

**Lincoln Trade and Environment Model (LTEM):
An Agricultural Multi-Country, Multi-
Commodity Partial Equilibrium Framework**

**Selim Cagatay
and
Caroline Saunders**

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Summary

This research report introduces the Lincoln Trade and Environmental Model (LTEM). The report defines the model as well as comparing it to other trade modelling frameworks. The theoretical and technical specification of LTEM are detailed. The report then identifies the policies which can be incorporated into the LTEM. These policies are distinguished into unilateral policies and bilateral policies, and illustrate the capability of the model to simulate the impact of various complex policies on trade.

The unilateral policies include the more traditional policies such as import tariffs and export subsidies, as well as market and input subsidies. However, the LTEM also includes the ability to model direct payments, production quotas and minimum prices.

The bilateral policies in the LTEM include preferential access quotas with and without in-quota tariffs. In addition the LTEM can include more general trade access quotas, again with or without in- or out-quota tariffs, thus enabling the impact of more complex policies to be assessed.

The research report then outlines the model interactions, and how the policy changes or other shocks to the LTEM are simulated.

Chapter 1

Introduction

In the last two decades, with shifts in applied policies towards a more liberal agricultural sector and with the related developments in international agricultural markets, there has been a considerable increase in applied studies that attempt to evaluate the impacts of domestic agricultural, environmental and trade policies on world economies in various contexts. The applied methods that are used for modelling international trade with a focus on agricultural sector can be grouped into two, based on the economic interactions that the methods encompass. These are the economy-wide general equilibrium (GE) and partial-economy partial equilibrium (PE) frameworks¹. Lincoln Trade and Environment Model (LTEM) is an agricultural multi-country, multi-commodity model which uses a partial equilibrium framework to analyse the impact of agricultural domestic and trade policies. The LTEM is also used to quantify the linkages between the agricultural sector and the environment in various contexts by extending the main model structure to include environmental sub-modules or environmental damage functions². This paper aims to clarify the theoretical and technical specifics of the LTEM without encompassing the specifics of environmental sub-modules. Before moving to that, the main differences between the agriculture focused GE and PE approaches are discussed briefly in this paper in order to clarify the differences in purpose of use of these two approaches. In addition, the main differentiating factors between various agricultural PE international trade models from each other are also introduced in order to provide a good understanding of the LTEM.

The second section presents a brief review of differences between agriculture focused GE and PE frameworks and also of differences within the PE frameworks. In the third section, the main characteristics of the LTEM are presented. In the fourth section, the behavioural equations are introduced at commodity group level. The paper concludes with a Further Research section. Two Annexes present the parameters and exogenous variables of the LTEM respectively.

¹ Economy-wide frameworks here exclude the macroeconometric type models as their interest is on total output, however they refer to all GE type models which are based on the Walrasian equilibrium concept, and are neoclassical in spirit but also extended to include macro and micro structuralist characteristics (Robinson, 1989). Partial-economy frameworks here exclude agricultural activity type mathematical programming models which are mostly referred to as the agricultural sector models.

² See Ervin (1999) for details on environmental damage functions.

Chapter 2

A Brief Look at the Agriculture Focused GE and PE Frameworks

Partial and general equilibrium models of the market equilibrium type quantify the response of economic agents to changes in various prices that adjust to clear markets. The main objective of these models is to determine the equilibrium prices and quantities on set(s) of market(s), which are subject to various policy shocks. Both PE and GE frameworks can focus on single- or multi-commodity/industry depending on the level of commodity aggregation used to represent the market(s). These frameworks can be used for single-, multi-country analysis at the national level and can also be used at the sub-national level, depending on the availability of the data.

The temporal properties of both frameworks can vary from short to long-term and can provide either a dynamic (giving the adjustment path of endogenous variables) or comparative static solution (giving the solution at a point in time). If the PE and GE frameworks are at levels rather than differences, the dynamics can be introduced in these frameworks by a recursive structure and/or sequential simulation (year by year), however in addition to these in a GE framework intertemporal dynamics can also be introduced based on the formulation of the expectations of economic agents.

One of the main differences between the PE and GE frameworks is illustrated by the way the economy is structured in the models. An agriculture focused PE model analyses the interactions within only one sector (agriculture) of the economy without considering the linkages with the rest of economy. The coverage of the agricultural sector can however be extended and disaggregated providing the data is available. An agriculture focused GE model on the other hand, analyses the interactions both within the agricultural sector and with the other sectors of the economy. In addition, a GE framework also analyzes the interactions with the factor markets, providing the solution for income-expenditure equilibrium in the economy. Therefore, while PE frameworks integrate technical change, population growth and income exogenously for example, these variables are generally derived endogenously in GE frameworks³. In other words, the opportunity costs of inter-industry factor movements, the effect of changing factor returns on demand level and the cost to the economy of agricultural support and subsidy policies are computed in GE frameworks only (Hertel, 1990).

A further major difference between PE and GE frameworks arises in the modeling of the supply and demand response in the economy. In PE frameworks generally a reduced form approach is generally utilized for the supply and demand response, which are specified as functions of prices, income and related elasticities (Tongeren and Meijl, 1999). However, in a general equilibrium framework the behavioral responses of producers and consumers are explicitly specified as production and consumption functions. Two main issues arise from this difference: the theoretical consistency of the frameworks and obtaining parameters of the frameworks.

The theoretical consistency of the frameworks can be ensured at least by three methods. Firstly, the numerical results should be qualitatively in accordance with the theoretical foundations (Tongeren and Meijl, 1999). Secondly, microeconomic theory places restrictions on the parameters of the supply and demand functions, either modeled explicitly or derived implicitly. Therefore, a check on these parameters is another method to verify the theoretical

³ The GE models which emphasize the monetary and financial aspects of the economy are not the focus points here.

consistency. The macroeconomic equilibrium conditions imposed by the closure rules and Walras's Law is the third method to ensure the theoretical consistency (Hertel, 1990). Obviously the way the economy is structured in the GE frameworks actually forces the modellers to obey the restrictions on parameter values and equilibrium conditions. However, in PE frameworks theoretical consistency can be considered as weaker compared to GE models or not forcing, since the only parameter restrictions are on output supply and demand equations. Therefore, in case these parameters do not obey the restrictions the PE modelers would not consider the disequilibrium situations in the other markets that might be caused by output market parameters.

In modeling applications of both PE and GE frameworks the parameters of the equations can either be found through econometric and mathematical procedures or can be adopted from other studies, by applying appropriate test procedures such as homogeneity and symmetry (Varian, 1992; Henrichsmeyer, 1990). In the latter case these models are called synthetic. However, applied literature becomes "inadequate" for various reasons in providing the econometrically estimated parameter values of production and consumption functions specifically when it comes to the aggregate agricultural sector or to particular agricultural commodities as stated by Colman (1983) and Just and Pope (1979). This is one aspect of PE frameworks and reduced form supply and demand functions that makes them attractive for agriculture focused modeling studies (Moschini, 1989; Rao, 1989; Schiff and Montenegro, 1997). Lack of data, the quality of data collected in the agricultural sector and also disaggregation and distribution issues of data among specific agricultural products are the main reasons for poor quality of the estimated production and consumption functions for agricultural products. On the other hand, it is more common to find econometrically estimated parameter values of supply and demand functions of the agricultural sector. Therefore, whether the frameworks are synthetic or not, in PE models the parameters may be considered more robust as they are the outcomes of econometric procedures, which reflect the historical variable behavior. In GE models, however, the parameters generally are the outcomes of mathematical procedures that reflect only one year's behavior.

The approach used to model international trade is another major difference between PE and GE frameworks. International trade can be modeled either with a "simplistic but transparent" or "complex" approach in both frameworks. In a simplistic approach, classical trade models, goods (especially primary agricultural products) are assumed to be similar and perfectly substitutable in international markets and are called homogeneous. In these models, the assumption of large numbers of suppliers for each good provides the perfectly competitive outcome in international markets, and prices across suppliers equalize. The assumptions of homogeneity and perfect competition imply that countries in the international markets can only be exporters or importers of a certain good. Therefore, homogeneity and perfect competition simplify the trade modeling procedure in two aspects (Tongeren and Meijl, 1999). Firstly, the model does not need to track explicitly the bilateral trade between countries, as the products are homogenous, and there is only one price in the international markets. Secondly, the model needs only to track explicitly a single trade flow for each country, as countries are either exporters or importers. Because of its transparency in tracing the trade patterns at commodity and country levels and ease of interpretation, the "simplistic but transparent" approach is used widely in PE frameworks, particularly in agriculture based specific policy analysis.

Since countries report both exports and imports for most goods, product differentiation may become important in trade modeling. Product differentiation (heterogeneous products) is a complexity that may be introduced to the trade modeling procedure. Product differentiation implies that goods are distinguished by other factors than price alone, and hence are viewed as imperfect substitutes in international markets (Tongeren and Meijl, 1999). Therefore, in

these models there is no need for prices to equalize across suppliers, as different buyers are willing to pay different prices. Also, product differentiation allows each country to be both a buyer and a seller at the same time, implying that the trade model has to track twice as many activities explicitly than under the homogeneity assumption. Product differentiation can be introduced in two ways into applied trade models. One method is the use of the Armington (1969) approach which assumes that imports and domestic goods are imperfect substitutes in demand (products are differentiated by country of origin). This approach is commonly used in GE frameworks but also sometimes in PE frameworks, by employing export supply and import demand functions explicitly as well as domestic demand and supply functions (Francois and Hall, 1997). The other method of introducing product differentiation involves the differences in fixed costs such as R&D or marketing costs on the supply side. This method is applicable only in GE frameworks since the way the economy is structured in PE framework does not allow this.

In most cases products are differentiated accordingly with the Armington approach. However, lack of data and parameters in the agricultural sector may result in aggregation of commodities into sub-sectors, as in most cases of GE applications, such as total meat, total grains, total oils etc. These aggregations can obviously be considered to be a drawback of agriculture focused GE models since information about specific details may be lost. Also, these types of models may lose transparency in interpretation and the ability to follow the interactions, due to the inclusion of increasing numbers of trade activities as well as the inter-industry interactions.

A second complexity to trade modeling relates to the differences in the characterization of the global markets (Tongeren and Meijl, 1999). In trade models the global market can be thought of as a pool to which each country supplies and others demand from, without specifying explicitly the bilateral relationships. Alternatively, by specifying the bilateral trade relations in the model, each country's specific trade amounts with each other can be modeled. The pooled approach aggregates supply and demand for a certain good into one figure, and equilibrates demand and supply on a market-wide basis. In this approach supply and demand shares of countries in trade can be traced down, however the information regarding the bilateral relationships is not provided. This is called the non-spatial approach. The other way to represent the global market is bilateral specification which is the explicit representation of the complete set of interactions between each buyer and seller for each commodity. The bilateral approach is mostly used in GE frameworks, but is also possible in PE Frameworks. However, due to the same reasons stated above, the framework may lose the ability to perform specific commodity based policy analysis as well as maintain transparency in terms of ease of simulation, and the ease by which relationships can be altered within the model.

It can be concluded that the choice of PE and GE framework depends primarily on the specific purposes of the modeling exercise. Both frameworks can provide better answers to different questions in various contexts.

At first glance the level of commodity disaggregation, ease of trace ability of the interactions and transparency of the results, relatively small size of the models and the number of behavioural parameters and the methods used to obtain those parameters may encourage modelers to prefer PE frameworks in quantifying the effects of agricultural and trade policy measures (Francois and Hall, 1997; Roningen, 1997; Gaisford and Kerr, 2000; Beers and Bergh, 1996). In addition, the ability to include agricultural input markets endogenously and to treat commodities as imperfect substitutes (so to include bilateral trade relationships) with some effort may make PE frameworks more attractive. These factors may be the cause of increasing interest in agriculture focused PE trade models by international institutions and organization in the last two decades. A list of these models are given in Table 1.

Agricultural PE trade models can also show differences based on various factors. It is not the aim here to review different models but a brief explanation on how these models may differ will be given in the following paragraphs in order to clarify where LTEM stands in this class of models. A first difference among PE trade models may appear between the policy focus or between the aims of policy analysis. Based on the policy analysis, the base year of the models, the commodity and country coverage, and the level of disaggregation used to represent those commodities and countries may differ.

Another difference may be seen in the temporal properties of these models. The simulation period may extend from short- to long-term and so the simulation type can be recursive dynamic or comparative static. However, dynamics can also be introduced by a sequential simulation which provides year to year solutions without considering the dynamic structure of the equations⁴.

A fundamental difference between agricultural PE trade models may be the approach they use to specify the main behavioural equations, commodity supply and demand functions. In some models commodity demand is disaggregated into food, feed and processing demand, while in others the total demand is modeled. On the supply side in some models, instead of endogenizing total supply amount for crop products, the harvested area and yield are endogenized, and total supply is derived by multiplying those two variables. In a similar way, number of animals and milking rate or meat rate are endogenized for calculating the domestic supply of livestock products.

The level of commodity disaggregation, ease of tracability of the interactions and transparency of the results, relatively small size of the models and the number of behavioural parameters and the methods used to obtain those parameters encourage modelers to prefer PE frameworks in quantifying the effects of agricultural and trade policy measures (Francois and Hall, 1997; Roningen, 1997; Gaisford and Kerr, 2000; Beers and Bergh, 1996). In addition, the ability to include agricultural input markets endogenously and to treat commodities as imperfect substitutes (so to include bilateral trade relationships) with some effort may make PE frameworks more attractive. These factors may be the cause of increasing interest in agriculture focused PE trade models by international institutions and organization in the last two decades. A list of these models are given in Table 1.

⁴ Exact lag lengths and the behavioral equations that embody these lags.

Table 1
Agricultural Multi-Country, Multi-Commodity PE Trade Models

Name of the Model	Developed by	Reference
AGLINK	OECD	OECD (1991a; b; c; 1992)
CER	World Bank	Ingco (1987), Larson (1990)
ESIM	Uni. of Goettingen	Munch (1999)
FAPRI	FAPRI-CARD	FAPRI (1989a; b)
GAP GLS	MA and FAL	Salomon (1998a; b) Tyers and Anderson (1986)
GOL	USDA/ERS	Liu and Roningen Roningen (1986), Roningen et al. (1991)
IIASA-BLS	IIASA	Parikh et al. (1988)
MISS	INRA	Guyomard et al. (1991)
MTM	OECD	OECD (1991a; b; c; 1992)
SPEL	Bonn Uni.	Henrichsmeyer (1990)
SWOPSIM	USDA/ERS	Roningen (1986), Roningen et al. (1991)
VOMM	World Bank	Ingco (1987), Larson (1990)
WATSIM	Bonn Uni.	Lampe (1998)
WFM	FAO	FAO (1986)
WTM	SEAP	SEAP (1992)
<i>no specific acronym</i>		Tyers (1985)
<i>no specific acronym</i>		Zietz and Valdes (1990)

Source: Adopted from Cagatay (1996) and Tongeren and Meijl (1999)

Agricultural PE trade models can also show differences based on various factors. It is not the aim here to review different models but a brief explanation on how these models may differ will be given in the following paragraphs in order to clarify where the LTEM stands in this class of models. A first difference among PE trade models is the policy analysis, the base year, the commodity and country coverage and the level of disaggregation in the models may differ.

Another difference between PE Models may occur in the temporal properties of these models. The simulation period may extend from short- to long-term, and therefore the simulation type maybe recursive dynamic or comparative static. However, dynamics can also be introduced through a sequential simulation, providing year-to-year solutions, without considering the dynamic structure of the equations⁵.

A fundamental difference within all agricultural PE trade models is the approach they use to specify the main behavioural equations, commodity supply and demand functions. In some models, commodity demand is disaggregated into food, feed and processing demand, while in others the demand is modeled as total. On the supply side, some models, instead of endogenizing total supply amount for crop products, the harvested area and yield are endogenized and total supply is derived by multiplying those two variables. In a similar way, number of animals and milking rate or meat rate are endogenized in order to calculate the domestic supply of livestock products.

⁵ Exact lag lengths and the behavioral equations that embody these lags.

The approach for modeling stock amount can also change. By using speculative or transaction motives the stock amount can be endogenized (Tyers and Anderson, 1986) or it can be included exogenously. In a more simplistic approach stocks can be excluded totally.

The number of behavioural equations may also differ based on the method the PE models use to model international trade. If the modeller is interested in the net trade of countries on various homogenous products, then a non-spatial, net-trade model will be enough. In this approach, domestic supply and demand functions are estimated, and the net-trade amount will be determined with an economic identity that incorporates supply, demand and stocks (if included) amounts. Alternatively, if the modeller is interested in some heterogeneous products and in bilateral relations between the countries, then import demand and export supply functions are also estimated in addition to the domestic supply and demand functions, and trade becomes an economic identity that incorporates all this information plus the stock amount.

The partiality of the agricultural PE trade models is another criteria that may result in differences. In a model focused on the agricultural sector, the term partiality refers to the variables/parameters that reflect the other sectors, markets or components of the economy, either endogenously or exogenously. For example, in some modeling studies agricultural input sectors are included to incorporate the input-output relation and also to reflect the cost factor. In most of the models exchange rate, income level, population, agricultural land area and production technology are treated exogenously.

Finally, the approach used to quantify the agricultural policy instruments may differ. The specification of the supply equation and price transmission mechanism play a key role in the approach used to incorporate policies. For example, in the models which use a two-stage supply function the policies such as acreage reduction, land set-aside, constraint on physical number of animals, are integrated into the harvested area and number of animal equations, whereas in one-stage supply equations these policy instruments are integrated by changing the shift factor. Incorporation of any per unit border policy can be done through price transmission equations using a price wedge variable. The definition and coverage of this price wedge variable however, may show differences. Integration of input subsidies also changes between one- and two-stage supply functions. While they are integrated as per unit subsidies in the price transmission mechanism in the former type models, they are integrated in the yield equation in the latter type.

Chapter 3

Main Characteristics of the LTEM

The LTEM is a multi-country, multi-commodity PE framework which focuses on the agricultural sector. The linkages of the agricultural sector with the rest of the economy are not considered. The commodities included in the model are treated as homogenous with respect to country of origin and destination and to physical characteristics of the product. Therefore commodities are perfect substitutes in consumption in international markets. Importers and exporters are assumed to be indifferent about their trade partners. Based on this, the model is built as a non-spatial type which emphasizes the net trade of commodities in each region instead of the bilateral trade flows between the countries. However, the supply and demand shares of countries in trade can be traced down.

The LTEM is a synthetic model since the parameters are adopted from the literature. The symmetry condition holds for the supply and demand elasticities, therefore own- and cross-price elasticities are consistent. The model is used to quantify the price, supply, demand and net trade effects of various policy changes. The policy parameters and/or variables and non-agricultural exogenous variables are listed in Table 2. The economic welfare implications of policy changes are also calculated in the LTEM, using the producer and consumer surplus measures. The model is used to derive the medium- to long-term policy impact in a comparative static fashion basing the beginning date to either 1997 or 2000. The model also provides short-run solutions as it applies a sequential simulation procedure year by year in which the stock change is used to link two consecutive years.

Table 2
Policy Variables/Parameters and Non-Agricultural Exogenous Variables

<i>Policy Variables-Domestic Market</i>	<i>Policy Variables-Border</i>	<i>Non-Agricultural Exogenous Variables</i>
Land set-aside	Import tariff	Gross domestic product
Production quota	Export subsidy	Country price index
Support/minimum price	Trade quota	Population
Producer market subsidy	In-quota tariff	Exchange rate
Producer input subsidies	Out-quota tariff	
Producer direct payments	Export tax	
Producer general services		
Consumer market subsidy		

The LTEM includes 19 commodities and 17 countries. These are presented in Tables 3 and 4. The dairy sector is modelled as five commodities, raw milk is defined as the farm gate product and is then allocated to the liquid milk, butter, cheese, whole milk powder or skim milk powder markets depending upon their relative prices, subject to physical constraints. The meat sector is disaggregated into sheepmeat, beef and pig meat, and the poultry sector (poultry meat and eggs) and wool are also modelled explicitly. There are seven crop products (wheat, sugar, coarse grains, rice, oilseeds, oil meals, oil) in the LTEM.

Table 3
Country Coverage of the LTEM

Argentina	Japan	Slovakia
Australia	Mexico	Switzerland
Canada	New Independent States	Turkey
Czech Republic	Norway	United States
European Union (15)	New Zealand	Rest of World
Hungary	Poland	

Table 4
Commodity Coverage of the LTEM

Wheat	Beef and Veal	Raw milk
Coarse grains	Pig meat	Liquid milk
Sugar (refined)	Sheep meat	Butter
Rice	Wool	Cheese
Oilseeds	Poultry meat	Whole milk powder
Oilseed meals	Eggs	Skim milk powder
Oils		

Basically, the model works by simulating the commodity based world market clearing price on the domestic quantities and prices, which may or may not be under the effect of policy changes, in each country. Excess domestic supply or demand in each country spills over onto the world market to determine world prices. The world market-clearing price is determined at the level that equilibrates the total excess demand and supply of each commodity in the world market. The LTEM is built using a spreadsheet-based framework using Excel software.

Chapter 4

Behavioural Equations

In general there are six behavioral equations and one economic identity for each commodity under each country in the LTEM framework. Therefore, there are seven endogenous variables in the structural-form of the equation set for a commodity under each country⁶. There are four exogenously determined variables, but the number of exogenous variables in the structural-form equation set for a commodity varies, based on the cross-price, cross-commodity relationships. The behavioral equations are domestic supply, demand, stocks, domestic producer and consumer price functions and a trade price equation. The economic identity is the net trade equation which is equal to excess supply or demand in the domestic economy. For some products the number of behavioral equations may change, as the total demand is disaggregated into food, feed, processing industry demand, and are determined endogenously. The functional form and variable specification of each equation is explained in the following sections separately.

4.1 Domestic Supply

In the LTEM framework a uniform aggregate domestic supply function is used for each commodity and country, which is specified as a function of own- and cross-prices. Colman (1983) refers to this type of agricultural supply response function, whose theoretical underpinnings are of an *ad hoc* nature, as directly estimated partial supply response models. An agricultural commodity is assumed to be produced in a single farm, and the agricultural sector is therefore treated as a single multi-product farm producing under perfect competition and producers are assumed price takers in the domestic market. The conditions that allow this exact aggregation are given in Moschini (1989). The Cobb-Douglas (CD) constant elasticity functional form is specified at the level of the variables to reflect the domestic supply response with respect to various prices. In the LTEM framework, the interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities.

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

$$qS_{it} = \alpha_0 PP_{it}^{\alpha_1} \prod_j PP_{jt}^{\alpha_j} ; \quad \alpha_1 > 0, \alpha_j < 0 \quad 1$$

Livestock Products

Meat: Beef and Veal, Sheepmeat, Pig Meat

$$qS_{it} = \alpha_0 PP_{it}^{\alpha_1} \prod_j \prod_k PP_{jt}^{\alpha_j} PC_{kt}^{\alpha_k} ; \quad \alpha_1 > 0, \alpha_j < 0, \alpha_k < 0 \quad 2$$

Dairy: Raw Milk

$$qS_{it} = \alpha_0 PP_{it}^{\alpha_1} \prod_j \prod_k PP_{jt}^{\alpha_j} PC_{kt}^{\alpha_k} ; \quad \alpha_1 > 0, \alpha_j < 0, \alpha_k < 0 \quad 3$$

Dairy: Liquid Milk, Butter, Cheese, Whole Milk Powder, Skim Milk Powder

$$qS_{it} = \alpha_0 PP_{it}^{\alpha_1} qS_{RMt}^{\alpha_{RM}} \prod_j PP_{jt}^{\alpha_j} ; \quad \alpha_1 > 0, \alpha_{RM} > 0, \alpha_j < 0 \quad 4$$

⁶ There are 126 equations for each country and in total there are 2142 equations.

$$qs_{it} = \alpha_0 pp_{it}^{\alpha_1} \prod_j \prod_k pp_{jt}^{\alpha_j} pc_{kt}^{\alpha_k}; \quad \alpha_1 > 0, \alpha_j < 0, \alpha_k < 0 \quad 5$$

Variables and Parameters:

- i*: own commodity
- j*: substitutes
- k*: feed products
- qs*: domestic supply
- pp*: producer price
- pc*: consumer price

In the LTEM, the dairy sector supply and demand response is modelled explicitly, as opposed to the two other main approaches used to model this sector⁷. Explicit modelling is essential as the sector is under the effect of various domestic and border policies in the world markets. In addition, full exhaustion of the domestic supply of raw milk into various demand categories is also another challenge of modeling exercises, which is overcome by explicit modelling in the LTEM.

4.2 Domestic Demand

A uniform CD type aggregate domestic demand function is used in the LTEM framework for each commodity and country. The behavioural relationship is assumed to be derived from the consumer's utility maximization problem (at an *ad hoc* nature) acting under perfect competition. Therefore, demand is specified as a function of own- and substitute prices, per capita income and population growth rate. The variables per capita income and population are exogenous to the model. The interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities.

Crops

Wheat and Coarse Grains

$$qd_{i,for} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop_t^{\beta_3} \prod_j pc_{jt}^{\beta_j}; \quad \beta_1 < 0, \beta_2 > 0, \beta_3 > 0, \beta_j > 0 \quad 6$$

$$qd_{i,ret} = \beta_0 pc_{it}^{\beta_1} \prod_j \prod_q pc_{jt}^{\beta_j} qs_{qt}^{\beta_q}; \quad \beta_1 < 0, \beta_j > 0, \beta_q > 0 \quad 7$$

Oils and Oilseeds

$$qd_{i,for} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop_t^{\beta_3} \prod_j pc_{jt}^{\beta_j}; \quad \beta_1 < 0, \beta_2 > 0, \beta_3 > 0, \beta_j > 0 \quad 8$$

$$qd_{i,ret} = \beta_0 pc_{it}^{\beta_1} \prod_j \prod_q pc_{jt}^{\beta_j} qs_{qt}^{\beta_q}; \quad \beta_1 < 0, \beta_j > 0, \beta_q > 0 \quad 9$$

$$qd_{OS,prt} = \beta_0 pc_{OS,t}^{\beta_{OS}} \prod_r pp_{rt}^{\beta_r}; \quad \beta_{OS} < 0, \beta_r > 0 \quad 10$$

⁷ The first and more traditional approach deals with dairy products in terms of raw milk equivalents. Various components of the raw milk produce a variety of dairy products when combined in different proportions. The second approach allocates raw milk to various product categories such as fluid milk, cheese etc. in a hierarchical fashion and the rest and left over is then assumed to be processed for butter and skim milk powder production (Lariviere and Meilke, 1999).

Sugar and Rice

$$qd_{i,for} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop_t^{\beta_3}; \quad \beta_1 < 0, \beta_2 > 0, \beta_3 > 0 \quad 11$$

Livestock Products

Meat: Beef and Veal, Sheepmeat, Pig Meat

$$qd_{it} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop^{\beta_3} \prod_j pc_{jt}^{\beta_j}; \quad \beta_1 < 0, \beta_2 > 0, \beta_3 > 0, \beta_j > 0 \quad 12$$

Dairy: Liquid Milk, Butter, Cheese, Skim Milk Powder, Whole Milk Powder

$$qd_{it} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop^{\beta_3} \prod_j pc_{jt}^{\beta_j}; \quad \beta_1 < 0, \beta_2 > 0, \beta_3 > 0, \beta_j > 0 \quad 13$$

Poultry: Eggs, Poultry Meat

$$qd_{it} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop^{\beta_3} \prod_j pc_{jt}^{\beta_j}; \quad \beta_1 < 0, \beta_2 > 0, \beta_3 > 0, \beta_j > 0 \quad 14$$

Variables and Parameters:

- i*: own commodity
- j*: substitutes
- pc*: consumer price
- pinc*: per capita income
- pop*: population
- ppr*: producer price of oilmeals and oil
- qdf_{fe}*: domestic feed demand
- qdf_{fo}*: domestic food demand
- qd_{OS}*: domestic processing demand for oilseeds
- qs_q*: domestic supply of meat, poultry products and raw milk

4.3 Stocks

The stocks are explicitly modelled in the LTEM framework by using inventory demand theory (FAPRI, 1989). The main determinant of the stock demand is the transaction motive, which responds to the quantity of production or consumption, rather than speculative motives.

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

Livestock Products

Meat, Dairy, Poultry

$$qe_{it} = \varphi_0 qs_{it}^{\varphi_1}; \quad \varphi_1 > 0 \quad 15$$

$$qe_{it} = \varphi_i qd_{it}^{\varphi_1}; \quad \varphi_1 > 0 \quad 16$$

Variables and Parameters:

- i*: own commodity
- qd*: domestic demand (can be food, feed or processing)
- qe*: stocks
- qs*: domestic supply

In these equations φ_l represents the elasticity of stock demand with respect to quantity of supply and demand respectively. There is no stock demand for raw and liquid milk. It is assumed that raw milk is stocked in the form of butter, cheese and/or milk powder.

4.4 Net Trade

The net trade function for a commodity and country is defined as an economic identity which accounts for the difference between domestic supply and the sum of various demand amounts and stocks. Stocks are incorporated as a change from the previous year, Δqe_{mi} , therefore they are the difference between ending stocks at time $t-1$ (which is the beginning stocks at time t) and estimated stocks at time t . (which is the ending stocks at time t).

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

Livestock Products

Meat, Dairy, Poultry

$$qt_{it} = qs_{it} - (qd_{i,fof} + qd_{i,fet} + qd_{i,prt}) - (\Delta qe_{it}) \quad 17$$

Variables and Parameters:

- i*: own commodity
- j*: substitutes
- pc*: consumer price
- pinc*: per capita income
- pop*: population
- ppr*: producer price of oilmeals and oil
- qdf_e*: domestic feed demand
- qdf_o*: domestic food demand
- qd_{os}*: domestic processing demand for oilseeds
- qs_q*: domestic supply of meat, poultry products and raw milk

The produced raw milk is assumed to be completely used in the production of other dairy products and therefore not traded.

4.5 Prices

The domestic producer and consumer prices in the LTEM are determined by the trade prices of the related commodity and country, domestic and border policies that affect domestic prices and transportation costs. Equations 19 and 20 illustrate this price transmission mechanism which consists of protection, tp_i and tc_i , and stabilization $(Wdp_i/ex)^{\varepsilon_\tau}$ components (Tyers and Anderson, 1988). The trade price of a commodity in a country is determined by the world market price of that commodity, equation 18, in which the variable ex is the nominal exchange rate and the parameter ε_τ shows the price transmission elasticity. The price transmission elasticity shows how much a change in world prices is transmitted to the domestic market, the effect of which is referred to as stabilization component. If a country for example is applying a fixed-price policy for a certain commodity, then ε_τ takes the value of 0, or alternatively if there is a completely free market policy, then ε_τ equals 1. When there are no policy measures that affect domestic prices (protection component is 0) and under the assumptions of no transportation costs and homogenous, perfectly substitutable products then

the domestic producer and consumer prices are determined by the stabilization component and defined as in equations 19 and 20.

Various producer and consumer support and subsidy measures can also be incorporated in the protection component of the price transmission mechanism through the use of commodity based price wedge variables which differentiate the domestic and trade price of the commodity. These measures include per unit direct payments, inputs subsidies, general services expenditures and other market subsidy payments to the producers and consumer market subsidy, equations 21 and 22. Each of these policy instruments are calculated as per tones of production or consumption, as was previously introduced with the of producer and consumer subsidy equivalent (PSE and CSE) variables methodology (Cahill and Legg, 1990).

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

Livestock Products

Meat, Dairy, Poultry

$$pt_{it} = \left(\frac{WDP_{it}}{ex} \right)^{\epsilon_{\tau}} \quad 18$$

$$pp_{it} = pt_{it} + tp_{it} + tc_t ; \quad tc = 0 \quad 19$$

$$pc_{it} = pt_{it} + tc_{it} + tc_t ; \quad tc = 0 \quad 20$$

$$pp_{it} = (pt_{it} + tp_{it} + sd_{it} + si_{it} + sg_{it} + sm_{it}) \quad 21$$

$$pc_{it} = pt_{it} + tc_{it} + cm_{it} \quad 22$$

Variables and Parameters:

- i*: own commodity
- cm*: consumer market subsidy
- ex*: exchanger ate
- pc*: consumer price
- pp*: producer price
- pt*: trade price
- sd*: direct payments
- sg*: general services expenditure
- si*: input subsidy
- sm*: other producer market subsidy
- tc_i*: export subsidy
- tc*: transportation costs
- tp_i*: import tariffs
- WDP*: world price

Chapter 5

Introducing Policy Variables

5.1 Introduction

Various unilateral and bilateral agricultural and border policies can be simulated through the LTEM with some modifications to behavioral equations. The unilateral domestic and border policy changes are incorporated in the LTEM via two channels. The first channel is through the supply function which allows the simulation of direct supply-related policies such as: production quotas, land set-aside policy and acreage reduction. The second channel is the price formation equations which allow the simulation of various per unit border policies and a minimum price policy, as well as various per unit producer and consumer support and subsidy measures. In general, any policy measure that creates directly a per unit wedge between domestic and trade prices can be incorporated through the price functions. Bilateral policies such as preferential access, including trade quotas and in- and out-quota tariff rates can also be incorporated in the LTEM through modifications to the supply, price and net trade equations of the two countries. Policy instruments used in the LTEM framework are listed in Table 1 and are grouped into unilateral and bilateral policy measures.

Table 5
Policy Variables and Parameters

<i>Unilateral Policies</i>	<i>Bilateral Policies</i>
Land set-aside	Preferential access
Production quota	Trade quota
Minimum price	In-quota tariff
Producer market subsidy	Out-quota tariff
Producer input subsidies	
Producer direct payments	
Producer general services	
Consumer market subsidy	
Import tariff	
Export subsidy	

5.2 Unilateral Policies

Minimum Price

Minimum price policy applied in the domestic market is incorporated again in the solution procedure. The producer price function is respecified here as in equation 4 by adding a MAX function. With this method the minimum price level (mp_{it}) becomes binding if the calculated equilibrium pp_{it} is less than the mp_{it} and the model is pushed to choose mp_{it} as the solution value. If the calculated equilibrium pp_{it} is greater than the mp_{it} , then the model chooses the calculated pp_{it} as the solution price level.

$$pp_{it} = \text{MAX}((pt_{it} + tc_i), mp_{it}) ; \quad tc_i = 0 \quad 4$$

Output and Input Related Subsidies/Support Expenditures

Various producer and consumer support and subsidy measures are incorporated in the price transmission mechanism through the use of commodity based price wedge variables which

differentiate the domestic and trade price of the commodity. These measures include direct payments (sd_{it}), inputs subsidies (si_{it}), general services expenditures (sg_{it}) and other market subsidy payments (sm_{it}) to the producers and consumer market subsidy (cm_{it}). Each of these policy instruments are calculated as per tonne of production or consumption, as it was first described with the methodology of producer and consumer subsidy equivalent (PSE and CSE) variables (Cahill and Legg, 1990).

$$\begin{aligned} pp_{it} &= \text{MAX}((pt_{it} + tc_i + sd_{it} + si_{it} + sg_{it} + sm_{it}), mp_{it}); & tc_i &= 0 & 5 \\ pc_{it} &= pt_{it} + tc_i + cm_{it}; & tc_i &= 0 & 6 \end{aligned}$$

Border Measures: Import Tariffs and Export Subsidies

Border policies such as per unit import tariffs and export subsidies are incorporated in the price transmission mechanism through the use of commodity based price wedge variables, tp_{it} and tc_{it} , which differentiate the domestic and trade price of the commodity.

$$\begin{aligned} pp_{it} &= \text{MAX}((pt_{it} + tc_i + sd_{it} + si_{it} + sg_{it} + sm_{it} + tp_{it}), mp_{it}); & tc_i &= 0 & 7 \\ pc_{it} &= pt_{it} + tc_i + cm_{it} + tc_{it}; & tc_i &= 0 & 8 \end{aligned}$$

Land Set-Aside Policy

The changes in, for example, the pasture and grazed areas or in the sown area are incorporated in the domestic supply equation by an exogenously determined shift factor, that is given the value 1 initially. The variable shf_{qs} proxies the supply side shift factors⁸, which is commonly used in partial equilibrium (PE) trade models such as GAP, GLS, SPEL, WATSIM⁹. When a policy that reduces the acreage, for example by 5 percent, is implemented, then the value of the shift factor is decreased by the same amount exogenously in order to simulate the upward shift in the supply curve.

$$qs_{it} = \alpha_0 shf_{qs}^1 pp_{it}^{\alpha_1} \prod_j pp_{jt}^{\alpha_j}; \quad \alpha_1 > 0, \alpha_j < 0 \quad shf_{qs} = 1 \text{ initially} \quad 1$$

$$qs_{it} = \alpha_0 (shf_{qs} - 0.05)^1 pp_{it}^{\alpha_1} \prod_j pp_{jt}^{\alpha_j}; \quad shf_{qs} = 1 - 0.05 = 0.95 \text{ with policy change} \quad 2$$

Production Quota

Production quotas are incorporated exogenously during the simulation procedure by using the MIN function. For example if production of a specific commodity in a country is limited with a maximum production quota amount, pq_{it} , then this quota amount can be introduced as a constraint in determining the equilibrium level of domestic supply during the mathematical solution procedure, as in equation 3. With this method the production quota amount becomes binding if the calculated equilibrium qs_{it} is greater than the pq_{it} , and the model is pushed to choose pq_{it} as the solution value. If the calculated equilibrium qs_{it} is less than pq_{it} then the model chooses the calculated qs_{it} as the solution amount.

$$qs_{it} = \text{MIN}((\alpha_0 (shf_{qs} - 0.05)^1 pp_{it}^{\alpha_1} \prod_j pp_{jt}^{\alpha_j}), pq_{it}) \quad 3$$

⁸ In a similar way, in order to analyse the effects of demand side shifters the demand function is respecified to include an exogenously determined shift factor which gets the value 1 initially. The variable shf_{qd} proxies the demand side shift factors which is commonly used in PE trade models such as GAP, GLS, SPEL, WATSIM.

⁹ See Salomon (1998a; b) for GAP, Tyers and Anderson (1986) for GLS, Henrichsmeyer (1990) for SPEL and Lampe (1998) for WATSIM models.

5.3 Bilateral Policies: Modelling Preferential Access Policy

Import Quotas

The original specification of the LTEM does not allow the measuring of the impact of any bilateral relationships between two countries therefore, the structure of the model is not appropriate to measure the impact of preferential access policies. In order to measure the impact of preferential access between any two countries, d and x , the equation sets of these two countries must be modified. If, for example it the aim is to quantify the impact of an import quota applied on commodity i by country d on the exporting country x then the specification of the net trade functions of d and x , (qt_{dit} and qt_{xit} , equations 9 and 10), and the producer price function of x (pp_{xit} , equation 11) for i has to be respecified. In addition, a weight (w_{di}) is constructed in order to measure the share of country d 's import quota (tq_{dit}) in x 's supply (qs_{xit}), equation 12. Accordingly, the tq_{dit} (assuming that x fills this quota) is removed from qt_{xit} and it is added to qt_{dit} (equations 9 and 10 respectively). This specification allows the trade impact of policy changes when a quota amount is removed from two countries' net trade amount to be measured. The producer price (pp_{xit}) impact in country x therefore becomes a weighted-average of d 's internal price (pp_{dit}) multiplied by the proportion of quota (w_{di}), since the quota amount administered by d is traded at d 's internal price, and x 's trade/world price (pt_{xit}), multiplied by the proportion of x 's exports to world market ($1 - w_{di}$), equation 13.

If the importing country has an in-quota tariff rate (tr_{dit}) policy applied on imports, then its effect on the exporting country x can be measured by subtracting tr_{dit} from pp_{dit} (equation 13).

$$qt_{xit} = qs_{xit} - tq_{dit} - qd_{xit} - \Delta qe_{xit} \quad 9$$

$$qt_{dit} = qs_{dit} + tq_{dit} - qd_{dit} - \Delta qe_{dit} \quad 10$$

$$pp_{xit} = [pt_{xit}(1 - w_{di}) + pp_{dit}w_{di}] \quad 11$$

$$w_{di} = \frac{tq_{dit}}{qs_{xit}} \quad 12$$

$$pp_{xit} = [pt_{xit}(1 - w_{di}) + (pp_{dit} - tr_{dit})w_{di}] \quad 13$$

Export Quotas

In this case country d is assumed to both subsidize its exports of i and at the same time apply quota on imports of i from country x . In addition, the country d is also allowed to export only a certain amount of i , therefore export quotas are also in place in d . In order to measure the effects of this complex preferential access policy structure, the equation set of country d has to be modified. Assuming d is a net exporter, these net exports (qt_{dit}) become a decision variable for the modelling framework between the total exportable (tb_{dit}) and subsidised export amounts, xq_{dit} (export quota). The solution algorithm is pushed to choose the minimum of these two amounts using the MIN function, equation 14. The tradable amount now includes d 's import quota amount given to x (tq_{dit}), as a result of the preferential access policy and one year lagged sink stock variable (qes_{dit}), equation 15. The policy applies such that when the solved exportable (tb_{dit}) amount is greater than the export quota (xq_{dit}), the model is pushed to export the xq_{dit} amount, and the difference between the tb_{dit} and the xq_{dit} goes into the sink stocks (qes_{dit}), which feed back into the next year's domestic supply amount through the use of tb_{dit} , equation 16. However, if the solved exportable amount is less than the export quota, then the model continues with the solved tb_{dit} amount.

$$qt_{dit} = MIN(tb_{dit}, xq_{dit}) \quad 14$$

$$tb_{dit} = qs_{dit} - qd_{dit} + tq_{dit} - \Delta qe_{dit} + qse_{dit-1} \quad 15$$

$$qse_{dit} = IF(tb_{dit} \leq xq_{dit}, 0, tb_{dit} - xq_{dit}) \quad 16$$

In- and Out- Quota-Tariff-Rate

The effects of the most favoured nation (MFN) tariff-rate-quota policy, applied by a country such as d to an exporter country such as x , are incorporated in the LTEM through the equations respecified in 18-21. The trade price (pt_{dit}) at the border is now determined as a function of the world price (WDP_{dit}) of the commodity and the applied tariff rate, which is based on the country's net trade position and on the difference between the net trade (qt_{dit}) and the MFN quota amounts. If the d becomes a net importer, and if net imports (qt_{dit}) happen to be larger than or equal to the MFN amount after a policy shock, then the applied tariff rate becomes a function of in- (itr_{dit}) and out-quota-tariff-rates (otr_{dit}), equation 18. The weights attributed to these different tariff rates are shown in equations 20 and 21. The share of the difference ($|qt_{dit}/MFN$) in $|qt_{dit}|$ is reflected as the weight (w_1) and multiplied by the out-quota-tariff-rate, otr_{dit} , if ($|qt_{dit}/MFN$) is larger than 0. The share of the rest of the trade is reflected by the w_2 and multiplied by the in-quota-tariff-rate, itr_{dit} , (in the case of $|qt_{dit}/MFN$ the applied tariff becomes $itr * w_2$ as w_1 goes to 0, equation 18). If d 's net imports are smaller than the MFN then the applied tariff becomes itr_{dit} , equation 18. Therefore if d is a net importer, (if qt_{dit} is larger than the MFN amount, the model calculates a new trade price, npt_{dit} , based on the applied tariff rate. However, during the simulations if d is a net exporter, then the trade price is calculated by using in-quota-tariff-rate, itr_{dit} , as given in equation 19.

$$npt_{dit} = WDP_{dit} + IF(|qt_{dit}| - MFN \geq 0, (w_1 * otr_{dit} + w_2 * itr_{dit}), itr_{dit}) \quad 18$$

$$pt_{dit} = WDP_i + IF(qt_{dit} > 0, itr_{dit}, npt_{it}) \quad 19$$

$$w_1 = \frac{(|qt_{dit}| - MFN)}{|qt_{dit}|} \quad 20$$

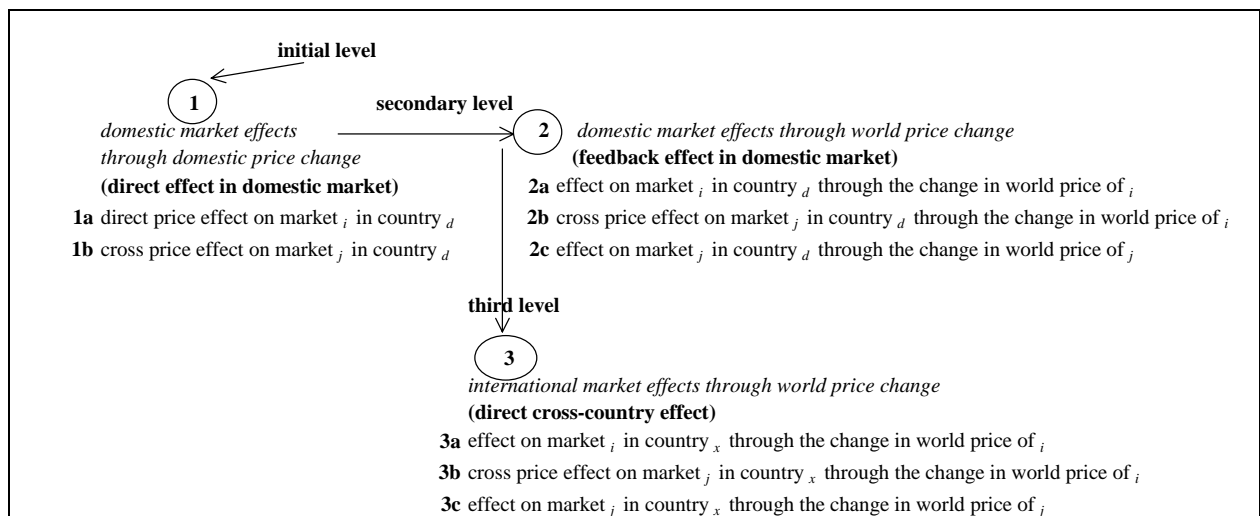
$$w_2 = 1 - w_1 \quad 21$$

Chapter 6

Model Interactions and Feedback Relations

In the LTEM an iterative simulation procedure is employed to find the equilibrium prices and quantities in the world market using Newton's Global (Search)¹⁰ non-linear optimisation algorithm. The simulation process allows the feedbacks into the own- (i) and cross-commodity (j) markets and both into domestic (d) and foreign (x) countries as long as the iterations continue, and the iteration process finishes when the algorithm finds market clearing prices that equalize excess demand and supply in the world market after a shift in a particular policy instrument. Therefore, in the LTEM the total impact of a policy change is seen in three different areas: the impact on the own-commodity (i) market in the domestic country (d)-direct domestic market effect-, the impact on the substitute/complementary commodities (j) in the domestic country (d)-feedback effect in the domestic country-, and the own- and cross-commodity impacts in the international markets (x)-direct cross-country effect. The policy impacts are transmitted through the shifts in domestic and world prices. These new prices then feed-back into the individual country markets to determine the impact on the domestic supply, demand, stock and net trade quantities. These policy effects are summarized as initial, secondary and third level effects in Figure 1.

Figure 1
Effects of a Directly Price Related Policy Change



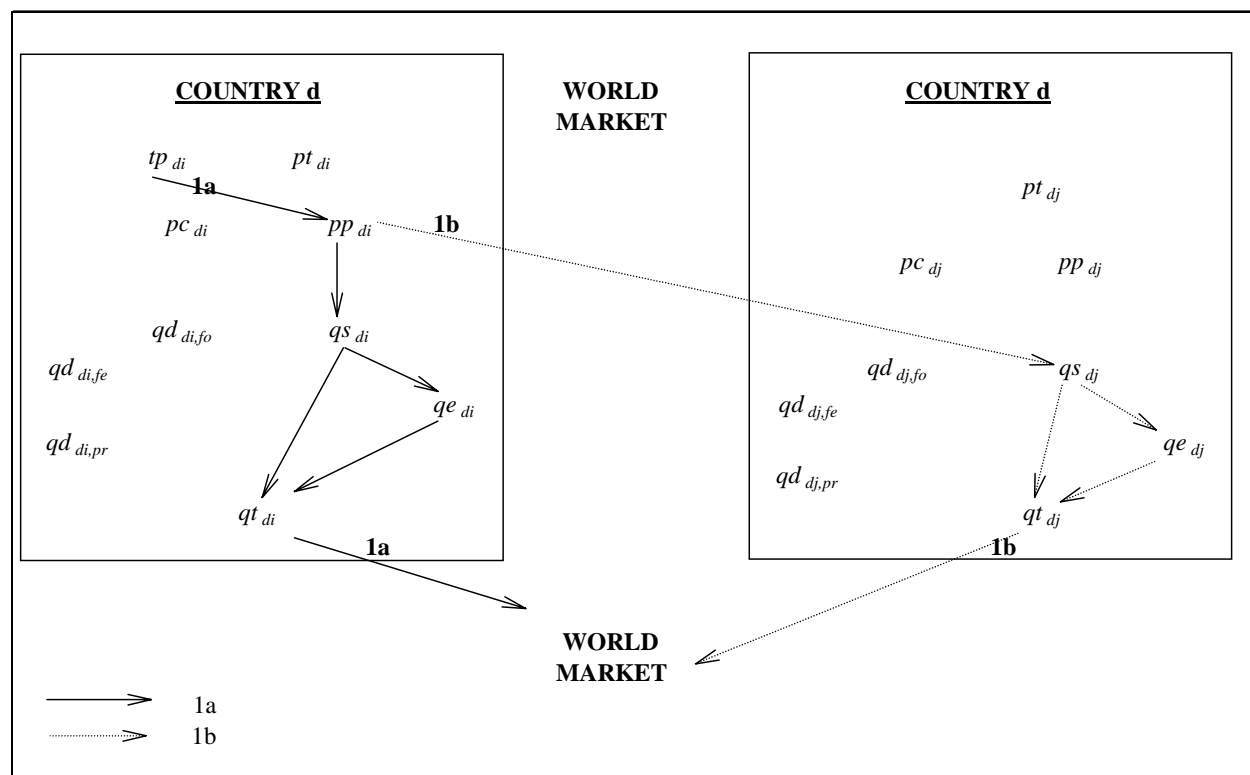
In this section the model interactions are demonstrated with flow charts, using the example of an increase in tariffs on imports of i to country d . It is assumed that there are only two commodities (i, j) which are gross substitutes and two countries (d, x). A trade policy change, an increase in the import tariff rate on imports of i in country d for example, results in shifts of the equilibrium price and quantities in both domestic (d) and international markets (x) as well as of the equilibrium price and quantities both in own (i) and cross commodities (j). The flow charts do not consider the cross-price feedback effects from market j to i neither in country d nor x . Also, flow charts ignore the feedback effects from country x to d .

¹⁰ See Fair (1984) p. 29, Kehoe (1991) p. 2058, and Wooldridge (2002) for more explanation on Newton's global algorithm.

6.1 Domestic Market Effects through Domestic Price Change

Figure 2 demonstrates the effects of an increase in tp_i in d through the change in domestic prices. The left side of the figure shows the own-price effect in country d (the effect 1a in Figure 1) while the right side presents the cross-price effect on market j (the effect 1b in Figure 1) through the change in domestic price of i .

Figure 2
Direct and Cross-Price Effects on Markets i and j in Country d

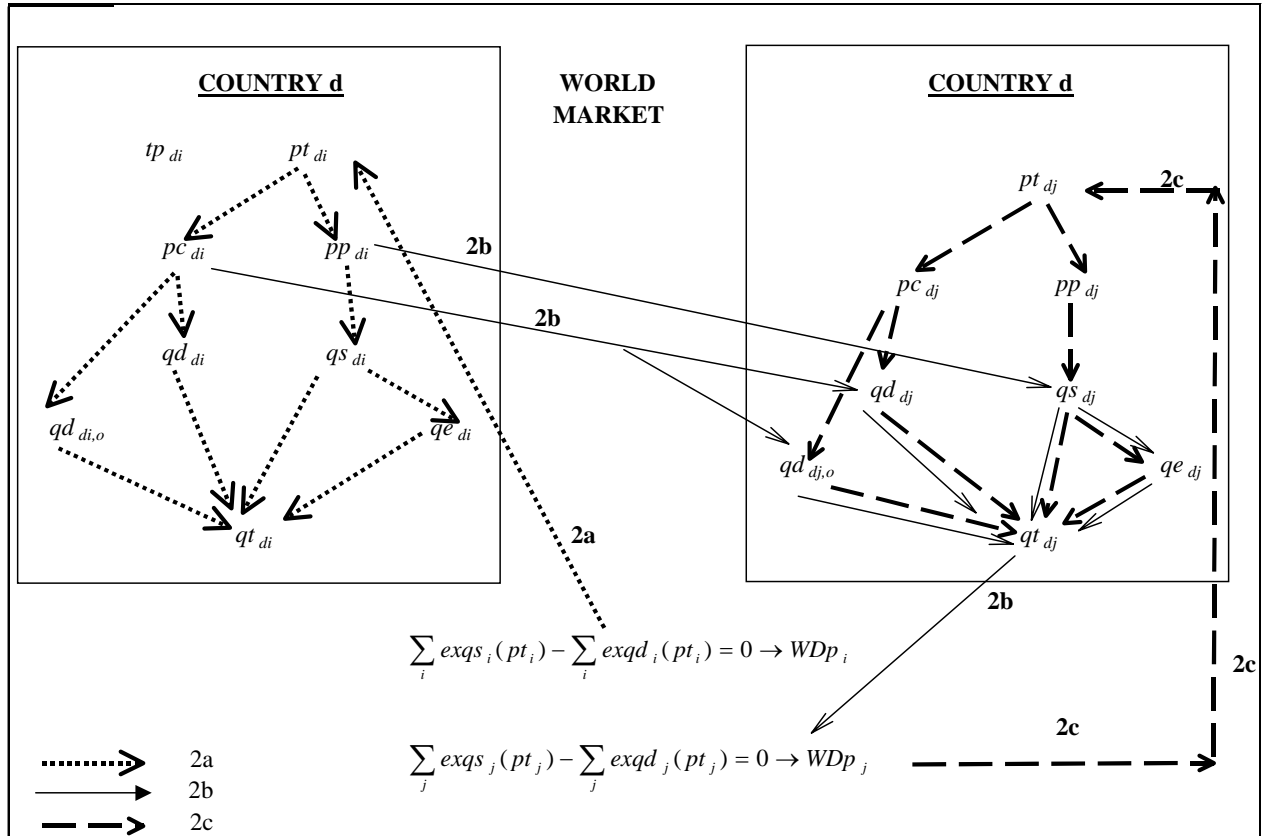


6.2 Domestic Market Effects through World Price Change

Once a change occurs in qt_{di} , as a result of the change in tp_{di} , world price of i (WDP_i) is also effected, as the excess supply/demand ($exqs_i/exqd_i$) amount that the country d provides to world markets changes. The new WDP_i is determined at the level that equilibrates the total excess demand and supply of i in the world market. In other words, the LTEM derives the new world market-clearing price, WDP_i , that makes the difference of total $exqs_i$ and $exqd_i$ zero by using a non-linear optimization algorithm (Newton's global or search algorithm).

Figure 3 demonstrates the effects of an increase in tp_{di} in d through the change in WDP_i . The new WDP_i has an effect on the trade price in d , pt_{di} , (policy effect 2a in Figure 1) and pt_{di} determines the producer (pp_{di}) and consumer (pc_{di}) price of i . Once the pp_{di} and pc_{di} feed back into other behavioural relationships in market i , the iterative process in this market stops. The changes in pp_{di} and pc_{di} also affect the demand and supply amount of j in d because of the cross-commodity relationships (policy effect 2b in Figure 1). The new qs_{dj} and qd_{dj} affects the amount of excess supply/demand that the country d provides to world market and a new world market-clearing price (WDP_j) is derived (end of iterative process for policy effect 2b). The new WDP_j feeds back into the market j 's trade price (policy effect 2c in Figure 1) and the iterative process for the policy effect 2c stops when the new pt_{dj} iterates to determine new qs_{dj} , qd_{dj} and qt_{dj} .

Figure 3
Direct and Cross-Price Effects on Markets i and j in Country d
through the Change in World Price of i ⁴

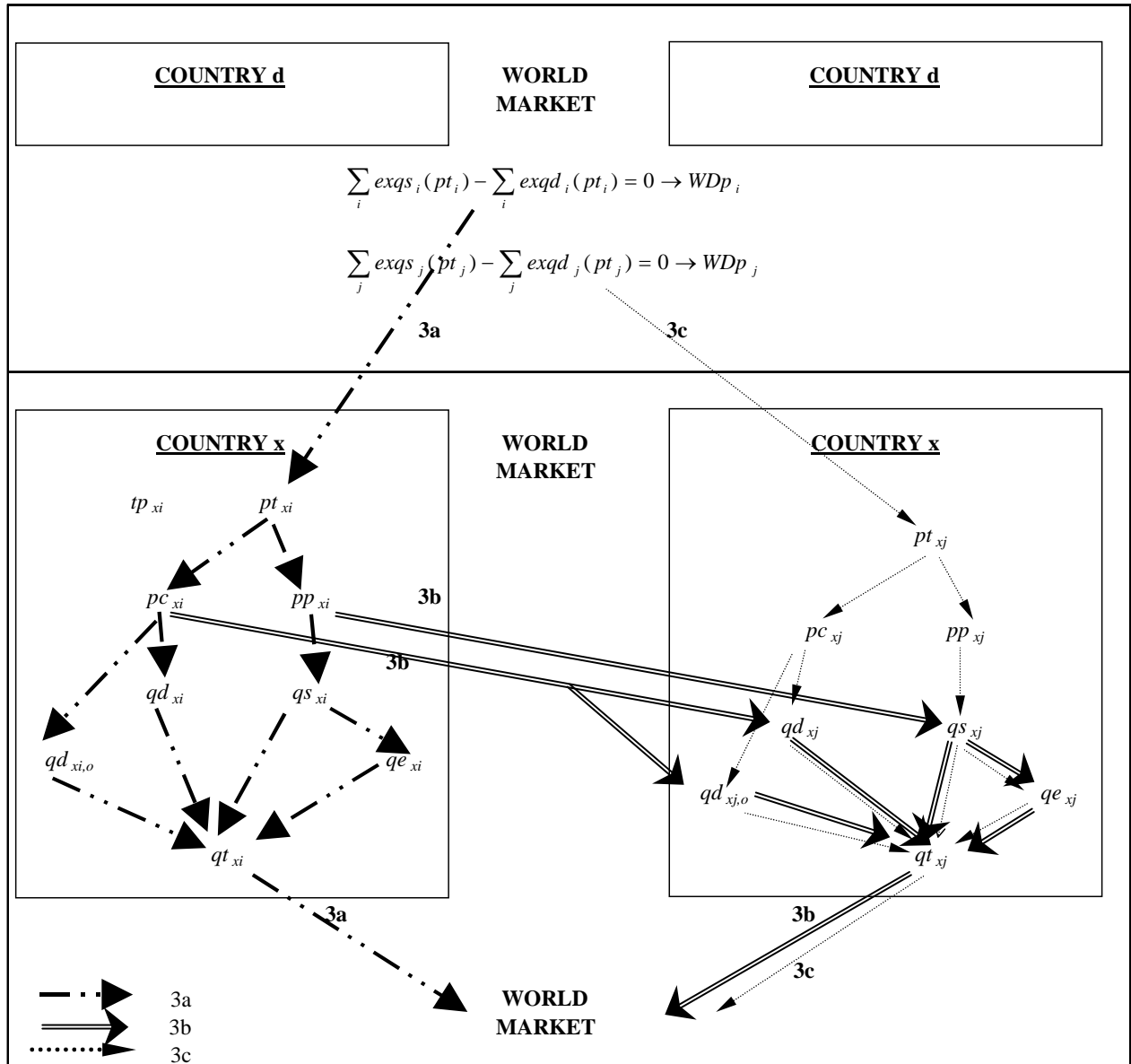


⁴: $qd_{di,o}$ represents demand types other than food demand.

6.3 International Market Effects through World Price Change

The international market effects of an increase in tp_{di} in d is presented in Figure 4. The new market-clearing WDP_i and WDP_j obtained after the trade policy shock in d , feed back into both markets i and j in country x . Therefore, direct and cross-price interactions occur between countries d and x and also between the markets i and j in x .

Figure 4
Direct and Cross-Price Effects on Markets i and j in Country x
through the Change in World Prices of i and j ⁵



⁵: $qd_{di,o}$ represents demand types other than food demand.

The purpose of this research report was to review agricultural trade modelling and to introduce the LTEM. In particular the report provides detail on the structure of the LTEM.

This provides, not least, information regarding the model but also a background paper for the applied studies which use LTEM.

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Appendix

Variables and Parameters:

i:	own commodity
j:	substitutes and complements
t:	time period
d:	domestic market
x:	international market
α_1 :	own-price elasticity of supply
α_j :	cross-price elasticity of supply
cm:	other market subsidies to consumers
itr _{dit} :	in-quota-tariff rate
mp:	minimum price
npt:	new trade price
otr _{dit} :	out-quota-tariff rate
pc:	consumer price
pp:	producer price
pq:	production quota
pt:	trade price
qd:	domestic demand
qe:	stocks
qs:	domestic supply
qse:	sink stocks
qt:	net trade
sd:	direct payments
sg:	general services expenditures
shf _{qs} :	supply shifter
si:	input subsidies
sm:	other market subsidies to producers
tb:	tradable amount
tc:	transportation cost
tc _{it} :	export subsidies
tp _{it} :	import tariffs
tq:	import quotas
tr _{dit} :	in-quota-tariff rate in d
w _{di} :	ratio of import quotas in d over domestic supply in x
w ₁ :	share of difference of net trade and MFN in net trade
xq:	export quotas

Annex I

Table A1: Supply Side Parameters: Own- and Cross-Price Elasticities

Country		Producer Price						Consumer Price			
<i>Commodity</i>		<i>Beef</i>	<i>Pig Meat</i>	<i>Sheep</i>	<i>Wool</i>	<i>Poultry</i>	<i>Raw Milk</i>	<i>Wheat</i>	<i>Coarse Grains</i>	<i>Oil Seeds</i>	<i>Oilseed Meal</i>
<i>Beef</i>	<i>Australia</i>	0.70	-0.03	-0.08	-0.15	-0.01	-0.05	-0.07	-0.09	0.00	-0.02
	<i>EU (15)</i>	0.52	-0.07				0.15	-0.11	-0.19	0.00	-0.1
	<i>New Zealand</i>	0.45	-0.02	-0.06	-0.06		0.20	-0.02	-0.24	0.00	-0.04
	<i>USA</i>	0.60	-0.04				0.05	-0.02	-0.31	-0.01	-0.07
<i>Sheep</i>	<i>Australia</i>	-0.33		0.66	-0.01		-0.05				
	<i>EU (15)</i>			0.4			-0.03	-0.09	-0.05	0.00	-0.03
	<i>New Zealand</i>	-0.06	0.00	0.80	0.10			-0.04	-0.52	-0.01	-0.07
	<i>USA</i>			0.6	0.01			-0.04	-0.12	-0.04	-0.21
Country		Producer Price						Consumer Price			
<i>Commodity</i>		<i>Wheat</i>	<i>Coarse Grains</i>	<i>Oil Seeds</i>	<i>Oilseed Meal</i>	<i>Rice</i>	<i>Sugar</i>	<i>Wheat</i>	<i>Coarse Grains</i>	<i>Oil Seeds</i>	<i>Oilseed Meal</i>
<i>Wheat</i>	<i>Australia</i>	0.80	-0.05	0.00		-0.01		0.80	-0.05	-0.01	-0.02
	<i>EU (15)</i>	0.55	-0.10	-0.02			-0.01	0.55	-0.01	-0.1	-0.02
	<i>New Zealand</i>	0.80	-0.15					0.80	-0.15		
	<i>USA</i>	0.70	-0.10	-0.04				0.70	-0.10	-0.01	-0.04
<i>Sugar</i>	<i>Australia</i>	-0.05	-0.01				0.50	-0.05	-0.01	0.50	
	<i>EU (15)</i>	-0.01	-0.01				0.35	-0.01	0.35		
	<i>New Zealand</i>										
	<i>USA</i>	-0.03					0.44	-0.03		0.44	

Table A1: Supply Side Parameters: Own- and Cross-Price Elasticities

Country Commodity	Producer Price				Consumer Price			
	Raw Milk	Beef and Veal	Sheepmeat	Wool	Wheat	Coarse Grains	Oil Seeds	Oil Meals
<i>Raw Milk</i>								
Australia	0.50	-0.04	-0.01	-0.01	-0.10	-0.13		-0.02
EU (15)	0.50	0.11			-0.11	-0.20		-0.09
New Zealand	0.80	0.06			-0.04	-0.52	-0.01	-0.09
USA	0.40	0.05			-0.01	-0.19	-0.01	-0.04
Country Commodity	Producer Price							
	Liquid Milk	Raw Milk	Butter	Cheese	Skim Milk P.	Whole Milk P.		
<i>Liquid Milk</i>								
Australia	0.50	-0.17	-0.03	-0.05	-0.03	-0.02		
EU (15)	0.50	-0.12	-0.05	-0.10	-0.01	-0.02		
New Zealand	0.50	-0.06	-0.08	-0.07		-0.08		
USA	0.30	-0.04	-0.01	-0.03	-0.01			
<i>Butter</i>								
Australia	-0.07	-0.24	0.80	-0.40	0.30	-0.19		
EU (15)	-0.07	-0.23	0.59	-0.12	0.06	-0.03		
New Zealand	-0.01	-0.03	0.15		0.10			
USA	-0.07	-0.25	0.74	-0.29	0.10	-0.03		
<i>Cheese</i>								
Australia	-0.04	0.07	-0.12	0.44	-0.15			
EU (15)	-0.03	0.01	-0.03	0.29	-0.01	-0.02		
New Zealand	-0.01	0.05	-0.01	0.17				
USA	-0.02	0.06	-0.03	0.26	-0.04	-0.02		
<i>Skim Milk Powder</i>								
Australia	-0.07	-0.24	0.80	-0.40	0.30	-0.19		
EU (15)	-0.07	-0.23	0.59	-0.12	0.06	-0.03		
New Zealand	-0.01	-0.03	0.15		0.10			
USA	-0.07	-0.25	0.74	-0.29	0.10	-0.03		
<i>Whole Milk Powder</i>								
Australia	-0.08	-0.30	-0.25	-0.02	-0.07	0.91		
EU (15)	-0.14	-0.32	-0.12	-0.40		1.18		
New Zealand	-0.01	0.06				0.16		
USA	-0.22		-0.31	-1.54		2.29		

Annex II

Table A2: Demand Side Parameters: Own-, Cross Price and Income Elasticities

<i>Country</i> <i>Commodity</i>	Consumer Price							Income
	Beef	Sheep	Pig Meat	Poultry Meat	Eggs	Butter	Cheese	
<i>Beef</i>								
<i>Australia</i>	-0.78	0.03	0.10	0.02	0.01		0.01	0.18
<i>EU (15)</i>	-0.7	0.01	0.15	0.02	0.00	0.01	0.03	0.20
<i>New Zealand</i>	-0.60	0.15	0.08	0.02	0.01			0.14
<i>USA</i>	-0.70		0.05	0.03		0.00	0.01	0.16
<i>Sheep</i>								
<i>Australia</i>	-0.78	0.03	0.10	0.02	0.01		0.01	0.05
<i>EU (15)</i>	-0.7	0.01	0.15	0.02	0.00	0.01	0.03	0.20
<i>New Zealand</i>	-0.60	0.15	0.08	0.02	0.01			0.14
<i>USA</i>	-0.70		0.05	0.03		0.00	0.01	0.13
<i>Wheat</i>	Wheat	Rice	Pig Meat	Coarse Grains				
<i>Australia</i>	-0.35			0.02				-0.10
<i>EU (15)</i>	-0.37	0.01	-0.37	0.07				-0.10
<i>New Zealand</i>	-0.24			0.04				-0.07
<i>USA</i>	-0.27			0.07				-0.18
<i>Sugar</i>								
<i>Australia</i>				-0.25				0.11
<i>EU (15)</i>				-0.50				0.12
<i>New Zealand</i>				-0.20				0.19
<i>USA</i>	0.03			-0.50				0.04

Table A2: Demand Side Parameters: Own-, Cross-Price and Income Elasticities

<i>Commodity</i>	<i>Country</i>	<i>Consumer Price</i>					<i>Income</i>
		<i>Liquid Milk</i>	<i>Butter</i>	<i>Cheese</i>	<i>Skim Milk P.</i>	<i>Whole Milk P.</i>	
<i>Liquid Milk</i>							
	<i>Australia</i>	-0.23				0.01	-0.03
	<i>AEU(15)</i>	-0.50			0.01		0.05
	<i>New Zealand</i>	-0.20					0.09
	<i>USA</i>	-0.30	0.01	0.02	0.01		-0.01
<i>Butter</i>							
	<i>Australia</i>		-0.45	0.05	0.01		0.24
	<i>EU(15)</i>		-0.48	0.05	0.01		0.30
	<i>New Zealand</i>		-0.45	0.01			0.19
	<i>USA</i>	0.06	-0.70	0.01	0.01		0.10
<i>Cheese</i>							
	<i>Australia</i>		0.01	-0.40			0.31
	<i>EU(15)</i>		0.01	-0.45			0.35
	<i>New Zealand</i>		0.01	-0.45			0.42
	<i>USA</i>	0.01		-0.55			0.40
<i>Skim Milk Powder</i>							
	<i>Australia</i>	0.02	0.01		-0.45	0.04	-0.04
	<i>EU(15)</i>	0.02	0.03	0.02	-0.40	0.03	0.30
	<i>New Zealand</i>				-0.40		0.18
	<i>USA</i>	0.03	0.01	0.03	-0.55	0.01	0.35
<i>Whole Milk Powder</i>							
	<i>Australia</i>	0.07			0.05	-0.45	-0.04
	<i>EU(15)</i>	0.01		0.04	0.10	-0.50	0.30
	<i>New Zealand</i>	0.05			0.02	-0.45	0.18
	<i>USA</i>	0.08			0.15	-0.70	0.38

Table A3: Macroeconomic and Non-Agricultural Data of the Major Markets-1997

	<i>Gross Domestic Product</i>	<i>Consumer Price Index</i>	<i>Population</i>
<i>Australia</i>	100	100	18454
<i>EU</i>	100	100	373710
<i>NZ</i>	100	100	3686
<i>USA</i>	100	100	267938