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Developing a model of live cattle and beef trade in South East Asia and China

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Developing a model of live cattle and beef trade in South East Asia and China[1]

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1. Introduction

Beef markets and trade in China and Southeast Asia have undergone major change in ways that could not have been envisioned only a decade ago. Unprecedented economic growth and urbanization has resulted in increased beef consumption in parts of the region. For example, between 2000 and 2013, average beef consumption increased by 5.3% in Vietnam and around 4% in China annually, while beef prices increased by 8% and 11% respectively.[5]
The increases in consumption have not, however, seen a parallel response in cattle numbers. Over the same period, the overall cattle herd in China and Southeast Asia decreased (especially in China which makes up 69% of cattle numbers) for several reasons, including increasing opportunity costs of labour in countries that experienced broad-based growth; large-scale farm mechanisation that has reduced the need for draught cattle; and farmers selling cattle to take advantage of high prices. In a regional cattle industry dominated by small-holders, the supply response to rising prices has been muted – especially for cow-calf production – compared to other more commercialised livestock industries (pigs and chickens).

These supply–demand settings have forged significant industry changes. While cattle numbers have stagnated (-0.3%), turnoff numbers have increased (1.9%) as has beef production (2.5%) indicating higher turnoff rates and increased carcass weights (FAOStat, 2014), which indicates gradual increases in industry productivity. While regional beef industries are dominated by small-holders and individual household actors, there have several "hotspots" of industry growth – especially in the feedlot sector and other downstream sectors.

Perhaps most importantly there has been a major increase in the trade of cattle and beef. The volume of beef officially imported into China, Vietnam and Indonesia increased from approximately 100,000 tonnes in 2008 to 430,000 tonnes in 2013 (UNComtrade, 2015). About another one million tonnes entered China through informal channels in 2015 (from India, Brazil and the US). These countries formally imported more than 900,000 cattle, while hundreds of thousands more – mainly from Myanmar – crossed into China and traversed Thailand, Laos, Cambodia and into Vietnam through a myriad of established and opportunistic trade routes.

These rapidly evolving market and trade settings have major implications for:

- Disease and bio-security risks associated with livestock trading
- Food price inflation and consumer access to red meat protein
- Rural development. Beef industries in China and Southeast are dominated by individual household actors, are highly labour-intensive, contributing to the livelihoods of perhaps 15 million people. Increasing trade and price integration provides opportunities for small-holder cattle producers and other chain actors (traders, transport operators, processors) to access more distant markets, but also exposes other actors to increased competition, and price effects.

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[5] China consumption data extrapolated from National Bureau of Statistics (various years) adjusted with an additional 35% out of home consumption and one million tonnes of informal beef imports in 2013. China price data from China Livestock Yearbook (various years). All annual average growth figures are compounded. Vietnam consumption data from FAOStat (2015) and price data from CIS/MARD 2014.

The Australian Centre for International Agricultural Research (ACIAR) has developed a strong research program on cattle production and marketing systems across Southeast Asia and China. There is also a growing body of research on trans-boundary livestock trade, especially in relation to disease and bio-security risks from livestock trading (e.g. Adams *et al.* (ed), 2012).

However, what is missing is systematic analysis and tools to assess the demand and supply side drivers of regional industry change and trade flows into the future. This analysis would quantify how rapid and fundamental change in the region – including the growth in incomes and beef consumption in particular urban centres, the growth in rural wages and farm mechanisation, increased competition for resources, improved infrastructure and freer trade – impacts on beef industries throughout the region.

This paper presents the specifications of a model to assess ex-ante how particular scenarios – for example changes in cattle slaughter and export policy in Myanmar, the Indonesian live cattle import quota, the ESCAS system; economic integration under the ASEAN Economic Community, or increased quarantine controls resulting from disease outbreaks – might affect cattle and beef prices and trade in the broader region. Incorporation of new information relating to the factors that drive complex flows of cattle and beef would assist policy-makers throughout the region to improve strategies for beef industry development.

Section 2 of this paper presents a brief review of interregional trade modeling techniques, and Section 3 outlines the specifications of a Spatial Price Equilibrium model.

2. Review of Interregional Trade Modeling Techniques

This section discusses spatial modeling issues and reviews previous spatial modeling studies in order to develop the most appropriate spatial modeling system to describe the marketing and distribution of cattle and beef in South East Asia and China.

The choice of the most appropriate modeling framework will be made on the basis of the objectives of the analysis, the availability and reliability of data, and the flexibility of the various possible approaches for policy analysis.

Models that are capable of achieving relatively complex analytical objectives, using the available data and retaining a degree of flexibility, fall into the category of programming models that model the interaction of supplies of and demands for, products in a number of spatially separated regions.

Many approaches have been used to solve transportation type problems. Two of the more common approaches are stochastic behaviour models and deterministic optimization models. Stochastic behaviour models are usually applied to transportation modeling to examine pricing behaviour and competition amongst alternative transport types.

Interregional deterministic optimization models can be categorized into three types. These are quadratic programming, linear programming and network flow models. The objective function and constraints of linear programming and network flow models must be linear, but those of quadratic programming models are not necessarily linear in nature. These models are used to optimize an objective function, subject to spatial equilibrium conditions. The objective function is usually either a welfare or utility function that is maximized, or a cost function that is minimized.

Linear optimization models deal with optimal levels of inter-regional flows needed to satisfy supply and demand levels in various regions. A two-region equilibrium model with no trade will result in production levels in each region that fulfil domestic demand. If trade between the two regions is allowed with no transfer cost, then production will flow between the two regions to satisfy excess supply and demand requirements.

Linear optimization models are generally presented as a set of supply regions and demand regions. The sum of supply figures is generally equal to the sum of demands ($\sum_i Q_s = \sum_j Q_d$ for i supply regions and j demand regions. If there is an excess supply ($\sum_i Q_s > \sum_j Q_d$) then an export region is introduced to the model with a demand level of $\sum_i Q_s - \sum_j Q_d$. If there is an excess demand ($\sum_i Q_s < \sum_j Q_d$) then an import region is introduced to the model with a supply value of $\sum_j Q_d - \sum_i Q_s$.

The common objective of linear optimization models is to find the most efficient way to transfer product from the excess supply regions to the excess demand regions.

Linear programming models can solve many problems, but one of the more common formulations is to minimize total transport costs. Minimizing transportation costs between supply and demand regions and import and export regions subject to capacity constraints solves these models. This is outlined below.

Minimize;

$$Z = \sum_i \sum_j t_{ij} X_{ij} + \sum_i \sum_n t_{in} X_{in} + \sum_m \sum_j t_{mj} X_{mj}$$

Subject to the following constraints;

$$\sum_j X_{ij} + \sum_n X_{in} \leq S_i$$

$$\sum_j X_{mj} \leq ES_m$$

$$\sum_j X_{ij} + \sum_m X_{mj} \leq D_j$$

$$\sum_i X_{in} \geq ED_n$$

Where;

S_i = quantity of commodity supplied in the ith producing region ES_m = quantity of commodity exported in the mth exporting region D_j = quantity of commodity demanded in the jth consuming region
ED_n = quantity of commodity demanded in the nth importing region
X_{ij} = quantity of commodity shipped from the ith producing region to the jth consuming region
X_{in} = quantity of commodity shipped from producing region i to the nth importing region
X_{mj} = quantity of commodity shipped from exporting country m to consuming region j
t_{ij}, t_{in},t_{mj} = Corresponding unit transport costs

Trans-shipment models extend the simple spatial model by adding transformation nodes where modes of transport are changed or where the nature of the product has been changed. Examples of typical nodes used in modeling of the agricultural sector are abattoirs, silos, mills and cotton gins.

Processing activities can be added to the linear programming model to reformulate the objective function in terms of minimizing processing and transportation costs. The model would then consist of domestic demand and supply regions, importing and exporting regions and domestic processing regions. Products must pass from supplying regions (or countries), through the processing regions and finally to consuming regions (or countries).

Further refinements of the linear programming model include the introduction of quadratic transport cost functions (Schmitz and Bawden, 1973), flow dependent supply and demand functions (Smith and Friez,1985) and discriminatory trade practices (Anania and McCalla, 1991). A linear optimization model of the South East Asian and Chinese live cattle and beef sector could be developed in order to evaluate the most efficient flows and processing locations under a given set of regional supply and demand levels. Products could be transformed and flows of products and fattening and slaughtering locations would be determined on the basis of cost advantage. The main disadvantage of this type of model is that regional demand and supply levels are taken as static. This means that the effects of price levels on demand and supply curves at the regional level could not be adequately modeled. This would require the addition of price responsive supply and demand functions and a quadratic objective function as part of a non-linear optimization model.

<u>Non-linear optimization models</u> introduce a price dimension to the objective function and include regional price responsive demand and supply functions. This class of models is commonly known as “spatial price equilibrium” models because they are optimized when interregional prices are in an equilibrium consistent with interregional transport/processing costs.

Enke (1951) developed the first method of discovering competitive equilibrium commodity flows and price levels. Samuelson (1952) formulated a mathematical programming problem as that could be solved simultaneously for input supply functions and commodity demand functions. Takayama and Judge (1964c) developed the spatial equilibrium problem into a quadratic programming algorithm with linear supply and demand functions for a single commodity with multiple supply and demand regions. An example of an objective function used in the Takayama and Judge framework is to maximize Samuelson’s (1952) net welfare function.

A quadratic objective function for a single commodity multi-region model is developed by integrating domestic demand for the jth consuming region ($D_j = \alpha_{oj} - \alpha_{1j}P_j$) and domestic supply for the ith producing region ($S_i = \beta_{oi} - \beta_{1i}P_i$) with respect to prices and deducting the cost of transportation between the two regions.

In addition to transportation, processing activities can also be added to the quadratic model. The objective function in this case is to maximize social welfare, net of transport and processing costs. This is formulated as:

Maximize;

$$W = \sum_i \int S_i \, \partial P_i + \sum_j \int D_j \, \partial \, P_j - \left(\sum_i \sum_k T_{ik} X_{ik} + \sum_k \sum_j T_{kj} X_{kj} + \sum_i \sum_k T_{ik} C_k \right)$$

A spatial equilibrium condition is achieved amongst the regions by maximizing the objective function subject to a number of constraints;

$$\beta_{oi} + \beta_{1i} P_i = \sum_k X_{ik}$$

$$\alpha_{oj} - \alpha_{1j} P_j = \sum_k X_{kj}$$

$$P_k - P_i \leq T_{ik}$$

$$P_j - P_k \leq T_{kj}$$

$$\sum_i X_{ik} = \sum_j X_{kj}$$

Where;

D_j = domestic demand in jth region
S_i = domestic supply in ith region
α_{oj}= intercept of demand function
α_{1j}= slope coefficient of demand function
β_{oi}= intercept of supply function
β_{1i}= slope coefficient of supply function
P_i = price in supply region i
P_k = price in processing region k
P_j = price in demand region j
X_{ik} = quantity of commodity shipped from the ith producing region to the kth processing region
X_{kj} = quantity of commodity shipped from the kth producing region to the jth consuming region
T_{ik} = Cost of transporting a unit of product between i and k
T_{kj} = Cost of transporting a unit of product between k and j

Takayama and Judge (1971) propose that the welfare function can be restated as a quadratic net revenue function which aims to maximize the total revenue of producers and consumers in all regions, net of transport and processing costs. According to Takayama (1985), the Kuhn-Tucker conditions associated with the spatial price equilibrium problem are necessary conditions for a global optimal solution in the presence of linear constraints.

Spatial price equilibrium models have been extended to include multiple products (Lee and Seaver, 1973; Webb *et al*, 1992 and Waquil and Cox, 1995). Two approaches are possible when constructing a spatial price equilibrium model with multiple commodities. If the products are not related to each other through transformation, then a model incorporating cross and own price elasticities of supply and demand may be appropriate.

An example of multiple product analysis is Webb *et al*'s (1992) analysis of the spatial nature of the Chinese grain market. Relationships between the various grain types were described by a system of own and cross price elasticities. This multi-crop spatial price equilibrium model is used to analyse the effect of policy changes on Chinese grain production, distribution and imports.

Webb *et al.*'s analysis modeled products that were related through cross-price elasticity effects. If the products are vertically related, or have a relationship based on transformation at a transshipment point then a model incorporating multiple stages of production may be more appropriate. Examples of this type of approach include Arndt *et al*'s 1998 analysis of maize markets and storage in Mozambique and Waquil and Cox's 1995 model of agricultural integration in the MERCOSUR region.

Multiple production stage models with primary, intermediate and final commodities are based on the work of Vanek (1963) and Samuelson (1962), who suggested that any productive system could be considered to be a black box, with inputs of primary factors of production and outputs of final commodities. The optimal solution to the spatial price equilibrium model with intermediate commodities will reveal the equilibrium price and quantities of supply and demand in each region. Spatial price equilibrium models with intermediate products are optimized by maximizing the sum of producer and consumer surplus net of transportation and transformation costs.

A number of previous spatial price equilibrium studies that analyse systems with intermediate products (Takayama and Judge, 1964a; Thore, 1992; Bishop, Pratt and Novakovick, 1993) assume constant cost of processing, which may vary between regions. Other studies (Waquil and Cox, 1995) assume positively sloped cost of transformation functions which represent the increasing marginal costs of processing intermediate inputs into outputs. A combination of these two approaches is to estimate constant cost functions for a number of different scales of operation. This is useful when information on the utilized proportion of processing capacity is unknown.

A multiple product model with vertical relationships would be the most appropriate type of model to analyse South East Asian and Chinese cattle and beef distribution systems because this model type allows for production to occur in a number of vertically related stages. These are; initial production of feeder cattle, intermediate production of slaughter cattle and final production of beef. In each stage of production, commodities produced are to be used as inputs into the next stage of production. The final product (beef) is destined for consumption. All commodities are transportable between regions at each level.

3. A Spatial Price Equilibrium Model of Live Cattle and Beef trade in South East Asia and China

This section presents the spatial price equilibrium model of live cattle and beef trade in South East Asia and China. The model is based on the spatial price equilibrium model with vertically related products presented in Section 2 and considers cattle/beef to be a single commodity that is subject to transformation and transportation between supply and demand. The model incorporates intermediate products by including feedlots and slaughterhouses as transformation points. The objective of the model is to maximize the sum of producer and consumer surplus, net of transportation and transformation costs. Spatial linkages between 68 producing regions, 166 fattening regions, 88 slaughtering regions and 136 consumption regions are examined. In an unconstrained format, the model permits 135,094,784 possible paths of product transfer between production and consumption.

For the purposes of the model, Southeast Asia and China have been divided into 68 basic regions (see Figure 1). Each region has a nodal point. Transportation within the region is assumed to have no cost, and perfect competition is assumed within the regions. The regions are shown in Figure 1 and listed in Annex 1.

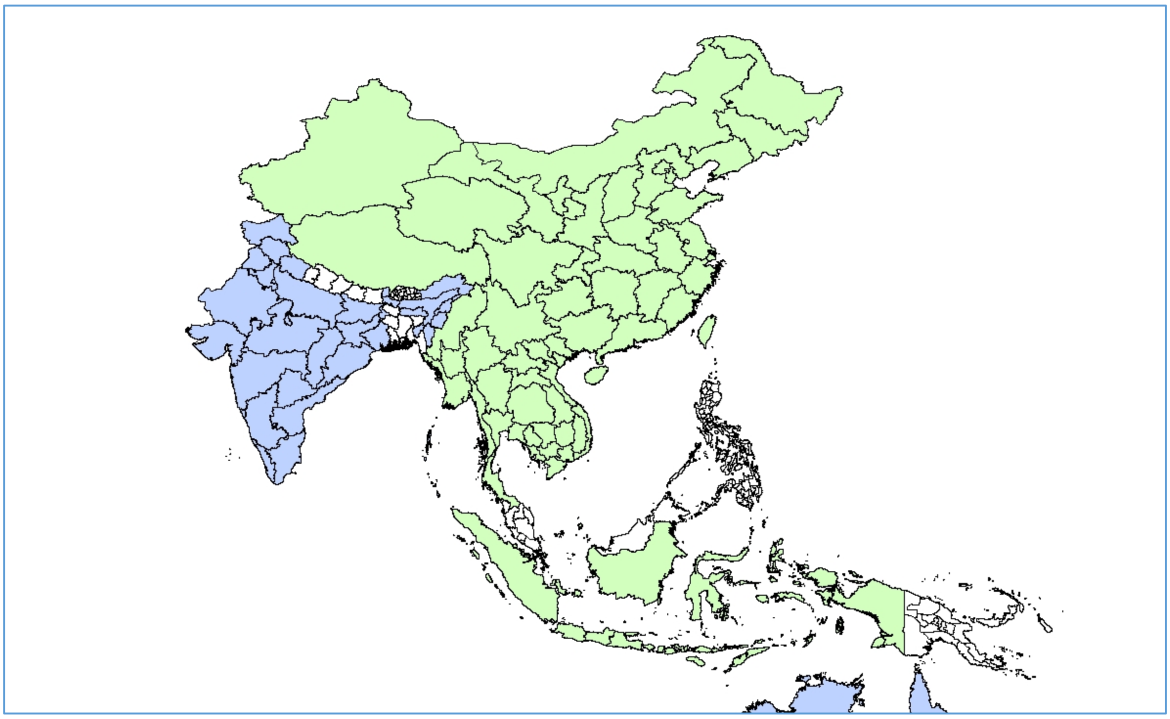


Figure 1: Regions in Spatial Price Equilibrium Model

These 68 basic regions serve as the 68 feeder cattle supply regions. Within the basic regions, there are three options for cattle fattening. These are fattening in a cow-calf integrated operation (in all regions), fattening in specialised household level fattening operations (in all regions) and fattening in a large feedlot (in 30 of the 68 regions). This gives a total of 166 possible fattening regions.

Within the 68 basic regions, there are two options for slaughtering cattle. These are at the household level (in all 68 regions) and at the large abattoir level (in 20 of the regions). This gives a total of 88 slaughtering regions. Beef produced in large abattoirs is classified as high quality, and beef produced in household slaughterhouses is classified as general quality. Consumption in each region is differentiated into urban consumption and rural consumption. This gives a total of 136 possible consumption regions.

Feeder cattle are a homogenous commodity in each region. There are three types of slaughter cattle. These are slaughter cattle from large feedlots, slaughter cattle from household fattening operations and slaughter cattle from cow-calf households. Commercial abattoirs accept slaughter cattle from large feedlots or household fattening operations whereas small slaughterhouses accept slaughter cattle from either household fattening operations or cow-calf households.
There are two types of beef produced. These are beef from large abattoirs and beef from small slaughterhouses. Beef consumed in urban regions can come from commercial abbatoirs or household slaughterhouses, while beef consumed in rural regions comes only from household slaughterhouses.

Each of the 68 regions will have an imbalance between supply of cattle and demand for beef. Some regions (particularly large cities) will have a high demand for beef and a low level of supply of feeder cattle and cull cows. Other more rural regions will have a low demand for beef but a high level of supply of feeder cattle and cull cows. Cattle and beef must flow between regions in order to satisfy demand for beef in each region. The path of the flows and the regions where transformation takes place are dependent on the cost of transformation for each actor type and the cost of transportation of product between regions.

The objective of the model is to maximize the sum of producer and consumer surplus, less the total cost of transporting and transforming the products. In addition to the standard constraints for finding the optimal value of a quadratic objective function, the model is also subject to a number of constraints that balance the flows of products between supply, transformation and demand regions.

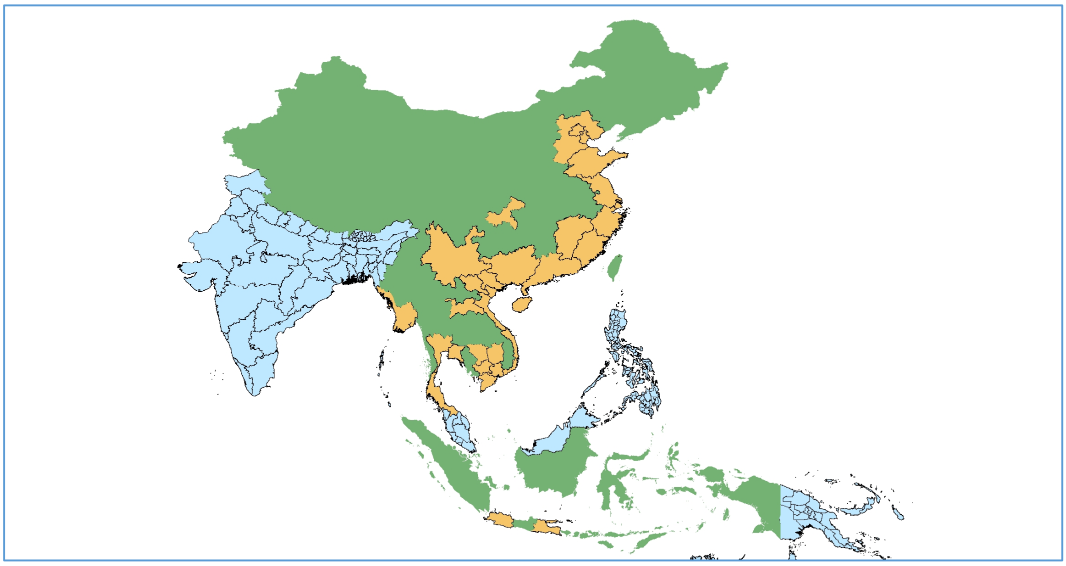
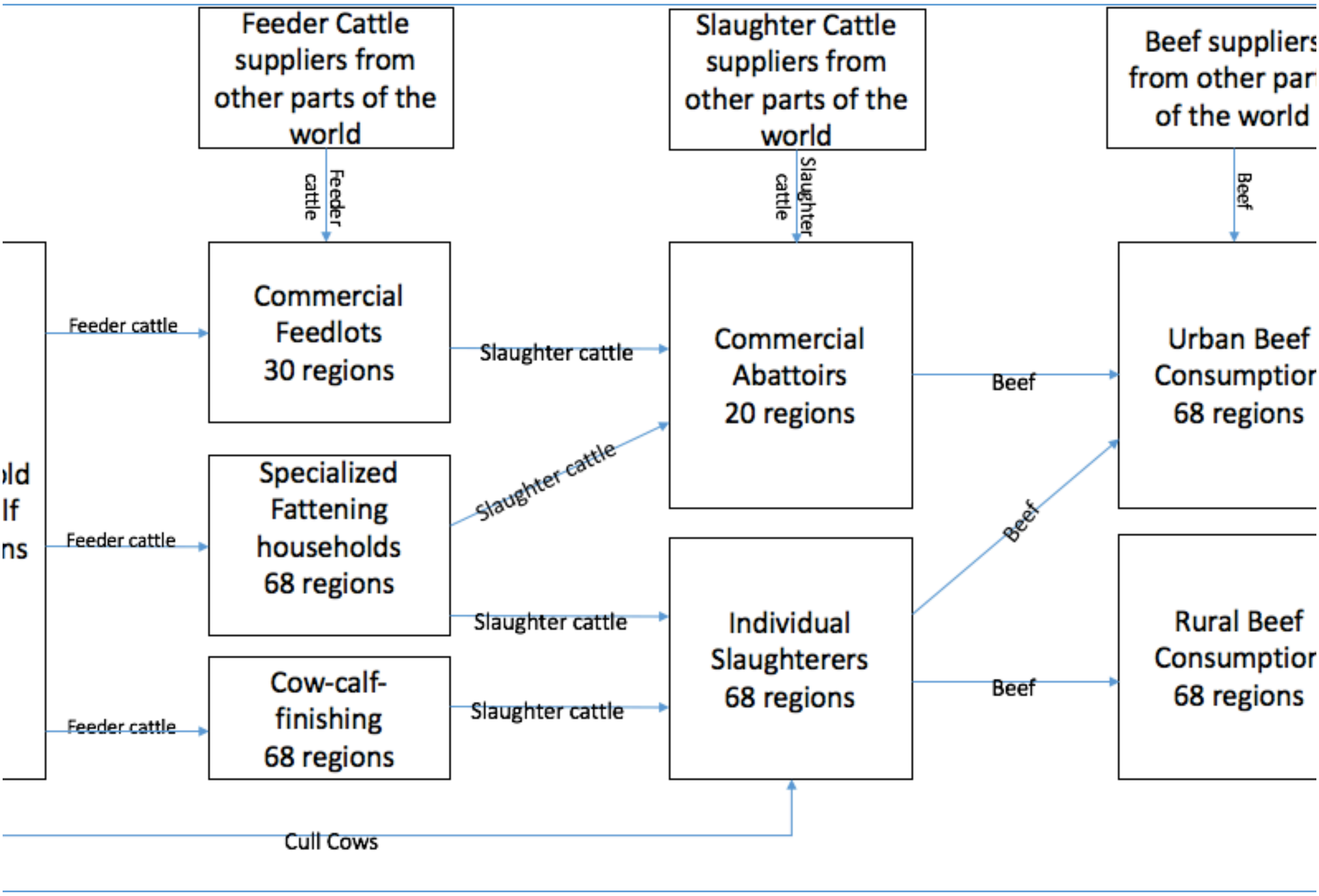


Figure 2: Example of Demand and Supply Imbalance in each region (Green = Excess Supply of Cattle , Orange = Excess Demand for Beef)



resentation of the Linkages Between Industry Participants

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$$Maximize\ NCPS = \sum_{i}(\alpha_j Q_{dj} + \frac{1}{2}\beta_j Q_{dj}^2 - \delta_i Q_{si} - \frac{1}{2}\varepsilon_i Q_{si}^2) - T_{if} * M_{if}$$
$$- T_{\square s} * M_{fs} - T_{sj} * M_{sj} - \sum\nolimits_{f}(Q_f C_f) - \sum_{s}(Q_s\, C_s)$$

for I = 68 producing regions, f = 166 fattening regions,s = 88 slaughtering regions, j = 136 consumption regions (total 135,094,784 possible paths of product transfer in unconstrained form)

Basic Constraints
$P_{dj} = \alpha - \beta Q_{dj}$ Demand Function
$P_{si} = \delta + \varepsilon Q_{si}$ Supply Function
$Q_{si} - \sum_f(T_{if}) \geq 0$ Supply Balance
$Q_{dj} - \sum_s(T_{sj}) \leq 0$ Demand Balance
$\sum_i(T_{if}) \geq \sum_s(T_{fs})$ Feeding Location Balance
$\sum_f(T_{fs}) \geq \sum_j(T_{sj})$ Slaughtering Location Balance
$P_{dj} - P_{dk} \leq T_{jk}$Price Arbitrage
$Q_s, Q_d, T_{if}, T_{fs}, T_{sj} \geq 0$ Positive Variables

Additional Constraints
$\sum_i T_{islf} \geq \sum_{slf} T_{slfcs}$ Feedlot location balance
$\sum_{slf} T_{slfcs} \geq \sum_{cs} T_{csj}$ abattoir balance

Where;
$\alpha_j = P_j'(1 - \frac{1}{\eta_{dj}})$ Demand Function Intercept Coefficient
$\beta_j = \frac{P_J'}{\eta_{dj} Q_J'}$ Demand Function Slope Coefficient
$\delta_i = P_i'(1 - \frac{1}{\eta_{si}})$ Supply Function Intercept Coefficient
$\varepsilon_i = \frac{P_i'}{\eta_{si} Q_i'}$ Supply Function Slope Coefficient
NCPS = Sum of producer and consumer surplus net of transportation and transformation costs
P_j'= Price of beef in region j in base time period
η_{dj}= Price elasticity of demand of beef in region j in base time period
Q_J' = quantity of beef demanded in region j in base time period
P_i'= Price of feeder cattle in region i in base time period
η_{si}= Price elasticity of supply of cattle in region i in base time period
Q_i'= quantity of cattle supplied in region i in base time period
Q_{dj}= Equilibrium quantity of beef demanded in region j in base time period
Q_{si}= Equilibrium quantity of cattle supplied in region i in base time period
T_{if} = quantity of feeder cattle transported between supply region i and fattening region f
M_{if} = cost of transporting one unit of feeder cattle between supply region i and fattening region f
T_{fs} = quantity of slaughter cattle transported between fattening region f and slaughtering

region s

M_{fs}= cost of transporting one unit of slaughter cattle between fattening region f and slaughtering region s

T_{sj}= quantity of beef transported between slaughtering region s and consumption region j

M_{sj} = cost of transporting one unit of beef between slaughtering region s and consumption region j

Q_f = quantity of cattle fattened at location f

C_f = cost of fattening one unit of cattle at location f

Q_s = quantity of cattle slaughtered at location s

C_s = cost of slaughtering one unit of cattle at location s

P_{dj} = Equilibrium demand price of beef at location j

P_{si} = Equilibrium supply price of cattle at location i

P_{dk} = Equilibrium demand price of beef at illustrative location k

T_{jk} = cost of transporting one unit of beef between location j and location k

T_{islf} = Quantity of feeder cattle transported to large feedlots and specialized fattening households

T_{slfcs} = Quantity of slaughter cattle transported from large feedlots and specialized fattening households to commercial abattoirs

T_{csj} = Quantity of beef transported from commercial abattoirs to consumption regions

Maximizing the objective function subject to the constraints reveals equilibrium quantities of feeder cattle supplied in each region, the quantity of beef demanded in each region, quantities of cattle and beef transported between regions and the quantities of cattle fattened and slaughtered at various regions. Examining the marginal values of the product balance equations gives the shadow price at equilibrium of various products by region. The relationship between equation and shadow price is given in Table 1.

Table 1: Marginal Values as Shadow Prices

Equation	Shadow Price from Marginal Value
Supply Balance	Feeder Cattle Price
Feeding Location Balance	Slaughter Cattle Price
Beef Demand Balance	Beef Price

The linearly constrained quadratic objective program is solved using the reduced gradient method (Wolfe, 1962) in conjunction with a quasi-Newton algorithm (Davidson, 1959). This solves the model to meet a global optimal market equilibrium condition. GAMS (Brooks *et al*, 1987) software in conjunction with the MINOS 5.1 (Murtagh and Saunders, 1988) add on can be used to find the optimal solution to this problem.

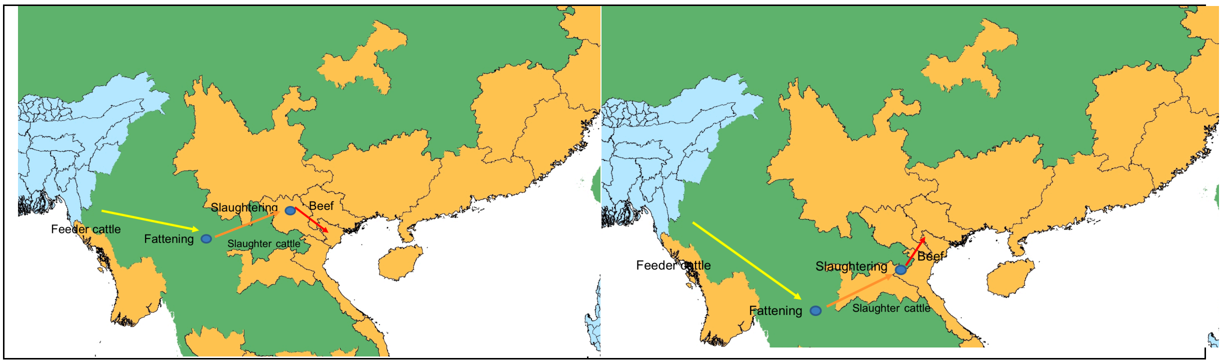

Figure 4: Paths between supply and demand areas depend on the relative costs of transport and transformation of products

Supply
"Domestic" supply of feeder cattle and cull cows is dependent on the size and characteristics of the cattle herd in each region. The number of calves born is dependent on (i) the overall herd size; (ii) the proportion of breeding females in the herd; and (iii) the fertility rate of breeding females within the herd.

$NC_i = NT_i*BCR_i*FR_i$
Where NC_i = number of calves born in region i
NT_i = number of cattle in region i
BCR_i = proportion of breeding females within the herd in region i
FR_i = fertility rate of breeding females in region i

The supply of feeder cattle is related to (i) the number of calves born in the previous year; and (ii) the proportion of female calves retained for breeding purposes.

$NF_{in} = (NC_{i(n-1)*}0.5)+ ((NC_{i(n-1)*}0.5*(1-PH_{in}))$

Where NF_{in} is the supply of feeder cattle in region i in year n
$NC_{i(n-1)}$ is the supply of calves in region I in year n-1
PH_{in} is the proportion of female calves retained for breeding

The supply of cull cows (cows that are slaughtered at between 8 and 12 years of age after being used in calf production) is related to (i) the number of female calves born per year; (ii) the retention rate of female calves; and (iii) the length of time that cows are kept in the herd before being culled.

$CF_i = (NT_i*BCR_i)/Y_i$
Where CF_i = number of cull cows from region i
NT_i = number of cattle in region i
BCR_i = proportion of breeding females within the herd in region i
Y_i = the number of years that breeding females are kept in the herd before culling

Transport
Costs of transport can generally be divided into tangible and intangible components. Tangible components can easily be quantified and built into pricing structures. Intangible components cannot easily be quantified and are not easily incorporated into pricing schedules. Table 2 outlines some tangible and intangible aspects of cattle and beef transport costs.

Table 2: Tangible and Intangible Transport Cost Components

Tangible Cost Components	Intangible Cost Components
Truck purchase amount, Depreciation, Fuel, Maintenance, Insurance, Registration, License Fees, Tolls, Workers wages.	Deterioration of beef quality, loss of cattle weight during journey, mortality and morbidity of cattle, commissions and access payments, possible need for overnight accommodation.

Fattening
In the model, fattening is defined as the transformation of feeder cattle (defined as cattle at around 280kg liveweight) into slaughter cattle (defined as cattle at 350 – 400kg liveweight) through relatively intensive feeding of rations including grass, crop residues and grains.

Fattening can be done in:

- Commercial feedlots – these are the largest scale and most intensive of the fattening operations and fatten predominately using a high proportion of grains in the feed rations. Imported feeder cattle (from outside South-East Asia/China) are fattened in commercial feedlots along with feeder cattle from within South-East Asia/China. Commercial feedlots only exist in 30 regions, not all 68 regions.
- Specialized fattening households – these are medium scale and medium intensity fattening operations where around 5-20 head of cattle are fattened using a combination of grass, residues and grains. Specialized fattening households are not involved in cow-calf production. Specialized fattening households can be found in all 68 regions.
- Cow – calf to finishing households – these are relatively small scale and low intensity operations where households raise cows and keep calves until they reach slaughter weight. Feeding is mostly grass with some crop residues. These exist in all 68 regions.

Slaughtering

In the model, slaughtering is defined as the transformation of slaughter cattle (the outputs of the fattening transformation described above) into beef. Slaughtering can be done in:

- Commercial abattoirs – these are "modern" large scale certified operations capable of slaughtering at least 10,000 head of cattle per year. Commercial abattoirs source slaughter cattle from commercial feedlots, specialized fattening households and also slaughter cattle imported from countries outside South-East Asia/China. Commercial abattoirs supply beef to urban consumers. Commercial abattoirs only exist in 20 of the 73 regions.
- Individual slaughterers – these are relatively small scale household level slaughtering operations. They can operate independently, or can operate cooperatively (for example in municipal slaughter points where many small scale slaughterers work together in a common location. Individual slaughterers operate in all 68 regions.

Demand

Demand for beef in the simplified model is split into rural demand and urban demand. Demand in rural and urban regions depends on the population in each region and the per capita rural demand for beef and the per capita urban demand for beef. Per capita demand depends on income elasticity of demand and own price elasticity of demand.

4. Future Model Development

The model is currently a comparative static model with a time scale of one year. The comparative static model can be used to look at the impact of short-term shocks – disease outbreaks, changes in export or import policy etc.

The next step in model development is to expand the model to cover longer timeframes and to be able to model the impact of long-term trends. This will be done by converting the model into a dynamic intertemporal spatial price equilibrium model.

We are going to work with IFPRI and ILRI to link the spatial price equilibrium model with the IMPACT model to give us a stream of beef demand predictions. This will then be matched with a stream of cattle supply predictions for each region. This requires well defined long term supply curves for cattle which combine economic and biophysical (herd modeling) elements.

Annex 1: Regions in the SPE model

Country	Region
East Timor	East Timor
Vietnam	Red River Delta
	North East
	North West
	North Central Coast
	South Central Coast
	Central Highlands
	South East
	Mekong River Delta
Thailand	North
	Northeast
	Central
	East
	West
	South
Lao PDR	North
	Central
	South
Cambodia	Central
	Northern
	Southern
	Eastern
	Coastal
China	_Anhui
	_Beijing
	Chongqing
	Fujian
	Gansu
	Guangdong
	Guangxi
	Guizhou
	Hainan
	Hebei
	Heilongjiang
	Henan
	Hong Kong
	Hubei
	Hunan
	Inner Mongolia
	Jiangsu
	Jiangxi
	Jilin
	Liaoning
	Macau
	Ningxia
	Qinghai
	Shaanxi
	Shandong
	Shanghai

	Shanxi
	Sichuan
	Tianjin
	Tibet
	Xinjiang
	Yunnan
	Zhejiang
Myanmar	Central
	East
	Lower
	North
	South
Indonesia	Sumatra
	West Java
	Central Java
	East Java
	Bali
	Kalimantan
	Sulewesi
	MelakuPapua
Australia	
Rest of World	

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