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Abstract

Many livestock sector models have limited coverage of relevant variables and are somewhat ad hoc in their structure in the choice of what should be specified as behavioral equations. This study develops a generic conceptual approach to modeling the livestock sector that provides consistent rules of specification and better coverage of variables. The new approach departs significantly from existing models. This approach is applied to modeling the swine-pork sector of Japan and then used to analyze the impact of removing Japan's gate price policy and variable levy for pork imports.

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ABSTRACT

This study develops a generic conceptual approach to modeling the livestock sector that provides better coverage of variables to ensure the consistency in the underlying biologics of the model and also provides consistent rules of specification. This approach is applied to modeling the swine-pork sector of Japan and then used to analyze the impact of removing Japan's gate price policy and variable levy for pork imports.

The new approach departs significantly from existing models. For consistency in the biologics of the model both live animals and meat components of the sector are fully covered. The structure clearly differentiates stock and flow variables and investment and production decisions. A standard rule of specification is established that only flow variables that correspond to the actual decisions faced by producers and consumers are specified with a behavioral equation, while stock variables are derived from changes in the relevant flow variables using an accounting identity. The flow variables are expressed in rates rather than levels and specified with logistic functions to automatically impose biological-technological constraints. Swine slaughter number and weight are disaggregated into sow and barrow-gilt. Market-clearing price is endogenously solved.

The estimated 12-equation Japanese swine-pork model has good fit as shown by high R^2, no serial correlation with Durbin-Watson (DW) statistics approaching 2, significant coefficients, correct signs, and reasonable magnitudes. All validation statistics from a within-sample simulation of the model suggest that the model with enriched structural specification is also able to capture both the mean and variability of all endogenous variables. Except for swine death (2.3 percent) and pork stock (-1.9 percent) which are subject to unexpected technical and policy shocks, all other endogenous variables had mean percentage errors (MPE) of less than one percent. Prediction errors are mostly from random sources. Except for pork stock (5.3 percent), the share of bias for all other endogenous variables is less than 3 percent.

Finally, the model was also used to analyze the “No Gate Price Policy Scenario.” The model generated expected changes both in terms of direction and magnitude that are within reported range from earlier studies. Specifically, imports increased significantly but were mostly absorbed into pork stocks to cushion its impact on domestic prices.

Key words: livestock sector, partial equilibrium model, gate price policy

A GENERAL CONCEPTUAL APPROACH TO MODELING THE LIVESTOCK SECTOR: Application To The Japanese Swine-Pork Sector Model With Analysis Of The "No Gate Price Policy Scenario"

Introduction

Commodity modeling is a common tool used by economists either to analyze a specific subject matter or to make projections. An example of the former includes Buhr and Hayenga (1994) who used a quarterly econometric model (Buhr 1993) to analyze the impact of growth promotants in the U.S. livestock and meat sector. Brester and Wohlgenant (1997) analyzed the impact of the GATT/Uruguay Round trade negotiations on U.S. beef and cattle prices with a model of the cattle-beef sector. Wahl et al. (1992) used a meat model for Japan to analyze the impacts of liberalizing the Japanese pork market. Fuller (1997) developed a policy and projection model for the meat sector in the People's Republic of China that was later used by Fuller and Hayes (1998) to examine the impact of Chinese accession to the WTO on U.S. meat and feed-grain producers. Also, a number of organizations that provide a long-term outlook of world trade in agriculture maintain large partial equilibrium models of world agriculture. These include the United States Department of Agriculture (USDA), the Organization for Economic Cooperation and Development (OECD), Agriculture Canada, the Australian Bureau of Agricultural and Resource Economics (ABARE), and the Food and Agricultural Policy Research Institute (FAPRI). Each of these organizations publishes annual outlooks: USDA has its World Agricultural Supply and Demand Estimates (WASDE) and World Market and Trade Circular (1998); OECD has its Agricultural Outlook 1998-2003; ABARE has its Australian Commodities Forecasts and Issues; Ag Canada has its Medium Term Policy Baseline; and FAPRI has its World Agricultural Outlook. The organizations also participate in an annual "World Agricultural Outlook Meeting" where they compare projections.

A cursory review of published and unpublished documentation of models for either the subject-matter studies or projections reveals that many of the existing livestock sector models are limited in their variable coverage and ad hoc in the choice of what should be specified as behavioral equations.[1] Specifically, there is a lack of complete and proper accounting of the stock and flow of live animals making the consistency of their underlying biologics suspect. For example, a swine-pork sector model may consist only of three equations that include behavioral specifications of a pork import demand, pork domestic demand, and pork production. Pork stock is usually considered exogenous and there is no coverage of any live animal variables.

This study develops a general conceptual approach to modeling the livestock sector to capture more amply the behavioral and biological processes unique in this sector. The specific features of this approach are then applied to the Japanese swine-pork sector and used to analyze the impact of removing the gate price policy and variable levy for pork imports into Japan.

This study makes new contributions in modeling the livestock sector that depart from existing models in six significant ways.

- First, both the live animal and meat components of the sector are fully covered.
- Second, with better coverage of live animals, a clear differentiation of stock and flow variables becomes necessary. The differentiation allows for proper accounting of live animals to ensure consistency in the underlying biologics of the model. This is particularly important in the cattle sector where the unit of observation, usually one year, is shorter than the length of a production cycle.

  Also, this approach differentiates the investment and production decisions faced by livestock producers. That is, production decisions (e.g., swine slaughter) may be responsive to current (or transitory) price changes, whereas investment decisions (e.g., additions to the breeding herd) may respond more to permanent price changes. Moreover, this framework also allows the model to easily accommodate adjustments in inventory and production that may result from exogenous shocks such as the swine foot and mouth disease (FMD) outbreak in Taiwan and classical swine fever (CSF) in the European Union (EU).
- Third, the model establishes a consistent rule of specification. That is, only flow variables that correspond to the actual decisions facing producers and consumers are given behavioral specifications. These variables may include number of animals

slaughtered, number of animals added to the breeding herd, slaughter weight, import, export, consumption, pork stock demand, pig crop, and mortality. On the other hand, stock variables such as sow inventory and barrow-gilt inventory are not directly specified as behavioral equations. Instead, their levels over time are simply derived in an accounting identity, given their beginning levels, from the changes in the flow variables that impact them.

- A fourth new contribution is that the flow variables are modeled as rates rather than as levels. For example, the rate of barrow-gilt slaughter, which is defined as the ratio of the number of barrow-gilt slaughtered and the beginning barrow-gilt inventory, is used rather than the number slaughtered. This specification provides several advantages. Based on historical data, the rates appear to have more stable behavior and are usually comparable over time and across countries. Moreover, this specification delineates the direct impact that is captured in the equation representing the rates of flow variables from the indirect and lag effects that are captured in the stock variables where the rates are applied. This advantage can be demonstrated in the treatment of policies in the EU to support the cattle sector from the Bovine Spongiform Encephalopathy (BSE) crisis.
  The Over Thirty Months Scheme (OTMS) removed cattle over 30 months old from entering the food chain and the Early Calf Processing Scheme (ECPS) removed some calves from entering the food chain. When these policies are ended, the impact can be accommodated easily with this structure through changes in the inventory number and not on the intercept or the slope of the slaughter rate equation. Moreover, specification of flow variables in rates lends itself easily to imposing biological-technological restrictions using a logistic function.
- Fifth, swine slaughter is disaggregated into sow and barrow-gilt slaughter to allow differential impacts of price changes in both the direction and magnitude of these variables. This specification differentiates changes in the supply function with that of movements along a supply function. Without this feature one is forced to specify a downward sloping supply with respect to current price in order to mimic the stylized

fact—that of a cycle in the response of producers. An econometric decomposition method is applied to derive a slaughter weight equation that can estimate a separate average slaughter weight for sows and barrow-gilt slaughtered from aggregate data. Pork production is a product of number slaughtered and slaughter weight for sows and barrow-gilt.

- Finally, a market-clearing price determination is used instead of a simple price transmission. This structure recognizes possible differentiation between domestic and imported products and volume of trade.

Model

The new features in the proposed general conceptual approach in modeling the livestock sector are applied in the Japanese swine-pork sector. Generic diagrams of the swine-pork sector identifying the relevant variables and relating the stock and flow variables from production to consumption are given in Figures 1 and 2. The live animal inventory and production component has two stock variables, namely, the breeding inventory (mostly sows) and barrow-gilt inventory. Swine death and pig crop are two flow variables that are driven mostly by biological-technical relationships. In contrast, the other flow variables including breeding addition, sow slaughter, barrow-gilt slaughter, slaughter weight, and live swine import and export directly relate to investment and production decisions of producers. Liveweight pork production is simply a product of the number slaughtered and slaughter weight, and carcass weight production is derived by applying a constant dressing percentage on liveweight production (e.g., 73 percent). The meat supply and demand component includes the following flow variables: pork import, export, stocks, and consumption demand.

The structure of the econometric model that follows closely represents the structure shown in the flow diagram. Because live swine import and export and pork export are not significant in Japan they are considered as exogenous. The model Japan swine-pork sector model has 12 endogenous variables with 9 behavioral equations for the flow variables, 2 accounting identities for the stock variables, and an equilibrium condition. The nine flow variables are domestic demand, pig crop, swine death, sow slaughter, barrow-gilt slaughter, slaughter weight, sow addition, pork import, and pork stock. The two stock variables are sow inventory and barrow-gilt inventory. A combination of linear, double log, and logistic functional forms is used. The disaggregation methodology for the slaughter weight lends itself easily to a linear function. A double log function is used for domestic demand, swine death, pork import, and pork stock. A logistic function is specified for pig crop, sow slaughter rate, barrow-gilt slaughter rate, and sow addition rate, to automatically impose biological-technological limits on these rates.

The equations given below are expressed in general form (as opposed to normalized form) in SAS where the error term is on one side of the equation. Definition of variables is given in Table 1. Per capita pork demand (1) is expressed as a function of real prices of substitute products, including wagyu beef, dairy beef, imported beef, pork, poultry, fish, and real income.

```
EQ.JPP01 = EXP ( PD0 + PD1*LOG(WBPRFJP/CPCPIJP)                    (1)
           + PD2*LOG(DBPRFJP/CPCPIJP)
           + PD3*LOG(IBPRFJP/CPCPIJP)
           + PD4*LOG(POPRFJP/CPCPIJP)
           + PD5*LOG(PYPRFJP/CPCPIJP)
           + PD6*LOG(FSPRFJP/CPCPIJP)
           + PD7*LOG(JPPCE/DEPOPJP/CPCPIJP)
           + LOG(DEPOPJP)
           - LOG(1000) )
           - POUDCJP;
```

As technical flow variables, pig crop (2) and swine death (3) are functions of time trend.

```
EQ.JPP02 = EXP ( SC0  + SC1*LOG(TREND)                             (2)
           + LOG(LAG(SWCOTJP))
           -  HQSPGJP;

EQ.JPP03 = EXP ( SD0 + SD1*LOG(TREND)                              (3)
           + SD2*D8990 + SD3*D9296
           + LOG(LAG(OTCOTJP+SWCOTJP)) )
           -  HQUDDJP;
```

Average slaughter weight (4) is a function of pork price to feed cost ratio and time trend. The decomposition procedure for sow and barrow-gilt slaughter weight makes it also a function of the proportion of sow and barrow-gilt slaughter.

EQ.JPP04 = SW0 + (OW0 - SW0)*(HQKOTJP/HQKTNJP) (4)
+ OW1*(POPRFJP/FDPRFJP)*(HQKOTJP/HQKTNJP)
+ OW2*(TREND)*(HQKOTJP/HQKTNJP)
+ WTD*D94
- ***POKWTJP***;

Sow slaughter (5) and barrow-gilt slaughter (6) are output decisions and are expressed as functions of pork price to feed cost ratio, whereas sow addition (7) is an investment decision and is expressed as a function of the average of the current and last year's price.

EQ.JPP05 = LAG(SWCOTJP)*(0.55/(1+EXP(-1* (SS0 (5)
+ SS1*(POPRFJP/FDPRFJP)
+ SS2*LAG(HQKSWJP/LAG(SWCOTJP))
+ SS3*D8284))))
- *HQKSWJP*;

EQ.JPP06 = LAG(OTCOTJP+HQSPGJP)*(0.70/(1+ EXP(-1*(OS0 (6)
+ OS1*(POPRFJP/FDPRJP))))
- ***HQKOTJP***;

EQ.JPP07 = LAG(SWCOTJP)*(0.55/(1+EXP(-1*(SA0 (7)
+ SA1*(((POPRFJP/FDPRFJP)
+ LAG(POPRFJP/FDPRFJP))/2)
+ SA2*TREND
+ SA3*D7080))))
- ***HQASWJP***;

Pork import (8) is a function of the market and standard import price ratio and the domestic and world price ratio.

EQ.JPP08 = EXP (PM0 + PM1*LOG(POPRFJP/POPSTJP) (8)
+ PM2*LOG(POPRFJP/(POPRFU9*JPEXCH))
+ PM3*LOG(TREND))
- ***POSMTJP***;

With the gate price policy and variable duties for pork import in Japan, the former capture the cost of import for pork products including insurance and freight (CIF) below the gate price, whereas the latter capture the cost of import for pork products with CIF above the gate price. Pork ending stock (9) is a function of the real price of pork.

```
EQ.JPP09 = EXP ( PE0 + PE1*LOG(POPRFJP/CPCPIJP)                    (9)
           + PE2*LOG(TREND) + PE4*D9596
           + PE5*D79 + PE6*D81 )
           - POCOTJP;
```

Stock variables including barrow-gilt inventory (10) and sow inventory (11) are derived in an accounting identity. Ending sow inventory is beginning sow inventory plus sow addition and less sow slaughter and sow death. Ending barrow-gilt inventory is beginning barrow-gilt inventory plus pig crop and swine imports, and less barrow-gilt death, barrow-gilt added to the breeding herd, swine export, and barrow-gilt slaughter.

```
EQ.JPP010 = LAG(OTCOTJP)                                           (10)
            +  HQSPGJP
            +  HQSMTJP
            -  LAG(OTCOTJP/(OTCOTJP+SWCOTJP))*HQUDDJP
            -  HQASWJP
            -  HQUXTJP
            -  HQKOTJP
            -  OTCOTJP;
```

```
EQ.JPP011 = LAG(SWCOTJP)                                           (11)
            +  HQASWJP
            -  HQKSWJP
            -  LAG(SWCOTJP/(SWCOTJP+OTCOTJP)) *HQUDDJP
            -  SWCOTJP;
```

The model solves for a price that clears the market (12). That is, equilibrium price is determined by equating total supply (beginning pork stock plus production plus import) and total demand (ending pork stock plus consumption plus export).

```
EQ.JPP012 = LAG(POCOTJP)                                           (12)
            +  POKWTJP*(HQKOTJP+HQKSWJP)
            +  POSMTJP
            -  POUDCJP
```

- POUXTJP
- ***POCOTJP***;

A double log function directly gives elasticities from the estimated parameters. The logistic function is given in (13)

$$y_t = \frac{K}{\left(1 - \exp^{-(x_t \beta)}\right)} + \mu_t , \tag{13}$$

where y is the dependent variable, K is the upper limit of y, x is a vector of regressors, β is a vector of parameters to be estimated, μ is an identically and independently distributed error process, and t is time index. The elasticity formula for a logistic function is

$$\varepsilon = \beta \bar{x}\left(1 - \frac{\bar{y}}{K}\right). \tag{14}$$

Because production is not directly estimated, the supply elasticity is derived as a weighted sum of the elasticity of supply from sows and barrow-gilt, with their respective elasticities also a sum of the elasticity of the number slaughtered and slaughter weight elasticity. The subscript b refers to sows and o to barrow-gilt, and the superscript k refers to number slaughtered and w to slaughter weight.

$$\varepsilon_s = \varpi_b(\varepsilon_b^k + \varepsilon_b^w) + \varpi_o(\varepsilon_o^k + \varepsilon_o^w). \tag{15}$$

Data Estimation and Results

Sources of Japanese data include the USDA's PS&D database, the Agriculture and Livestock Industries Corporation, FAPRI, and the International Monetary Fund (see Table 1). Estimation and simulation were conducted in SAS 6.12 (SAS Institute 1993).

Pork ranks number one in Japan's meat consumption basket at 11.8 kilograms (kg) per person per year (see Table 2). Poultry follows at 11.0 kg and beef at 7.8 kg. Japan plays a significant role in the world pork market. Of the total world pork net imports of 2.25 million metric tons (mmt) in 1998, Japan's share accounts for 36.1 percent, or 735 thousand metric tons (tmt). Pork imports are 28.49 percent of consumption. The number of hog farms in Japan is reported to be approximately 14,400 with an average number of 681 pigs per farm. Sows and gilts for breeding were 9.8 million in 1997. For 1990 to 1997, the average pig crop was 18.84 piglets per sow per year and the mortality rate was 10.17 percent. Sow slaughter rate is 47.05 percent and barrow-gilt slaughter rate is 62.3 percent. Average slaughter weight is 73 kg per head carcass weight. Barrow-gilt slaughter represents 97.39 percent of total slaughter, and the remaining 2.60 percent is accounted for by sow slaughter. The average sow addition rate is 46.95 percent.

Due to lack of comparative advantage, Japan's swine-pork sector has experienced a sustained contraction since 1990 at an annual average rate of 2.5 percent. From a high of 11.816 million-head inventory in 1990 it declined to the current level of 9.480 million head. As a result, imports have increased significantly. In 1980, the share of pork imports to total consumption was a mere 9 percent. This share more than doubled in 10 years reaching 24 percent in 1990, and again close to doubling in 6 years at 44 percent in 1996. In the last two years this share has remained at 36 percent.

Prior to its FMD outbreak, Taiwan was the main supplier of pork in Japan. Denmark supplied frozen pork for processing, while the United States and Canada supplied some fresh-chilled pork.

Tables 3 through 6 give the estimates of the model with demand and supply elasticities summarized in Table 7. Demand elasticity is –0.394 and 0.695 for own-price and income. Imported beef and fish are the strongest substitute for pork; wagyu beef, dairy beef, and poultry are distant substitutes. Stock demand elasticity has a higher elasticity of –1.847 driven by the price stabilization policy in pork. Under this policy the Government of Japan (GOJ) announces a price band (i.e., floor and ceiling price) at the beginning of each fiscal year. Then the Livestock Industry Promotion Corporation (LIPC) intervenes in the market through its buy-and-sell activity to ensure market price move within the set price band. Production elasticity is 0.0938, derived as a weighted sum of the sow slaughter elasticity of –0.127 and barrow-gilt slaughter of 0.098, and the slaughter weight elasticity of 0.002. Import supply elasticity is significantly higher than domestic supply.

Import supply is expressed as a function of the ratio of market price to the standard import price and the ratio of domestic price and world price. In the period prior to the General Agreement on Tariffs and Trade (GATT) all pork imports into Japan with CIF below the gate price enter at the standard import price using a variable levy. This price was directly related to the mid-point of the price band used in the price stabilization policy. Imports with CIF above the gate price are charged an ad valorem tax. GATT allowed Japan to retain its gate price but converted the variable levy into specific taxes with reduction commitments until the year 2000. However, the results of the two policy regimes are not fundamentally different.

The higher elasticity of the first ratio at 0.687 may be explained by the fact that since market price is supported so that it moves within a given price band, it is expected that the GOJ will not allow a significant and prolonged upward departure of the market price from the standard import price. Hence, a high ratio may signal possible reduction in the variable levy to allow more imports. The elasticity of the second ratio at 0.298 suggests responsiveness of suppliers despite the variable levy. This accounts for some portions of the pork imports that may have CIF values above the gate price. Moreover, suppliers can also respond with more quantity of higher valued pork cuts to avoid the variable levy.

The estimated model adequately captures the behavior of the historical data. It shows that the fit in all equations is good. Of the nine estimated behavioral equations, seven had R^2 above 0.90 with the lowest at 0.687 for swine death that showed random behavior. All the Durbin-Watson (DW) statistics suggest the absence of serial correlation. Most of the coefficients are significant and all have the expected signs and magnitudes.

A within-sample simulation was performed for 1985 to 1996. All validation statistics suggest that the richer structure proposed in the general approach to modeling the livestock sector also is able to capture both the mean and variability of all the endogenous variables in the model. For example, in the table of descriptive statistics (see Table 8), the mean of the actual wholesale price is 496 yen per kg, whereas the mean of the solved market clearing price is 498. The mean of the simulation values of the other endogenous variables is also close to the mean of their actual values. It is evident in the other validation statistics that variables that are impacted more by random technical shocks such as swine death and by policy shocks such as pork stock and import show relatively higher prediction errors. The statistics of fit in Table 9 show that of the 12 endogenous variables, 9 have mean percentage error (MPE) of less than 1 percent. The highest MPE is in swine death at 2.3 percent, followed by pork stock at –1.9. Table 10 shows the decomposition of the mean square error (MSE). The table suggests that the prediction errors in all endogenous variables are mostly from random sources. The share of bias for most variables is less than 3 percent, except for pork stock, which is 5.3 percent. Moreover, the Theil Inequality Coefficients all approach zero with pork stock at 0.150.

Furthermore, the model was used to analyze the impact of removing the gate price policy and variable levy for pork imports into Japan—a "No Gate Price Policy Scenario." This was accommodated in the model by reducing the pork standard import price in the pork import equation to an estimated CIF value with ad valorem duties. The results are within the reported range in an earlier study by Wahl, et al. (1992). Table 11 shows that pork import increased by 71.7 percent. To cushion its impact on domestic price, a large proportion of the increase in imports was absorbed into pork stocks, which increased by 42.3 percent. Domestic price declined by 15 percent. Sow ending inventory declined by 19.4 percent while other barrow-gilt ending inventory declined by 17 percent. Barrow-gilt slaughter declined by 16.4 percent, while sow slaughter declined by 12.3 percent. With a long-term downward trend in pork prices, sow addition declined by 17.9 percent. Pork production declined by 16.5 percent.

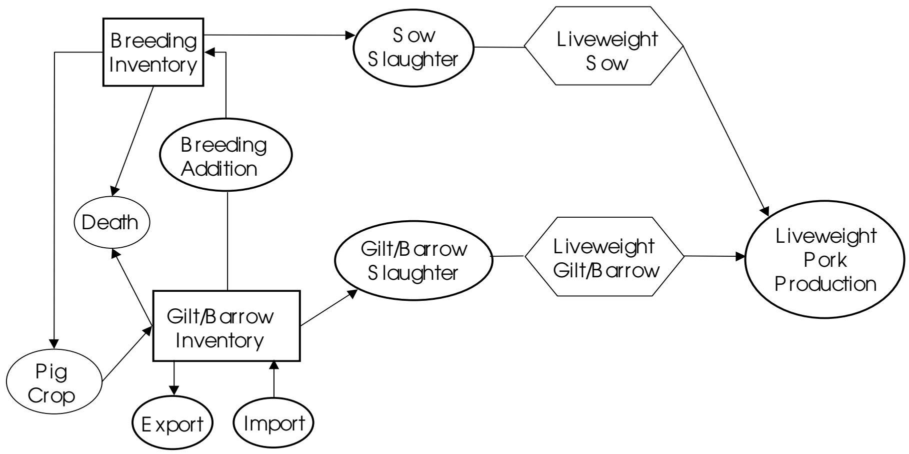
Conclusion

Many livestock sector models have limited coverage of relevant variables and are somewhat ad hoc in their structure in the choice of what should be specified as behavioral equations. Specifically, the lack of adequate coverage of the live animal component of the sector makes the consistency of the underlying biologics of the models suspect. This study developed a generic conceptual approach to modeling the livestock sector that provides consistent rules of specification and better coverage of variables.

The proposed approach has new and significant contributions that provide a richer livestock model structure. Both live and meat components of the sector are fully covered to ensure consistency of the biologics of the model. This approach clearly differentiates between stock and flow variables, where only flow variables that correspond to the actual decisions faced by producers and consumers are specified with a behavioral equation, whereas stock variables are derived from changes in the relevant flow variables using an accounting identity. The flow variables are modeled as rates rather than as levels, and logistic functional forms are used for some rates of flow variables to directly impose biological-technological limits. Slaughter number and slaughter weights are disaggregated into sow and barrow-gilt. Price is determined through market-clearing condition.

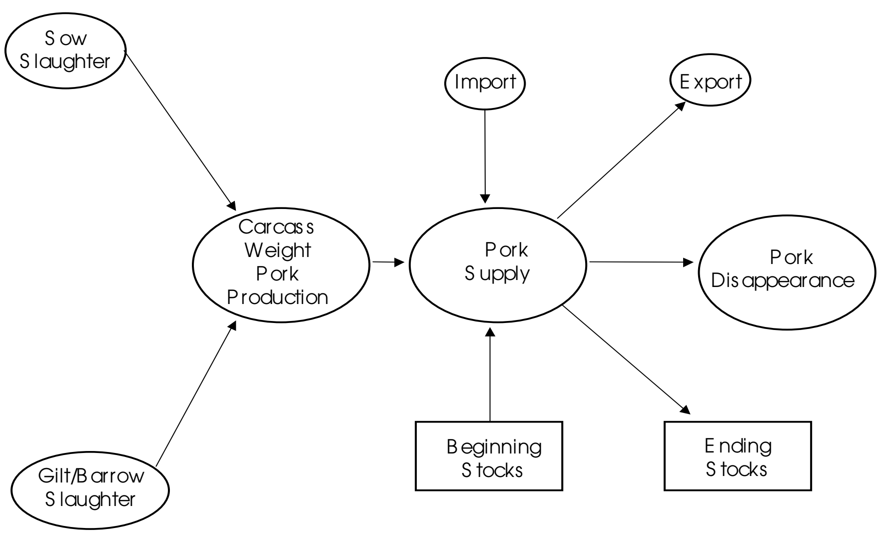
The model included nine behavioral flow variables, two accounting identities for stock variables, and equilibrium condition to solve for market-clearing prices. Estimates of the 12-equation Japanese swine-pork model have good fit, no serial correlation, and parameters are significant with expected signs and magnitudes. All validation statistics from a within sample simulation show that the proposed richer structure also is able to capture both the mean and the variability of all the endogenous variables in the model.

Finally, the model was also used to analyze the No Gate Price Policy Scenario by replacing the standard import price in the import equation with an estimated CIF with ad valorem duties. The model generated expected changes both in terms of direction and magnitude that are within the reported range of an earlier study. As the gate price is removed, increases in imports were mostly absorbed into pork stocks to cushion its impact on domestic prices. Wholesale price of pork declined only by 15 percent, pork consumption increased by 7 percent, and domestic pork production declined by 16 percent.



Live Inventory and Production Block: Swine-Pork Model

Figure 1. Live swine inventory.



Meat Supply Block: Pork Model

Figure 2. Pork production.

Table 1. Definition of variables and sources

CODE	DEFINITION	UNITS	SOURCE
Macro			
JPPCE	Personal consumption expend	Trillion Yen	IMF
JPEXCH	Exchange rate	Y/US$	IMF
CPCPIJP	Consumer price index	Index	IMF
DEPOPJP	Population	000	IMF
Prices			
WBPRFJP	Wagyu beef price	Y/kg	FAPRI
DBPRFJP	Dairy beef price	Y/kg	FAPRI
IBPRFJP	Imported beef price	Y/kg	FAPRI
POPRFJP	Pork price	Y/kg	FAPRI
PYPRFJP	Poultry price	Y/kg	FAPRI
FSPRFJP	Fish price	Y/kg	FAPRI
POPRFU9	World (U.S.) pork price	$/cwt	FAPRI
POPSTJP	Pork standard import price	Y/kg	FAPRI
FDPRFJP	Swine feed cost	Y/ton	Calculated
Live Animal			
SWCOTJP	Sow ending inventory	000 Head	USDA-PS&D
OTCOTJP	Barrow gilt ending inventory	000 Head	USDA-PS&D
HQSPGJP	Pigs born	000 Head	USDA-PS&D
HQSMTJP	Swine import	000 Head	USDA-PS&D
HQUXTJP	Swine export	000 Head	USDA-PS&D
HQKTNJP	Total slaughter	000 Head	USDA-PS&D
HQKOTJP	Barrow gilt slaughter	000 Head	USDA-PS&D
HQKSWJP	Sow slaughter	000 Head	USDA-PS&D
HQASWJP	Gilt added to sow inventory	000 Head	USDA-calculated
HQUDDJP	Swine death	000 Head	USDA-PS&D
Meat Balance			
POCOTJP	Pork ending inventory	000 mt	USDA-PS&D
POSMTJP	Pork import	000 mt	USDA-PS&D
POUXTJP	Pork import	000 mt	USDA-PS&D
POUDCJP	Pork consumption	000 mt	USDA-PS&D

Table 2. Historical consumption and production data

Per Capita Consumption	kg/person
All Beef	7.80
Wagyu	1.40
Dairy	1.60
Import	4.80
Pork	11.80
Poultry	11.00
Production Parameters	pigs/sow/year
Pig Crop	18.84
	percent
Mortality	10.17
Sow Addition Rate	46.96
Slaughter Rate	
Sow Slaughter Rate	47.05
Barrow-gilt Slaughter Rate	62.30
Average Slaughter Weight	kg/head
Sow Slaughter Weight	60.00
Barrow-gilt Slaughter Weight	73.95
Proportion of Slaughter	percent
Sow Slaughter	2.61
Barrow-gilt Slaughter	97.39

Table 3. Pork demand

Independent	Estimate	Std Dev	'T'Ratio	Prob>|T|
Linear				
Intercept	10.465	3.048	3.430	0.004
Real wagyu beef wholesale price	0.024	0.081	0.290	0.774
Real dairy beef wholesale price	0.030			
Real import beef wholesale price	0.133	0.048	2.760	0.015
Real pork wholesale price	-0.394	0.183	-2.150	0.048
Real chicken wholesale price	0.027	0.143	0.190	0.856
Real fish wholesale price	0.113	0.078	1.450	0.168
Real per capita personal income	0.695	0.306	2.270	0.038
Diagnostic				
R^2	0.982			
Adj R^2	0.975			
DW	1.353			

Table 4. Technical flow variables: Pig crop and swine death

Independent	Estimate	Std Dev	'T'Ratio	Prob>|T|
Pig Crop: Logistic				
Limit	22.000			
Intercept	1.160	0.158	7.330	0.000
Trend	0.023	0.007	3.470	0.002
Diagnostic				
R^2	0.940			
Adj R^2	0.937			
DW	0.976			
Swine Death: Double Log				
Intercept	-0.548	0.557	-0.980	0.338
Trend	-0.735	0.185	-3.980	0.001
Dummy 1	0.276	0.119	2.320	0.032
Dummy 2	-0.444	0.183	-2.420	0.026
Diagnostic				
R^2	0.687			
Adj R^2	0.637			
DW	2.042			

Table 5. Investment and output decision: Gilt addition to breeding rate, sow slaughter rate, and barrow-gilt slaughter rate

Independent	Estimate	Std Dev	'T'Ratio	Prob>|T|
Gilt Addition to Breeding: Logistic				
Limit	0.550			
Intercept	-1.920	1.160	-1.650	0.115
Pork-Feed price ratio	0.024	0.132	0.180	0.857
Trend	0.106	0.026	4.040	0.001
Dummy	-1.462	0.264	-5.550	0.000
Diagnostic				
R^2	0.958			
Adj R^2	0.951			
DW	0.935			
Sow Slaughter Rate: Logistic				
Limit	0.550			
Intercept	0.125	1.027	0.120	0.905
Pork-Feed price ratio	-0.295	0.126	-2.340	0.039
Lag sow slaughter rate	5.415	1.619	3.350	0.007
Dummy	-0.048	0.140	-0.340	0.738
Diagnostic				
R^2	0.895			
Adj R^2	0.866			
DW	1.300			
Barrow-gilt Slaughter Rate: Logistic				
Limit	0.700			
Intercept	0.856	0.066	12.980	0.000
Pork-Feed price ratio	0.300			
Diagnostic				
R^2	0.835			
Adj R^2	0.835			
DW	1.265			

Table 6. Slaughter weight, pork import, and pork stock

Independent	Estimate	Std Dev	'T'Ratio	Prob>|T|
Slaughter Weight: Linear				
Sow slaughter weight	0.06000			
Barrow-gilt slaughter weight				
Intercept	0.07066	0.00159	44.39000	0.00010
Pork-Feed price ratio	0.00004	0.00016	0.27000	0.80030
Trend	0.00014	0.00003	3.99000	0.01620
Diagnostic				
R^2	0.977			
Adj R^2	0.954			
DW	2.086			
Pork Import: Double log				
Intercept	-0.718	0.754	-0.950	0.358
Market-Standard price ratio	0.687	0.216	3.180	0.007
Domestic-World price ratio	0.298	0.108	2.760	0.016
Trend	2.298	0.151	15.210	0.000
Diagnostic				
R^2	0.987			
Adj R^2	0.983			
DW	2.031			
Pork Stock: Double log				
Intercept	8.486	3.764	2.250	0.039
Real pork price	-1.847	0.680	-2.720	0.015
Trend	-0.292	0.808	-0.360	0.722
Diagnostic				
R^2	0.931			
Adj R^2	0.906			
DW	1.854			

Table 7. Demand and supply elasticities

Elasticity	
Demand Elasticity	
Domestic Demand Elasticity	
Own-price	-0.3943
Wagyu Beef Price	0.0235
Dairy Beef Price	0.0300
Import Beef Price	0.1332
Poultry Price	0.0265
Fish Price	0.1131
Income	0.6954
Stock Demand Elasticity	1.847
Import Demand Elasticity	
Market-Standard Price	0.687
Domestic-World Price	0.298
Supply Elasticity	
Sow Slaughter	-0.1269
Barrow-gilt Slaughter	0.0981
Slaughter Weight	0.0016
Sow Addition	0.0173
Production	0.0938

Table 8. Descriptive statistics

	Actual		Simulation	
Endogenous Variable	Mean	S. Dev	Mean	S. Dev
Pork Price	496	38	498	43
Pork Consumption	2024	109	2026	95
Pig Crop	21188	2258	21096	1774
Barrow-gilt Inventory	9862	626	9820	429
Sow Inventory	1088	112	1087	122
Swine Death	1462	591	1479	582
Slaughter Barrow-gilt	19359	1590	19295	1877
Slaughter Weight	0.0745	0.0004	0.0745	0.0004
Slaughter Sow	454	38	451	39
Sow Addition	479	13	475	18
Pork Import	558	187	561	194
Pork Stock	110	31	106	29

Table 9. Statistics of fit

Endogenous Variable	MPE	MAPE	RMSE
Pork Price	0.579	3.252	3.685
Pork Consumption	0.157	1.157	1.320
Pig Crop	-0.193	2.061	2.573
Barrow-gilt Inventory	0.060	8.332	8.771
Sow Inventory	-0.139	1.397	2.038
Swine Death	2.323	9.711	11.514
Slaughter Barrow-gilt	-0.429	1.920	2.340
Slaughter Weight	-0.046	0.452	0.513
Slaughter Sow	-0.543	4.685	6.042
Sow Addition	-0.661	4.531	5.148
Pork Import	0.708	4.894	5.737
Pork Stock	-1.933	13.166	17.979

Table 10. MSE decomposition and Theil forecast error statistics

Endogenous Variable	Bias	Dist	U1
Pork Price	0.022	0.761	0.038
Pork Consumption	0.008	0.808	0.013
Pig Crop	0.030	0.261	0.025
Barrow-gilt Inventory	0.002	0.415	0.086
Sow Inventory	0.001	0.763	0.022
Swine Death	0.019	0.979	0.077
Slaughter Barrow-gilt	0.021	0.498	0.023
Slaughter Weight	0.008	0.780	0.005
Slaughter Sow	0.015	0.847	0.057
Sow Addition	0.022	0.249	0.052
Pork Import	0.013	0.890	0.052
Pork Stock	0.053	0.928	0.150

Table 11. Impact of "No Gate Price Policy Scenario"

Endogenous Variable	Percent
Pork Price	-14.974
Pork Consumption	6.915
Sow Inventory	-19.397
Pig Crop	-17.105
Barrow-gilt Inventory	-16.986
Swine Death	-13.104
Slaughter Barrow-gilt	-16.449
Slaughter Sow	-12.324
Slaughter Weight	-0.134
Sow Addition	-17.906
Pork Import	71.704
Pork Stock	42.291
Pork Production	-16.467

Endnote

1. FAPRI's Japanese Model already incorporates many of the features in this paper.

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