-0.42)	5.49 (39.53)	-0.13 (-0.42)	5.52 (39.74)

<sup>a</sup> Imports refers to changes in domestic imports.

<sup>b</sup> Exports refers to changes in domestic exports.

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Appendix A

Table A.1 Sectors Included in the Domestic Economy

<u>Sectors</u>	<u>Input/Output Sector Numbers</u>
<b>Agriculture</b>	
Dairy Farm Products <sup>a</sup>	1.01
Poultry and Eggs	1.02
Pork Farm Products <sup>b</sup>	1.0301
Other Meat Animals	1.0301
Food Grains	2.0201
Feed Grains	2.0202
Fresh Fruits and Vegetables	2.0401, 2.0501
Sugar	2.0502
Oil Bearing Crops	2.06
Other Agricultural Products	1.0302, 2.01, 2.03, 2.0203, 2.0402, 2.0503, 2.0701, 2.0702
<b>Food Manufacturing</b>	
Processed Pork (2011, 2013) <sup>c</sup>	14.0101, 14.0102
Other Red Meats (2011, 2013)	14.0101, 14.0102
Processed Poultry and Eggs (2016, 2017)	14.0103, 14.0104
Fluid Milk (2026)	14.06
Other Dairy Products (2021-2024)	14.02-14.05
Processed Fruits and Vegetables (203)	14.08-14.11, 14.1301, 14.1302
Grain Milling (2041)	14.1401
Other Milling Products (2043-2045, 2047)	14.1402, 14.1403, 14.1501, 14.16
Wet-Corn Products (2046)	14.17
Refined Sugar (2061-2063)	14.19
Confectionery Products (2065-2067)	14.2001-14.2003
Fats and Oils (207)	14.24-14.27, 14.29
Soft Drinks (2086, 2087)	14.22, 14.23
Other Beverages (2082-2085)	14.2101-14.2104
Other Food Products (205, 209)	14.07, 14.12, 14.30-14.32, 14.1801, 14.1802, 14.28
<b>Nonfood Manufacturing</b>	
Chemicals and Fertilizers	27.02, 27.03
Durable Manufactured Products	22, 37-63
Nondurable Manufactured Products	15-21, 23-36, 27.01, 27.04, 28-36
Services	All Else
<b>Wholesale/Retail Activities<sup>d</sup></b>	

<sup>a</sup> The prepared feed industry has been included in dairy farm products, poultry and eggs, pork farm products, and other meat animals.

<sup>b</sup> Pork products have been broken out of meat animals and red meats.

<sup>c</sup> The numbers in parentheses refer to SIC classifications.

<sup>d</sup> The margins were part of consumer expenditures on services in input/output table.

## Appendix B

### Model Formulation

There are five main parts of this model. The first part ensures that the markets for all goods produced in both regions clear. Second, the factor markets in both regions must clear. The third part of the model ensures that the zero profit conditions are met. The fourth part determines the level of welfare, or utility achieved in each region. Finally, the last part is composed of the budget constraints faced by the domestic and foreign households.

Goods Market Clearing Conditions: The market clearing conditions state the supply must be greater than or equal to demand for all commodities:

$$(A.1) \quad y_i - x_i \geq 0; \quad p_i \geq 0 \quad \text{and} \quad p_i (y_i - x_i) = 0 \quad \text{for all } i$$

where  $y_i$  is the supply of good  $i$ ,  $x_i$  is the demand for good  $i$ , and  $p_i$  is the price of good  $i$ . Note the complementarity variables in this formulation are product prices. If there is excess supply in any market, the price of that good is equal to zero.

This market clearing condition holds for three different types of goods: domestic consumer and producer goods, and foreign goods. We briefly describe the demand and supply conditions for these three types of goods below.

*Domestic consumer goods:* Consumer goods are "produced" by the domestic wholesale/retail sector by combining domestic producer and foreign goods, with labor and capital services. Demand for each consumer goods is then determined by the preferences of the domestic household, which are represented by a CDE (Constant Difference Elasticity) implicit expenditure function<sup>29</sup>. Thus, the demand for each consumer good is obtained by applying Shepard's lemma.

*Domestic producer goods:* The output from three sectors, agriculture, food manufacturing, and nonfood manufacturing are considered producer goods. The supply of each of these goods is determined in the zero profits conditions (see equation A.3). Total demand for each producer good is the sum of input demand from industries in the agricultural, food manufacturing, nonfood manufacturing and wholesale/retail sectors, plus

export demand from the foreign household. The input demands are derived from industry cost functions using Shepard's lemma. Export demand is determined by the preference structure of the foreign household, which is represented by a CDE implicit expenditure function. Thus, export demand is derived by also using Shepard's lemma.

*Foreign goods:* Production in the rest of the world is represented by a CDE implicit revenue function. Again, using Shepard's lemma, we can derive the net supply of each foreign good. Demand for foreign goods is the sum of the demand by the foreign household (derived using Shepard's lemma) and the input demand by the domestic wholesale/retail sector.

Factor Market Clearing Conditions: The second part of the model is the set of factor market clearing conditions. In both regions, the endowment of the primary factor(s) of production must equal or exceed their use:

$$(A.2) \quad v_0 - v \geq 0 ; w \geq 0 \text{ and } w (v_0 - v) = 0$$

where  $v_0$  is the endowment of the factor of production,  $v$  is the level of factor usage and  $w$  is the factor price. Again, the complementarity variable is the price of the factor of production. An excess supply in a factor market implies that the factor price equals zero.

Because there are three primary factors of production in the domestic economy, the model has three domestic factor market clearing equations. In each of these equations,  $v$  is the sum of the demand for that particular factor by all firms in the agricultural, food manufacturing, nonfood manufacturing, and wholesale/retail sectors. In this model, the foreign factor market is dropped by the imposition of Walras' Law and the foreign factor price becomes the numeraire and is set equal to one.

Zero Profit Conditions: The third main part of the model is the zero profit conditions. For the nonfarm sectors in the domestic economy this condition states that price can not exceed average cost (which equals marginal cost due to constant returns to scale technology) in an equilibrium:

$$(A.3) \quad MC_i - p_i \geq 0 ; y_i \geq 0 \text{ and } y_i ( MC_i - p_i ) = 0$$

where  $MC_i$  is the industry marginal cost, that also equals industry average cost, for domestic good  $i$ . Note that if economic profits are negative, no production will occur in domestic industry  $i$ . The zero profit condition is slightly different for domestic agriculture due its multiproduct representation. For this sector, total cost can not exceed total revenues. The complementarity variable for domestic agriculture is the aggregate level of the primary factors of production employed in agriculture.

The economywide zero profit condition for the rest of the world states that the aggregate factor price must equal or exceed the derivative of the revenue function with respect to the level of foreign primary factor endowment:

$$(A.4) \quad w^* - \left[ \frac{\partial r^*}{\partial v^*} \right] \geq 0 ; v^* \geq 0 \text{ and } v^* \left[ w^* - \left[ \frac{\partial r^*}{\partial v^*} \right] \right] = 0$$

where  $w^*$  is the foreign primary factor price,  $v^*$  is the foreign factor endowment, and  $r^*$  is the foreign CDE implicit revenue function. Thus, if profits are negative in the rest of the world in equilibrium, factor usage in this region, along with production, must be zero.

Determination of Utility: The fourth part of the model formulation determines the expansion effects of the CDE expenditure function. This condition states that the marginal utility of income must equal or exceed the reciprocal of the derivative of the expenditure with respect to utility (this is analogous to foreign zero profit condition). This can be expressed as:

$$(A.5) \quad \lambda - \frac{1}{\partial e / \partial u} \geq 0 ; u \geq 0 \text{ and } u \left( \lambda - \frac{1}{\partial e / \partial u} \right) = 0$$

where  $\lambda$  is the marginal utility of income and  $u$  is the level of utility. The level of utility is the complementarity variable in equation (A.5).

Budget Constraints: The last part of model is composed of the budget constraints for the domestic and foreign households. These conditions state that income must be greater than or equal to expenditures by each household. Income is defined as the sum of all factor payments to each household. Thus:

$$(A.6) \quad w \cdot v - \sum_{i=1}^n p_i x_i \geq 0 ; \lambda \geq 0 \text{ and } \lambda ( w \cdot v - \sum_{i=1}^n p_i x_i ) = 0$$

where  $\lambda$  is the marginal utility of income. In this part, the complementarity variable is the marginal utility of income. This equals zero if the household does not exhaust disposable income.

### Model Solution

The model described in the previous section is formulated as a nonlinear complementarity problem. That is, equilibria can be described as a solution to:

$$(A.7) \quad q \geq 0 ; \chi(q) \geq 0 \text{ and } q' \chi(q) = 0,$$

where  $q$  is a vector of commodity prices, factor prices, utility levels, factor usage, production levels, and the marginal utility of income;  $\chi(q)$  is a vector (of dimension equal to that of  $q$ ) made up of the supply-demand balance for each good, the supply-demand balance for each factor, zero profit conditions, the marginal conditions for the CDE expenditure function, and household budget constraints.

# PRIVATE STRATEGIES, PUBLIC POLICIES & FOOD SYSTEM PERFORMANCE

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