ECONOMIC FORECASTING AND POLICY ANALYSIS MODELS FOR CATFISH AND TROUT

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PROJECT OBJECTIVES

1. Identify, develop, and validate economic forecasting models of catfish and trout.

    a. Demand and supply effects,
    b. International trade effects,
    c. Potential effects of various policy alternatives and external economic shocks.

2. Identify data needs necessary to refine the models for these species and to potentially apply to other species.

3. Identify an industry-input frame-work to ensure model applicability.

ANTICIPATED BENEFITS

U.S. aquaculture industries and their product markets have matured such that the dynamics of the national economy, federal and state policies, and international trade can have significant and unanticipated effects on the financial health of U.S. aquaculture businesses. Other segments of the agriculture and food sectors rely upon and benefit from econometric models that estimate demand, supply and the relationships among key economic parameters. These models are used to forecast industry trends, effects of anticipated macroeconomic factors, and impacts of proposed policy initiatives. Linking general macroeconomic trends to aquaculture production and market sectors and following the effects through to the resulting impacts on farm price levels will provide guidance on policy initiatives for the catfish and trout industries.

The demand and supply models estimated will provide an indication of changes in catfish/trout prices and quantities demanded, effects on production/marketing channels, who will bear the costs, and to what extent demand would need to change to compensate for detrimental price shocks. The international trade models will estimate the effect of the import supply of catfish and trout on the domestic price. The effects of policy options such as tariffs, direct or countercyclical payments, feed assistance, crop disaster, export assistance, loan programs, or others as recommended by the industry panel will be identified, summarized, and made available to industry through trade associations. The team will develop a matrix of data requirements and availability for development of these types of models for: catfish, trout, crawfish, clams, tilapia, ornamental fish, prawns, hybrid striped bass, baitfish, alligators, and oysters. This matrix will be provided to the SRAC Industry Advisory Council and to trade associations.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Identify, develop, and validate economic forecasting models of catfish and trout.*

Sub-objective 1a. *Demand and supply effects.*

Mississippi State University/Auburn University. Demand and supply models were developed by estimating equations that relate the quantity demanded by consumers and supplied by producers at various prices. These models provide an indication of changes in catfish and trout prices and quantities at the domestic wholesale and farm levels. The model also indicates what the effect of negative economic effects would be on the price and quantity demanded of catfish and who will bear the costs.

Demand and supply models were developed based upon quantities and prices of production inputs (such as feed ingredients, fuel, and electricity) and raw products used in the manufacture of production inputs. The processing models include different labor wage rates, technologies, price expectations, taxes and subsidies.

U.S. catfish supply and demand model

The model estimated a farm-level price at equilibrium of $0.90/pound and a farm-level quantity at equilibrium of 145 million pounds. The weighted U.S. wholesale price for processed frozen products and frozen quantity sold to wholesalers was estimated to be $2.52/pound and 65 million pounds, respectively.

Results at a glance...

A user friendly economic model has been developed for the U.S. catfish market. Some key findings are:

- *Decreased feed prices benefit the U.S. farm-raised catfish industry by increasing product supply and, by reducing the domestic price, increasing consumer demand.*
- *Increased TCI expenditures marginally benefit U.S. farm-raised catfish but would hurt imports significantly.*
- *Increased tariff levels on basa/tra from Vietnam may enhance importation of channel catfish from China without substantially increasing the demand for U.S. farm-raised catfish.*
- *Increased U.S. per capita income would positively impact the catfish industry as a whole, with higher positive impacts on imported channel catfish and imported basa/tra.*
- *Country-of-origin labeling benefits U.S. farm-raised catfish marginally, but hurts channel catfish imports significantly.*

The demand and supply models were then used to estimate the effects of imposing a tariff (at levels of 20%, 28%, and 35%) on imported catfish products. At a tariff rate of 35%, the U.S. wholesale price was estimated to increase by $0.08/pound and the quantity sold was estimated to decrease by 120,000 pounds. Farm prices increased by $0.04/pound and farm quantity increased by 1.6 million pounds.

U.S. Trout Supply and Demand Model

Trout demand and supply models were not as robust as for the catfish models because there is less data available overall (annual data available from USDA National Agricultural Statistics Service (NASS) for 1988-2008 where monthly data are available for catfish). There also were fewer categories of trout in the NASS data than there were for catfish. The focus of this analysis is solely on food-size trout sold for processing and food use, excluding trout sold for recreational use.

Results indicate that if producers expect farm prices to increase by 10%, then farm production will increase by 4%. A 10% increase in stocker prices will cause production to fall by 3.5%, and a 10% increase in soybean prices will cause production to fall by 2.3%. The model was also used to see how farm prices respond to changes in output and wholesale prices. If farm output would increase by 10% then farm prices would fall by 4.7%. If the price of whole fresh trout increases by 10%, then farm prices rise by 1.2%. Table 1 presents the effects of increases in the prices of fresh trout, trout stockers, and soybean meal on farm prices and production levels.

Table 1. Results of the trout model showing the impact of a 10% increase in processor, stocker or feed prices.

	Before	After	Difference
		10% increase in wholesale price	
Farm price	$1.09	$1.20	$0.11
Farm production (1,000 lbs)	55,130	57,497	2,367
Farm revenue	$60,067,676	$69,049,492	$8,981,816
Buyer surplus	$14,191,604	$15,436,468	$1,244,864
Farmer surplus	$47,449,857	$53,720,727	$6,270,871
		10% increase in stocker price	
Farm price	$1.09	$1.10	$0.02
Farm production (1,000 lbs)	55,130	53,511	-1,619
Farm revenue	$60,067,676	$59,112,586	-$955,090
Buyer surplus	$14,191,604	$13,370,202	-$821,401
Farmer surplus	$47,449,857	$46,142,106	-$1,307,751
		10% increase in soybean meal price	
Farm price	$1.09	$1.10	$0.01
Farm production (1,000 lbs)	55,130	54,062	-1,068
Farm revenue	$60,067,676	$59,443,232	-$624,444
Buyer surplus	$14,191,604	$13,647,089	-$544,515
Farmer surplus	$47,449,857	$46,593,357	-$856,500

Sub-objective 1b. *International trade effects.*

Louisiana State University. International trade models were developed for the domestic catfish and trout industries to estimate the effect of import supply of fish on the domestic prices of catfish and trout. Full details of the models are available from Dr. Lynn Kennedy, Louisiana State University (Lkennedy@agcenter.lsu.edu).

Catfish

The major results of the international trade model for catfish are that the U.S. domestic catfish industry is negatively influenced from imports of major seafood like salmon, tuna, and shrimp in addition to imports of catfish.

Trout

Faced with a change in trout imports, this study attempted to identify how imports affect the U.S. domestic trout industry. During the last two decades, trout imports have changed from primarily that of frozen products to fresh or chilled products. Also, the major exporting country has changed from Argentina to Chile for frozen products and to Canada for fresh trout. According to the results of this study, we found five important facts related to trout imports during this sample period:

- Low farm prices of domestic trout may be due to reasons other than just increased trout imports.

- Domestic trout price decreases with an increase in total trout supply into the domestic market. The increase in imports of Chilean products exert the greatest influence on U.S. domestic trout price.

- Increases in the imports of low priced frozen trout products are a source of concern for the U.S. domestic trout industry because these were found to substitute directly for U.S. product.

- The greatest level of substitution of imported trout is from frozen trout fillets followed in descending order by frozen whole trout, and fresh whole trout.

- Depreciation of U.S. currency in terms of the currencies of the major trout exporting countries has helped to reduce the potentially negative impact of increased trout imports on the U.S. domestic trout price.

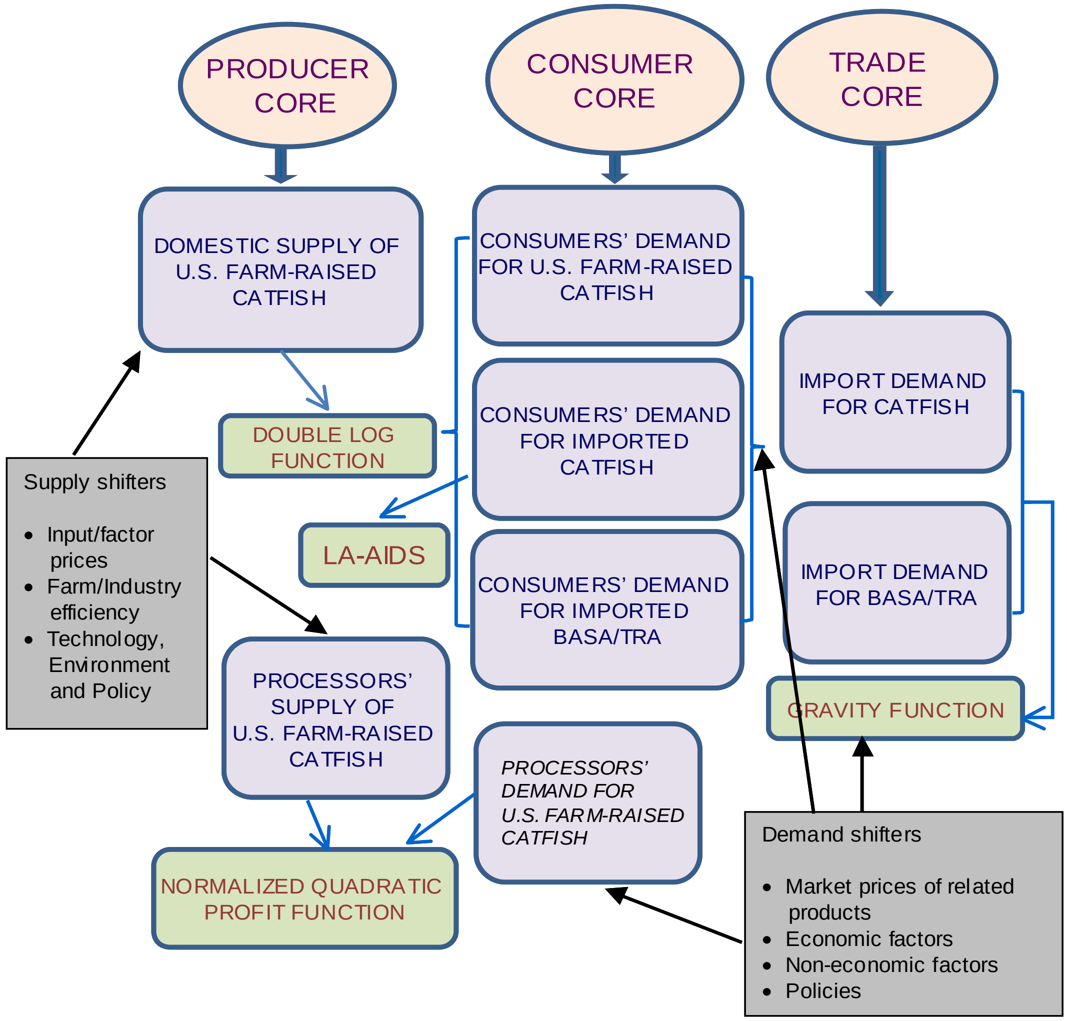
Sub-objective 1c. *Potential effects of various policy alternatives and external economic shocks.*

University of Arkansas at Pine Bluff (UAPB)

Catfish

A model for the catfish market in the U.S. (known as the U.S.-Catfish Model; Figure 1 and Appendix A) was developed, based on the demand-supply and international trade models developed in the previous sub-objectives. The model has been used to conduct simulations to determine the likely impact of changes in catfish feed price, The Catfish Institute (TCI) advertisement expenditures (for promoting U.S. farm-raised catfish), anti-dumping tariff levels imposed by the U.S. on basa/tra imported from Vietnam, and U.S. per capita income. We have also analyzed the effects of Country of Origin Labeling (COOL). A decrease in feed price would benefit the U.S. farm-raised catfish industry along with marginal gains to imported catfish. The decrease in feed price will lower the cost of production, which in turn increases the profitability of farmers, and hence increased supply. This will lower the domestic price of U.S. farm-raised catfish (processed), thereby increasing the demand for the same.

Figure 1. Model Structure



On the other hand, an increase in TCI expenditures would benefit U.S. farm-raised catfish marginally; however, it would hurt imports significantly. Imported channel catfish would benefit more than U.S. farm-raised catfish with an increase in tariff levels on basa/tra imported from Vietnam. An increase in the U.S. per capita income would have a positive impact on the catfish industry as a whole, with a greater positive impact on imported channel catfish and imported basa/tra. The results of the model further showed that COOL has benefited U.S. farm-raised catfish marginally, but has hurt channel catfish imports significantly.

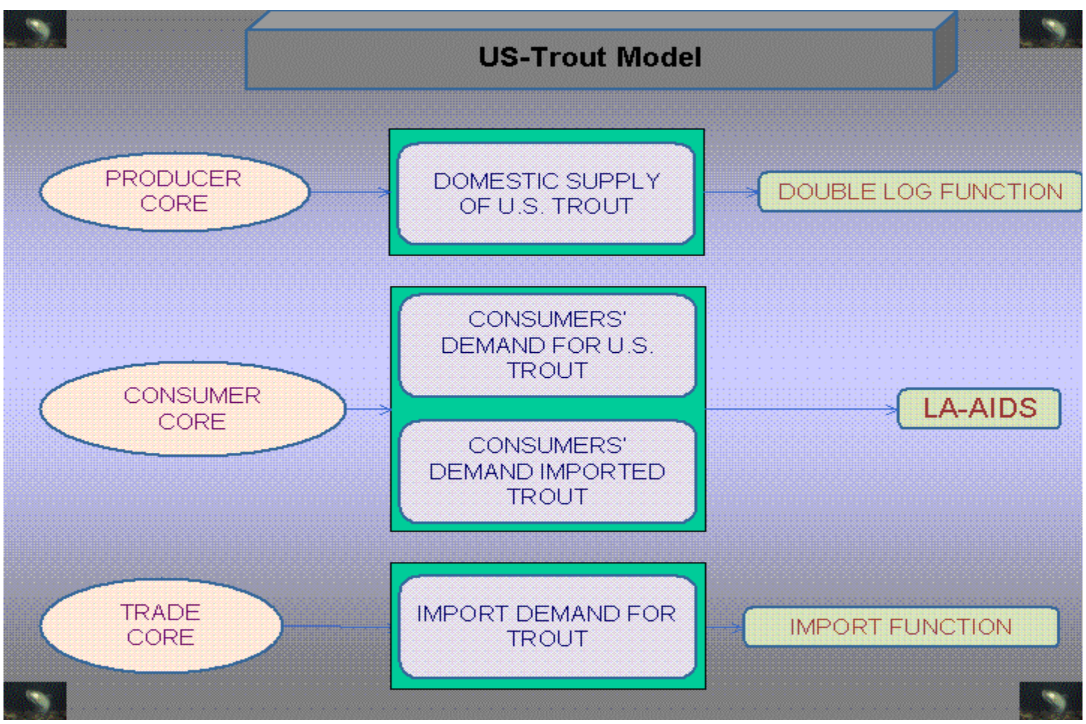
Trout

We have developed and validated an economic forecasting model for the trout market in the United States (US-Trout Model). The basic structure of the US-Trout model is outlined in Figure 2. The model consists of equations describing behaviors of trout farmers, consumers, and importers and exporters (Appendix B). The model differentiates between U.S.-raised trout and imported trout. The model provides links between technology, policy and the market. The imports are related to the non-domestic supply made available to the U.S. market, and the exports are related to the non-domestic market destinations for U.S. produced goods. The present model assumes negligible exports of U.S. trout. After developing a numerical version of the model, the model was solved using the Microsoft Office Excel Solver. Appendices C and D summarize key numerical values used to estimate the equations of the model.

To validate the model, preliminary results of the policy simulation exercise were discussed with different stakeholders in various conferences. Some of the parameters and variables in the model were re-adjusted based on the suggestions of the stakeholders.

The impact of changes in price of trout stockers, price of soybean meal, exchange rate of Chile, national income of the U.S., and national income of Chile on demand for and supply of U.S. domestic trout and imported trout were evaluated (Table 2). Key findings were:

Figure 2. Model Structure of US-Trout Model



• Trout stockers and feed (soybean meal) are important inputs for trout production. The U.S. trout industry would benefit significantly from a decrease in prices of stockers and price of soybean meal.

• Depreciation of the Chilean peso with respect to the U.S. dollar would increase demand of imported trout significantly, but this strategy would have only a marginal impact on the U.S. trout industry.

• With an increase in national income of the U.S., imported trout would gain significantly, whereas the U.S. trout industry would benefit only marginally.

• An increase in national income of Chile would increase the domestic demand for trout in Chile, thereby reducing its supply to the U.S. significantly. This would lead to an increase in demand and supply for domestic trout in the U.S.

Results at a glance...

Results of the model developed for the trout industry include:

- *The U.S. trout industry would benefit significantly from a decrease in prices of stockers and price of soybean meal.*
- *Depreciation of the Chilean peso with respect to the U.S. dollar would increase demand of imported trout significantly, but would have a marginal impact on the U.S. trout industry.*
- *Increased income in the U.S. would benefit imported trout to a greater degree than the U.S. trout industry.*
- *Increased income in Chile would increase the domestic demand for trout in Chile, thereby reducing the supply to the U.S., leading to an increase in demand and supply for domestic trout in the U.S.*

Table 2: Impact of Changes in Policy Variables on Demand for and Supply of Trout

Policy variable	Base line value	Change in policy variable over base	Change in demand/supply over base: Domestic Trout	Change in demand/supply over base: Imported Trout
Price of trout stockers ($/lb)	2.85	-10%	4.27	-0.09
		10%	-3.69	0.08
Price of soybean meal ($/ton)	120.33	-10%	2.80	-0.06
		10%	-2.46	0.05
Exchange rate of Chile (CLP/USD)	535.26	-10%	-1.73	-5.46
		10%	1.60	5.21
Inflation adjusted national income of U.S. ($billions, 2005 base)	12,994	-10%	-0.58	-4.35
		10%	0.53	4.11
Inflation adjusted national income of Chile ($billions, 2005 base)	136	-10%	-1.39	9.27
		10%	1.31	-7.70
Base line value (1,000 lb, average 2007-2009)			61,555	10,956

Objective 2. *Identify data needs necessary to refine the models for these species and to potentially apply to other species.*

All Project Participants. Data required for the demand and supply models include: quantities and prices of production inputs (feed ingredients, fuel, and electricity), prices and quantities of raw products used in the manufacture of production inputs, price and quantity of domestic product, and prices and quantities of competing products. Data requirements for the international trade model are monthly domestic price and quantity data. These data are required for a number of years. Generally, the more years of data available, the more accurate the results. Data are required not only for the species in question, but also for the major substitute products.

More specific data requirements for economic forecasting models are:

- Base period demand (consumption) and supply (domestic production and net imports);

- Base period levels of policy variables (prices of inputs, exchange rates, national income levels, quantities/prices of substitute products, etc.);

- Degree of responsiveness of demand and supply to changes in the levels of policy variables. If these responsiveness parameters are not available, then we need to empirically estimate those based on time-series and/or cross section data. We have been able to generate these parameters for catfish and trout, but these are not available for many other species.

While detailed data of the type and scope required for the catfish models are available in various published sources the data on trout are more sparse. Specific data required to enhance the trout models include:

- Monthly data on sales and prices of trout by size and state.

- Data on trout processing (e.g. weight processed, processed weight sold, prices paid to producers, prices received by processors, etc.). No data are available.

Objective 3. *Identify an industry-input framework to ensure model applicability.*

University of Arkansas at Pine Bluff. We held meetings with representatives of the catfish and trout industries to discuss the results of the models (U.S.-catfish and U.S.-trout model): a) 2009 Annual fall meeting of the USTFA (United States Trout Farmers Association), Harrisburg, Pennsylvania, and b) Annual convention of the Catfish Farmers of Arkansas 2010, Hot Springs, Arkansas. The model structures (U.S.-catfish and U.S.-trout model) and results of simulations have been presented in professional conferences/seminars: a) Aquaculture 2010, San Diego, California, and (b) the International Food Policy Research Institute (IFPRI), Washington DC. These presentations and consultations have identified a list of issues and policy options for consideration in the policy analysis. Accordingly, we have conducted impact analysis for the identified policy variables.

IMPACTS

Results of the simulations and relationships developed in these models have been of interest to both the trout and catfish industry. The U.S. Catfish Model has been used to respond to requests for economic information from congressional offices and is proposed to be used as part of a new SRAC project to examine alternative marketing structures that may provide greater control over the market price of U.S. catfish.

PUBLICATIONS, PRESENTATIONS, AND GRADUATE THESES

Publications

Lee, Y-J and P.L. Kennedy. In review. Measurement of substitutability between U.S. domestic catfish and imported fish. Journal of Agricultural and Applied Economics.

Lee, Y-J and P.L. Kennedy. In review. Theoretical development of implicit price and demand in oligopolistic competition: application to the U.S. trout market. Marine Resource Economics.

Lee, Y-J and P.L. Kennedy. In review. A demand system analysis of the U.S. trout market: imports versus domestic products. Canadian Journal of Agricultural Economics.

Muhammad, A. and K. Jones. 2009. An assessment of dynamic behavior in the U.S. catfish market: an application of the generalized dynamic, Rotterdam model. Journal of Agriculture and Applied Economics 41(3):745-759.

Presentations

Dey, Madan M., Kehar Singh and Carole Engle. 2010. Impact of marketing, trade and exchange rate policies on U.S. catfish and trout markets: results from disaggregated fish sector models. Page 506, Aquaculture 2010 – Meeting Abstracts, San Diego, California (U.S.).

Engle, C.R. 2010. Economic modeling of the U.S. trout industry. U.S. Trout Farmers Association Forum, San Diego, CA.

Dey, Madan M., Kehar Singh, Carole Engle and Abed Rabbani. 2009. Analysis of catfish supply, demand and trade in USA: baseline model, estimation strategy and preliminary results. Page 365, Aquaculture America 2009 - Meeting Abstract, Seattle, Washington (U.S.).

Dey, Madan M., Kehar Singh and Carole Engle. 2009. Analysis of catfish supply, demand and trade in USA: baseline model, estimation strategy and preliminary results. Paper presented at the forth forum of the North American Association of Fisheries Economists, May 17-20, 2009, Newport, Rhode Island (U.S.).

Dey, Madan M. 2009. Food safety standards and U.S.-Asia aquaculture trade: applications of disaggregated fish sector models. Presentation at the International Food Policy Research Institute (IFPRI), Washington DC, Aug 3, 2009.

Lee, Y-J and P.L. Kennedy. 2009. Measurement of substitutability between U.S. domestic catfish and imported fish. Paper presented at the Southern Association of Agricultural Scientists, Atlanta, Georgia.

Lee, Y-J and P.L. Kennedy. 2009. Import demand analysis for U.S. trout. Southern Regional Aquaculture Center Conference Call Meeting.

Lee, Y-J and P.L. Kennedy. 2008. Import demand analysis for U.S. catfish. Southern Regional Aquaculture Center Conference Call Meeting.

Graduate Theses

Neal, S. J. 2008. The Impact of Imported Catfish on U.S. Wholesale and Farm Sectors. Master's Thesis, Department of Agricultural Economics, Mississippi State University.

Appendix A

US Catfish Model: Equations and Identities

A. Model Development

The producer core consists of the supply equation for U.S. farm raised catfish, and supply equations of processed products. We have used double log function to represent the supply U.S. farm raised catfish:

$$\ln\left(Q_{frCatfish}^{FS-dom}\right) = \alpha_{0}^{FS-dom} + \alpha_{1}^{FS-dom} \times \ln(P_{frCatfish}^{PBP}) + \sum_{i=1}^{n} \beta_{i}^{FS-dom} \times \ln(P_{i}^{dom})$$

$$Where, P_{i}^{dom} \quad is \quad the \quad factor \quad prices \quad (\, fingerlings, feed, fuel, electricity, wage)$$

The catfish processing industry uses joint inputs and produces multiproduct. Therefore, we have employed 'normalized quadratic profit function' to derive supply equations for processed products. This approach is widely used in cases of joint agricultural production (e.g., Shumway *et al.*, 1987; Ball *et al.*, 1997). Estimation is undertaken here using the 'dual' approach, which is becoming the preferred method when sufficient price data are available (Jensen, 2003). It is particularly appropriate for multioutput, joint input production, e.g., Squires (1987), Kirkley and Strand (1988), and others have applied it to capture fisheries. Dey *et al.* (2005) have applied this approach in AsiaFish Model. The 'normalized quadratic profit function' is given as follows:

$$\pi = \alpha_0 + \sum_{i=1}^{m-1} \beta_i P_i + \sum_{i=m+1}^{n} \gamma_i X_i + \frac{1}{2}\left(\sum_{i=1}^{m-1}\sum_{j=1}^{m-1} \beta_{ij} P_i P_j + \sum_{i=m+1}^{n}\sum_{j=m+1}^{n} \gamma_{ij} X_i X_j \right) + \sum_{i=1}^{m-1}\sum_{j=m+1}^{n} \lambda_{ij} P_i X_j + e_i$$

Where, π is the normalized profit (normalized by P_m) evaluated at the optimum, P_i's are output and input prices normalized by P_m, X_i is a vector of variables on technology, environment, policy and fixed inputs, e_i is the error term, and α, β, γ, and λ are the parameters of the equation. Then by the 'envelope theorem', the output supply of i[th] product is:

$$\frac{\partial \pi}{\partial P_i} = X_i = \beta_i + \sum_{j=1}^{m-1} \beta_{ij} P_j + \sum_{j=m+1}^{n} \lambda_{ij} X_j + e_i$$

To derive the supply of the numeraire, multiply the expression in (…) by P_m to obtain normal profit; differentiating by P_m yields:

$$QNUM = \alpha_0` + \sum_{i=m+1}^{n} \gamma_i X_i - \frac{1}{2}\sum_{i=-}^{m-i}\sum_{j=1}^{m-1} \beta_{ij} P_i P_j + \frac{1}{2}\sum_{i=m+1}^{n}\sum_{j=m+1}^{n} \gamma_{ij} X_i X_j + e_i$$

The derivation of the supply functions from a profit function entails certain restrictions on the former. A profit function is homogenous of degree one in prices, and should have equal cross-price derivatives; hence, the supply parameters must conform to a homogeneity and symmetry restriction. Homogeneity is already incorporated by normalization, while symmetry can be implemented by imposing $\beta_{ij} = \beta_{ji}$ during estimation.

In the baseline model, it is assumed that technology and policy can be modeled as a proportional and factor-neutral shift in quantity. For a given supply function, this may be represented as a distinction between actual and effective prices (see Alston *et al.*, 1995 and Dey *et al.*, 2005). The effective price method is fairly flexible in representing a variety of changing supply conditions.

Consumer core

The consumer core consists of processors' demand equation for inputs and consumers demand for catfish. The processors' demand equation for inputs (live fish) has been derived from 'normalized quadratic profit function' given as follows:

$$\frac{\partial \pi}{\partial P_j} = -X_i = \beta_i + \sum_{j=1}^{m-1} \beta_{ij} P_j + \sum_{j=m+1}^{n} \lambda_{ij} X_j + e_i$$

We have used Almost Ideal Demand System (AIDS) to obtain consumers demand equations (in share forms) for U.S. farm-raised catfish, imported channel catfish and imported basa/tra.

$$w_i = \alpha_i^{CD} + \sum_i \beta_i^{CD} \times \ln(P_i) + \gamma^{CD} \times \ln(X / P) + \sum_j \varphi_j^{CD} X_j + e_{ij}$$

Where, w and P are the expenditure share and price of the products, respectively. X is the vector of exogenous variables, X/P is the real expenditure of the consumers, e is the error term, and α, β, γ and φ are the parameters of the model.

The consumers' demand for i^{th} product has been obtained from share equations as follows:

$$Q_i^{CD-dom} = w_i \times \frac{\sum_i p_i q_i}{P_i}, \textit{where } \sum_i p_i q_i \textit{ is the total expenditure.}$$

Trade core

We have used an augmented gravity model derived by Anderson and Wincoop (2003) from a general equilibrium model. This model differs from commonly used gravity models by including 'multilateral resistance' terms capturing the country i's and country j's resistance to trade with all regions. These variables measure bilateral trade barriers in relation to trade barriers with other trading partners. However, the multilateral resistance terms are not observable. We, therefore, have used exporter and importer fixed effects as proxies of the multilateral resistance terms (Anderson and Wincoop, 2003). Including these fixed effects also allows asymmetric trade flows with symmetric trade barriers, allowing a better fit with the data (Kupier and Tongeren, 2006). The augment gravity model is specified as follows:

$$\ln(Q_i^{\mathrm{S-imp}}) = \rho_k + \rho_j + \varphi^{\mathrm{S-imp}} + \sum_{i=1} \gamma_i^{\mathrm{dom}} \ln(P_i) + \sum_{\mathrm{m}} \gamma^{\mathrm{m}} \ln(\mathrm{EconV}) + \sum_{\mathrm{n}} \gamma^{\mathrm{n}} \ln(\mathrm{NEconV}) + \sum_{\mathrm{o}} \gamma^{\mathrm{o}} \ln(\mathrm{PolV}) + e_i$$

Where,

ρ 's are multilateral resistance terms (exporter and importer fixed effects); Subscript 'i', 'j' and 'k' denote the product (imported channel catfish and basa/tra), the exporting country, and the importing country (in our case U.S.), respectively; 'P_i' represents price of i^{th} product which include competing products; e_i is the error term; and γ and φ are the parameters of the model; EconV and NEconV signify economic variables (like gross domestic product, population, x-rates) and non-economic variable capturing cultural and political distances, respectively, effecting trade; and PolV denotes policy variable like promotional activities, antidumping measures, tariffs, etc.

Model identities

Model identities describe the price setting and market clearing conditions. These consist of price transmission functions, relationship between different variables and equilibrium conditions.

Parameterization of equations

The parameterization approach was used to estimate the relevant coefficients of the behavioral equations. Initially, we had estimated the demand, supply and trade elasticities using the approached discussed in the earlier section. Most of the estimated elasticities yielded satisfactory plausible values for the policy analysis. However, some of the elasticities were borrowed from earlier studies. Once obtained, these elasticities were transformed to suit the specification of the equations in the model. The intercept terms of all the relevant equations were then calibrated to ensure that the model replicated the baseline values. The preliminary results of the policy simulation exercise were discussed with different stakeholders in various conferences, and some of the elasticities and variables in the model were readjusted.

B. Consumer Core

Expenditure Share Equations (LA-AIDS)

Expenditure Share Equation for U.S. Farm-Raised Catfish $\left(w_{Catfish}^{fr}\right)$:

$$CC(1) \qquad w_{Catfish}^{fr} = -2.7857 + 0.0260 \times \ln(P_{frCatfish}^{*dom}) + 0.0678 \times \ln(P_{Catfish}^{*imp})$$

$$+ 0.0509 \times \ln(P_{Basa/tra}^{*imp-world}) + 0.0743 \times \ln(P_{Tilapia}^{*imp})$$

$$+ 0.1095 \times \ln(X/P) + 0.2228 \times TCI + +0.0053 \times Pop_{US} + 0.0316 \times COOL$$

Expenditure Share Equation for Imported Catfish $\left(w_{Catfish}^{imp}\right)$:

$$CC(2) \qquad w_{Catfish}^{imp} = -0.1050 + 0.0037 \times \ln(P_{frCatfish}^{*dom}) - 0.0105 \times \ln(P_{Catfish}^{*imp})$$
$$+ 0.0039 \times \ln(P_{Basa/tra}^{*imp}) + 0.0028 \times \ln(P_{Tilapia}^{*imp})$$
$$+ 0.0020 \times \ln(X/P) + 0.0212 \times Pop_{US} - 0.0058 \times COOL$$

Expenditure Share Equation for Imported Catfish $\left(w_{Basa/tra}^{imp}\right)$:

$$CC(3) \qquad w_{Basa/tra}^{imp} = 0.0986 + 0.0068 \times \ln(P_{frCatfish}^{*dom}) + 0.0129 \times \ln(P_{Catfish}^{*imp})$$
$$- 0.0265 \times \ln(P_{Basa/tra}^{*imp}) + 0.0068 \times \ln(P_{Tilapia}^{*imp})$$
$$+ 0.0008 \times \ln(X/P) + 0.0015 \times Pop_{US} - 0.0520 \times COOL$$

Processors' Demand Equation (Normalized Quadratic Profit Function)

Processors' Demand for U.S. Farm-Raised Catfish $\left(Q_{frCatfish-\Pr ocessedWt}^{\Pr ocessorD}\right)$:

$$CC(4) \qquad Q_{frCatfish-\Pr ocessedWt}^{\Pr ocessorD} = -12543.5074 + 761.50 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 378.92 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+ 144.03 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}} - 151.76 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 245.99 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 98.92 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+ 173.86 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 178.23 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 54337.78 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} + 1340.47 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$+ 26.16 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} - 39062.02 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 1928.86 \times \frac{CPI - F \& Bev}{P_{steakFroz}^{PSP}}$$

C. Producer Core

Domestic Supply Equation for US Farm-Raised Catfish (Double log Function)

Supply of U.S. Farm-Raised Catfish $\left(Q^{S-dom}_{frCatfish}\right)$:

$$S(1) \quad \ln\left(Q^{FS-dom}_{frCatfish}\right) = 27.7737 + 1.8235 \times \ln(P^{PBP}_{frCatfish}) - 0.1500 \times \ln(P^{dom}_{Fingerlings})$$

$$-1.7800 \times \ln(P^{dom}_{Feed}) - 0.1000 \times \ln(P^{dom}_{Fuel}) - 0.1000 \times \ln(P^{dom}_{Electricity})$$

$$-5.0550 \times \ln(P^{dom}_{WageRate})$$

Processors' Supply Equations for Different Products (Normalized Quadratic Profit Function)

Processors' Supply of Round and Gutted Fresh $\left(Q^{ProcessorS}_{R\&GFresh}\right)$

$$S(2) \quad Q^{ProcessorS}_{R\&GFresh} = 1636.3838 + 101.2072 \times \frac{P^{PSP}_{R\&GFr}}{P^{PSP}_{steakFroz}} - 78.4819 \times \frac{P^{PSP}_{WhDressFr}}{P^{PSP}_{steakFroz}} - 135.0662 \times \frac{P^{PSP}_{OtherFr}}{P^{PSP}_{steakFroz}}$$

$$+117.8168 \times \frac{P^{PSP}_{FilletFr}}{P^{PSP}_{steakFroz}} - 20.2359 \times \frac{P^{PSP}_{WhDressFroz}}{P^{PSP}_{steakFroz}} + 10.8645 \times \frac{P^{PSP}_{OtherFroz}}{P^{PSP}_{steakFroz}}$$

$$-121.5899 \times \frac{P^{PSP}_{FilletFroz}}{P^{PSP}_{steakFroz}} - 243.8940 \times \frac{P^{PBP}_{frCatfish}}{P^{PSP}_{steakFroz}} + 9831.9593 \times \frac{P^{dom}_{Fuel}}{P^{PSP}_{steakFroz}} - 329.7612 \times \frac{P^{dom}_{Eletricity}}{P^{PSP}_{steakFroz}}$$

$$-110.8100 \times \frac{P^{dom}_{WageRate/hr}}{P^{PSP}_{steakFroz}} + 3871.2206 \times \frac{GDP(2000=100)}{P^{PSP}_{steakFroz}} + 1878.2037 \times \frac{CPI-F\&Bev}{P^{PSP}_{steakFroz}}$$

Processors' Supply of Whole Dressed Fresh $\left(Q^{ProcessorS}_{WhDressFr}\right)$

$$S(3) \quad Q^{ProcessorS}_{WhDressFr} = 1407.1287 - 23.8473 \times \frac{P^{PSP}_{R\&GFr}}{P^{PSP}_{steakFroz}} + 52.6020 \times \frac{P^{PSP}_{WhDressFr}}{P^{PSP}_{steakFroz}} + 140.4788 \times \frac{P^{PSP}_{OtherFr}}{P^{PSP}_{steakFroz}}$$

$$+63.2134 \times \frac{P^{PSP}_{FilletFr}}{P^{PSP}_{steakFroz}} - 140.8869 \times \frac{P^{PSP}_{WhDressFroz}}{P^{PSP}_{steakFroz}} - 20.8239 \times \frac{P^{PSP}_{OtherFroz}}{P^{PSP}_{steakFroz}}$$

$$-41.3269 \times \frac{P^{PSP}_{FilletFroz}}{P^{PSP}_{steakFroz}} - 0.1876 \times \frac{P^{dom}_{RWP}}{P^{PSP}_{steakFroz}} - 10474.7926 \times \frac{P^{dom}_{Fuel}}{P^{PSP}_{steakFroz}} - 82.5059 \times \frac{P^{dom}_{Eletricity}}{P^{PSP}_{steakFroz}}$$

$$+104.4400 \times \frac{P^{dom}_{WageRate/hr}}{P^{PSP}_{steakFroz}} + 4538.9238 \times \frac{GDP(2000=100)}{P^{PSP}_{steakFroz}} - 1336.3932 \times \frac{CPI-F\&Bev}{P^{PSP}_{steakFroz}}$$

Processors' Supply of Other Fresh $\left(Q_{OtherFr}^{ProcessorS}\right)$

$$S(4) \qquad Q_{OtherFr}^{ProcessorS} = 499.7585 - 615.0150 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} + 723.0623 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} + 81.8293 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$-131.9244 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} - 190.8296 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 44.1848 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$-56.2260 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 225.4999 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 5004.8605 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} + 425.8890 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$+113.4300 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} - 7129.9032 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 1592.4748 \times \frac{CPI-F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Fillet Fresh $\left(Q_{FilletFr}^{ProcessorS}\right)$

$$S(5) \qquad Q_{FilletFr}^{ProcessorS} = 4764.6845 + 35.3252 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} + 20.1131 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 65.4681 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+4.3712 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 38.1056 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 5.1619 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$-104.1733 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 157.1416 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 17516.3238 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 323.1987 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$+204.5000 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 12035.0253 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 2059.9643 \times \frac{CPI-F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Whole Dressed Frozen $\left(Q_{WhDressFroz}^{ProcessorS}\right)$

$$S(6) \qquad Q_{WhDressFr}^{ProcessorS} = 1166.5806 - 128.7214 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 209.5112 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 71.6306 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+104.2277 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 23.1358 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 70.8024 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+71.1727 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 197.1554 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 9404.3915 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 153.5330 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$+109.7000 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 4160.6802 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} + 1131.9325 \times \frac{CPI-F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Other Frozen $\left(Q_{OtherFroz}^{ProcessorS}\right)$

$$S(7) \qquad Q_{OtherFr}^{ProcessorS} = 3058.2233 + 11.0722 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 48.1894 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 41.6692 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+17.5451 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} - 41.0994 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 13.0515 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+26.5325 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 185.5772 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 11065.7257 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 197.8075 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$-106.6000 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 5329.7926 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} + 2341.1632 \times \frac{CPI - F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Fillet Frozen

$$S(8) \qquad Q_{FilletFroz}^{ProcessorS} = 2119.2081 - 141.5231 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 80.6740 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 52.4991 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$-23.4900 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 85.8179 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 7.8158 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+51.7524 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 775.1779 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 16517.6262 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 264.6949 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$-134.9900 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 12342.4342 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 2252.9332 \times \frac{CPI - F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Steak Frozen $\left(Q_{SteakFroz}^{ProcessorS}\right)$

$$S(9) \qquad Q_{SteakFroz}^{ProcessorD} = 35.3196 - 0.0967 \times \left(P_{R\&GFr}^{PSP} \times P_{frCatfish}^{PBP}\right) - 0.3667 \times \left(P_{WhDressFr}^{PSP} \times P_{frCatfish}^{PBP}\right)$$
$$-0.1410 \times \left(P_{OtherFr}^{PSP} \times P_{frCatfish}^{PBP}\right) + 1593 \times \left(P_{FilletFr}^{PSP} \times P_{frCatfish}^{PBP}\right)$$
$$+0.1609 \times \left(P_{WhDressFroz}^{PSP} \times P_{frCatfish}^{PBP}\right) + 0.00 \times \left(P_{SteakFroz}^{PSP} \times P_{frCatfish}^{PBP}\right) + 0.1818 \times \left(P_{OtherFroz}^{PSP} \times P_{frCatfish}^{PBP}\right)$$
$$-0.0321 \times \left(P_{FilletFroz}^{PSP} \times P_{frCatfish}^{PBP}\right) - 4.2696 \times P_{Fuel}^{dom} - 41.5902 \times P_{Eletricity}^{dom}$$
$$-12.2761 \times P_{WageRate/hr}^{dom} + 0.8932 \times GDP(2000=100) + 1.5572 \times CPI - F\ \&\ Bev$$

D. Trade Core
Trade Equations (Gravity Function)

Import Demand of Catfish from World $(Q^{imp-D}_{catfish})$

$$TC(1) \qquad \ln(Q^{imp-D}_{catfish}) = \text{-}12.5540 + 1.3933 \times \ln(P^{*dom}_{frCatfish}) - 0.5007 \times \ln(P^{*imp,world}_{catfish})$$
$$+ 0.1666 \times \ln(P^{*imp,world}_{basa/tra}) + 1.6888 \times \ln(US-GDP) + 0.9384 \times \ln(US-Pop)$$
$$+ 2.0700 \times \ln(X-rateChina) - 0.6082 \times \ln(TCI-AdvExp.)$$

Import Demand of Basa/tra from World $(Q^{imp-D}_{basa/tra})$

$$TC(2) \qquad \ln(Q^{imp-D}_{basa/tra}) = \text{-}21.7634 + 1.6442 \times \ln(P^{*dom}_{frCatfish}) + 0.8059 \times \ln(P^{*imp,world}_{catfish})$$
$$- 0.0872 \times \ln(P^{*imp,world}_{basa/tra}) + 1.4623 \times \ln(US-GDP) + 2.0422 \times \ln(US-Pop)$$
$$+ 1.1115 \times \ln(X-rateVietnam) - 0.9987 \times in(TCI-AdvExp.) - 0.7974 \times \ln(Tariff)$$

Model Identities

Consumers' demand for U.S. farm raised catfish (Processed Weight) $(Q^{CD-dom}_{frCatfish-\Pr ocessedWt})$:

MI(1) $$Q^{CD-dom}_{frCatfish-\Pr oceesedWt} = w_{frCatfish} \times \frac{\sum_{i=1}^{n} p_i q_i}{P^{*dom}_{frCatfish}}$$

Consumers' demand for imported catfish $(Q^{CD-imp}_{Catfish})$:

MI(2) $$Q^{CD-imp}_{Catfish} = w^{imp}_{Catfish} \times \frac{\sum_{i=1}^{n} p_i q_i}{P^{*imp}_{Catfish}}$$

Consumers' demand for imported basa/tra $(Q^{CD-imp}_{Basa/tra})$:

MI(3) $$Q^{CD-imp}_{Basa/tra} = w^{imp}_{Basa/tra} \times \frac{\sum_{i=1}^{n} p_i q_i}{P^{*imp}_{Basa/tra}}$$

Where,

'i' is U.S. farm-raised catfish, imported catfish, imported basa/tra, and imported tilapia.

Processors' Demand in Live Weight Equivalent $\left(Q_{frCatfish-LiveWt}^{ProcessorD}\right)$ and processed weight equivalent $\left(Q_{frCatfish-ProWt}^{ProcessorD}\right)$

MI(4) $\quad Q_{frCatfish-LiveWt}^{ProcessorD} = 1.9871 \times Q_{frCatfish-ProWt}^{ProcessorD}$

Farmers' Total Supply (Live Weight) $\left(Q_{frCatfish}^{S-dom}\right)$ and Farmers' Supply to Processor (Live Weight) $\left(Q_{frCatfish-LiveWt}^{FS-Processor}\right)$:

MI(5) $\quad Q_{frCatfish-LiveWt}^{FS-Processor} = 0.95 \times Q_{frCatfish}^{S-dom}$

Farmers' Total Supply (Live Weight) $\left(Q_{frCatfish}^{S-dom}\right)$ and Farmers' Supply to Others (Live Weight) $\left(Q_{frCatfish}^{FS-Others}\right)$:

MI(6) $\quad Q_{frCatfish}^{FS-Others} = 0.05 \times Q_{frCatfish}^{S-dom}$

Aggregate Processors' Supply (Processed Weight) $\left(Q_{ProcessedWt}^{ProcessorS}\right)$:

MI(7) $$Q_{ProcessedWt}^{ProcessorS} = 1.2789 \times \sum_{j=1}^{n} Q_{j}^{ProcessorS} = \sum_{j=1}^{n} Q_{j}^{ProcessorS} + Q_{Nuggets}^{ProcessorS}$$

Where,

'j' represents processed products namely round and gutted fresh, whole dressed fresh, fillet fresh, other fresh, whole dressed frozen, fillet frozen, other frozen, and steaks frozen.

Consumers' Demand for Farm-raised Catfish in Live Weight Equivalent $(Q_{frCatfish-LiveWt}^{CD-dom})$ and Processed Weight $(Q_{frCatfish-ProcessedWt}^{CD-dom})$:

MI(8) $\quad Q_{frCatfish-LiveWt}^{CD-dom} = 1.9871 \times Q_{frCatfish-ProcessedWt}^{CD-dom}$

Price Transmission Functions

Domestic price of farm raised catfish $\left(P_{frCatfish}^{*dom}\right)$ and average price received by processor $\left(P_{frCatfish}^{Processor}\right)$:

PT(1) $\quad P_{frCatfish}^{*dom} = P_{frCatfish}^{Processor}$

Where

$P_{frCatfish}^{Processor}$ = *Average Price Received by the Processor*

Model Closure

Equilibrium Between Consumers' Demand $\left(Q_{Basa/tra}^{CD-imp}\right)$ and Import Demand $\left(Q_{Basa/tra}^{imp-D}\right)$ for Basa/tra:

$$Q_{Basa/tra}^{imp-D} = Q_{Basa/tra}^{CD-imp}$$

Equilibrium Between Consumers' Demand $\left(Q_{Catfish}^{CD-imp}\right)$ and Import Demand $\left(Q_{Catfish}^{imp-D}\right)$ for Channel Catfish Imported:

$$Q_{Catfish}^{imp-D} = Q_{Catfish}^{CD-imp}$$

Farmers' Supply to Processor (Live Weight) $\left(Q_{frCatfish-LiveWt}^{FS-\Pr ocessor}\right)$ and Processors' Demand in Live Weight Equivalent $\left(Q_{frCatfish-LiveWt}^{\Pr ocessorD}\right)$

$$Q_{frCatfish-LiveWt}^{FS-\Pr ocessor} = Q_{frCatfish-LiveWt}^{\Pr ocessorD}$$

Market Equilibrium

$$Q_{frCatfish-\Pr ocessedWt}^{\Pr ocessorS} + Q_{Catfish}^{imp-D} + Q_{Basa/tra}^{imp-D} = Q_{frCatfish-\Pr ocessedWt}^{CD-dom} + Q_{Catfish}^{CD-imp} + Q_{Basa/tra}^{CD-imp}$$

Adjustable Variable for Model Closure:

Domestic Price of U.S. Farm-raised Catfish $(P_{frCatfish}^{*dom})$, World Import Unit Value of Channel Catfish $(P_{Catfish}^{*dom})$, World Import Unit Value of basa/tra $(P_{Basa/tra}^{*dom})$, and Processors' sale price for j^{th} product ($P_{R\&GFr}^{j}$)

Where, 'j' represents processed products namely round and gutted fresh, whole dressed fresh, fillet fresh, other fresh, whole dressed frozen, fillet frozen, steaks frozen, and other frozen.

Appendix B

US Trout Model: Equations and Identities

A. Behavioral Equations

The structure of the US-Trout model consists of three cores: producer core, consumer core, and trade core. The model distinguishes between U.S. trout and imported trout.

The producer core consists of the supply equation for U.S. trout. We have used double log function to represent the supply U.S. trout:

$$\ln\left(Q_{trout}^{FS-dom}\right) = \alpha_0^{FS-dom} + \alpha_1^{FS-dom} \times \ln(P_{trout}^{PBP}) + \sum_{i=1}^{n} \beta_i^{FS-dom} \times \ln(P_i^{dom})$$

Where, P_i^{dom} is the factor prices (Stockers, feed, fuel, etc).

The consumer core consists of two equations: consumers' demand for U.S. trout, and consumers' demand for imported trout. We have used Almost Ideal Demand System (AIDS) to obtain consumers demand equations (in share forms) for U.S. trout, and imported trout.

$$w_i^{CD} = \alpha_i^{CD} + \sum_i \beta_i^{TD} \times \ln(P_i) + \gamma^{CD} \times \ln(X/P) + \sum_j \varphi_j^{CD} X_j + e_{ij}$$

Where, w and P are the expenditure share and price of the products, respectively. X is the vector of exogenous variables, X/P is the real expenditure of the consumers, e is the error term, and α, β, γ and φ are the parameters of the model.

The consumers' demand for i^{th} product has been obtained from share equations as follows:

$$Q_i^{CD} = w_i \times \frac{\sum_i p_i q_i}{P_i},$$

$$where \sum_i p_i q_i \text{ is the total expenditure}; i = U.S.\ trout,\ imported\ trout.$$

The trade core consists of the U.S. import demand for trout equation. We have used double log function to represent the U.S. import demand of trout.

$$\ln(Q_{imptrout}^{S-\mathrm{imp}}) = \varphi^{D-\mathrm{imp}} + \sum_{i=1} \gamma_i^{ID} \ln(P_i) + \sum_{m} \gamma^{m} \ln(\mathrm{EconV}) + \sum_{o} \gamma^{o} \ln(\mathrm{PolV}) + e_i$$

Where, ' $\mathbf{P}_i$ ' represents price of i^{th} product which include competing products; e_i is the error term; γ and φ are the parameters of the model; EconV signifies economic variables (like gross domestic product, population, x-rates) effecting trade; and PolV denotes policy variable (like promotional activities, antidumping measures, tariffs, etc.).

B. Parameterization of Behavioral Equations

The parameterization approach was used to estimate the relevant coefficients of the behavioral equations. Initially, we had estimated the demand, supply and trade elasticities using the approached discussed in the earlier section. Most of the estimated elasticities yielded satisfactory plausible values for the policy analysis. However, some of the elasticities were borrowed from earlier studies. Appendix C gives the variables and their elasticities used in the model.

Once obtained, these elasticities were transformed to suit the specification of the equations in the model (Appendix D). The intercept terms of all the relevant equations were then calibrated to ensure that the model replicated the baseline values. The preliminary results of the policy simulation exercise were discussed with different stakeholders in various conferences, and some of the elasticities and variables in the model were readjusted.

C. Model Identities

$$Q_{UStrout}^{CD} + Q_{imptrout}^{CD} = Q_{trout}^{FS-dom} + Q_{imptrout}^{S-\mathrm{imp}}$$

Appendix C
Variables and Elasticities for US-Trout Model

Variables	Elasticity
U.S. Trout Supply Equation	
Growers' price of trout (USD/lb)	0.4190
Price of trout stokers (USD/lb)	-0.3510
Price of soybean meal (USD/ton)	-0.2320
Price of fish meal (USD/ton)	-0.0001
Diesel fuel price index (cents/gallon)	-0.0001
Consumer Demand for U.S. Trout Equation	
Domestic trout price (USD/lb)	-1.1186
Imported trout price (USD/lb)	1.5950
Real GDP U.S. ($billions, 2005 base)	0.8567
Exchange rate Chile (CLP/USD)	0.5164
Consumer Demand for Imported Trout Equation	
Domestic trout price (USD/lb)	1.5950
Imported trout price (USD/lb)	-1.5380
Real GDP U.S. ($billions, 2005 base)	0.5567
Exchange rate Chile (CLP/USD)	-0.8982

Variables	Elasticity
U.S. Import Demand Equation	
Import price/domestic price	-0.8527
Real GDP U.S. ($billions, 2005 base)	0.4112
Exchange rate Canada (CAD/USD)	-0.9842
Exchange rate Chile (CLP/USD)	0.5036
Exchange rate Argentina (ARS/USD)	0.3081
Exchange rate Australia (AUD/USD)	1.7942
Real GDP Canada ($billions, 2005 base)	-4.6684
Real GDP Chile ($billions, 2005 base)	-0.8206
Real GDP Australia ($billions, 2005 base)	6.2515
Real GDP Argentina ($billions, 2005 base)	-1.0139

Appendix D
Parameters for US-Trout Model

Variables	Parameters
U.S. Trout Supply Equation	
Growers' price of trout (USD/lb)	0.4190
Price of trout stokers (USD/lb)	-0.3510
Price of soybean meal (USD/ton)	-0.2320
Price of fish meal (USD/ton)	-0.0001
Diesel fuel price index (cents/gallon)	-0.0001
Consumer Demand for U.S. Trout Equation	
Domestic trout price (USD/lb)	0.5362
Imported trout price (USD/lb)	1.3931
Real GDP U.S. ($billions, 2005 base)	-0.1041
Exchange rate Chile (CLP/USD)	-0.3513
Consumer Demand for Imported Trout Equation	
Domestic trout price (USD/lb)	0.8407
Imported trout price (USD/lb)	0.0051
Real GDP U.S. ($billions, 2005 base)	-0.1213
Exchange rate Chile (CLP/USD)	-0.5193

Variables	Parameters
U.S. Import Demand Equation	
Import price/domestic price	-0.8527
Real GDP U.S. ($billions, 2005 base)	0.4112
Exchange rate Canada (CAD/USD)	-0.9842
Exchange rate Chile (CLP/USD)	0.5036
Exchange rate Argentina (ARS/USD)	0.3081
Exchange rate Australia (AUD/USD)	1.7942
Real GDP Canada ($billions, 2005 base)	-4.6684
Real GDP Chile ($billions, 2005 base)	-0.8206
Real GDP Australia ($billions, 2005 base)	6.2515
Real GDP Argentina ($billions, 2005 base)	-1.0139

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