Report to

MINISTRY FOR THE ENVIRONMENT

APPENDIX 7
TO

ECONOMIC RISKS AND OPPORTUNITIES FROM THE RELEASE OF GENETICALLY MODIFIED ORGANISMS IN NEW ZEALAND

LTEM Model details

The LTEM model

In this section of the research, a partial equilibrium (PE) model, the LTEM (Lincoln Trade and Environment Model), is used to quantify the price, supply, demand and net trade effects of various policy and non-policy induced shocks. The LTEM is an agricultural multi-country, multi-commodity trade model. It is based upon VORSIM[i] which has evolved from SWOPSIM and associated trade-database used to conduct analyses during the Uruguay Round (Roningen, 1986; Roningen et al., 1991). The LTEM is modified in this study to quantify the global and regional effects of farmers' adopting GM technology in production, consumers' preference changes in relation to GM products and policy induced shocks on imports of GM products.

Although a PE framework uses a "standard approach" to model international trade policy, analysts tend to prefer PE frameworks in quantifying the effects of domestic agricultural and trade policy measures based on factors such as the level of commodity disaggregation, ease of traceability of the interactions, transparency of the results, relatively small size of the models, the number of behavioral parameters and the methods used to obtain those parameters (Francois and Hall, 1997; Roningen, 1997; Gaisford and Kerr, 2000; Beers and Bergh, 1996)[ii].

There are 9 countries and 14 agricultural commodities included in the model (see Appendix Table A1 for the list of these countries and commodities). The commodities included in the model are treated as homogenous with respect to country of origin and destination. Therefore commodities are perfect substitutes in consumption in international markets, and importers and exporters are assumed to be indifferent about their trade partners. Based on these the model is built as a non-spatial type which emphasizes the net trade of commodities in each region. However, the supply and demand shares of countries in trade can be traced down.

The LTEM is a synthetic model as the parameters are adopted from the literature. The interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities. The policy parameters and/or variables are listed in Appendix Table A2. The economic welfare implications of policy changes can also be calculated in the LTEM using the producer and consumer surplus measures. The model is used to derive the medium- to long-term (till 2010) policy impact in a comparative static fashion, basing the beginning date to 1997. The model provides short-run solutions as well, since it applies a sequential simulation procedure year by year in which the stock change is used to link two consecutive years.

In general there are six behavioural 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 country[iii]. There are four exogenously determined variables[iv], but the number of exogenous variables in the structural-form equation set for a commodity vary based on the cross-price, cross-commodity relationships. The behavioral equations are domestic supply, demand, stocks, domestic producer and consumer price functions and the 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 behavioral equations and parameters related to these commodities and quantification of domestic agricultural and trade policies are described in more detail in Cagatay and Saunders 2003.

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 using a non-linear optimization algorithm (Newton's global or search algorithm[V]).

Behavioral Specifics and Incorporation of Policy Shocks to the Main LTEM Structure

The sectoral focus of this study is dairy, meat, fruits and grains. Here the LTEM is explained using the dairy and fruit sectors as examples. This is followed by an explanation of the grains sector using maize as the example.

In dairy sector models a major challenge is to exhaust the domestic supply of raw milk that can be consumed in various forms (Lariviere and Meilke, 1999). In the applied literature there are two main approaches used to model dairy sector supply and demand. The first and more traditional approach deals with dairy products in terms of raw milk equivalents. Various components of raw milk produce a variety of dairy products when combined in different proportions. This constant raw milk equivalents approach, although inaccurate in some cases, can be useful, since dairy products are assumed to be homogenous in most of the international dairy models. However, lack of data on some fresh dairy products sometimes may result in aggregation of these categories into one single category, fluid milk, which is treated as a nontradable good (Lariviere and Meilke, 1999). 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. Although this allocation mechanism is consistent with the dairy policies in most of the major markets, market conditions such as changing relative prices and product based domestic and border polices do not play any role in the allocation mechanism except by assumption. This approach also lacks information about marginal production costs since a supply curve is not estimated (Lariviere and Meilke, 1999). As the dairy markets are under the effect of various domestic and border policies a third approach, explicit modelling of dairy sector supply and demand –which is the approach taken here-, becomes essential in modelling the various policy impacts as well as the full exhaustion of the domestic supply of raw milk into various demand categories.

Domestic Supply. In the LTEM framework, a uniform Cobb-Douglas (CD) constant elasticity functional form is specified at the level of the variables to reflect the aggregate domestic supply response of each commodity in each country with respect to the own-and cross-prices. Colman (1983) refers to this type of agricultural supply response function, whose theoretical underpinnings are of an *ad hoc* nature (assumed to be derived from producers' profit maximization problem), as directly estimated partial supply response models. An agricultural commodity is assumed to be produced in a single farm and therefore the agricultural sector is 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 dairy sector is modeled 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 domestic supply (*qs*) function for raw milk (qs_{mi}) is shown in equation A1. In equation A1, the subscript $_m$ stands for the country, $_i$ represents raw milk and $_j$ represents substitute commodities such as beef and veal, and $_k$ represents feed products such as wheat, coarse grain and oil meals. The variables *pp* and *pc* represent the producer and consumer price level respectively. Therefore, domestic supply of raw milk is specified as a function of producer price for raw milk, beef, and consumer prices of feed inputs. Domestic supply is assumed to adjust simultaneously to price changes. The own-price elasticity of supply is illustrated by the exponent $?_{ii}$ and is positive. The cross-price supply elasticity with respect to beef price ($^{?\,ij}$) and feed products ($^{?\,ik}$) are negative, as raw milk and beef are assumed to be gross substitutes, and feed products are the production inputs.

The domestic supply of dairy products (liquid milk, butter, cheese, skim and whole milk powder) is determined based on the raw milk production (qs_{mi}) which reflects the physical constraint on processed dairy production, and producer prices of various dairy products. For example, in equation A2, domestic supply of liquid milk (qs_{ml}) is specified as a function of qs_{mi}, producer price of liquid milk (pp_{ml}) and producer prices of other dairy products (pp_{mh}). The exponentials $?_{li}$, $?_{ll}$ and $?_{lh}$ show the supply elasticity of liquid milk with respect to raw milk production, producer price of liquid milk and producer prices of other dairy products respectively. The supply side parameters used in the LTEM are presented in Appendix Table A3.

$$qs_{mi} = a_{i0}\, pp_{mi}^{\;a_{ii}}\, pp_{mj}^{\;a_{ij}} \prod_k pc_{mk}^{\;a_{ik}} \;; \qquad a_{ii} > 0,\; a_{ij} < 0,\; a_{ik} < 0 \qquad \text{A1}$$

$$qs_{ml} = b_{l0}\, qs_{mi}^{\;b_{li}}\, pp_{ml}^{\;b_{ll}} \prod_h pp_{mh}^{\;b_{lh}} \;; \qquad b_{li} > 0,\; b_{ll} > 0,\; b_{lh} < 0 \qquad \text{A2}$$

$_h$: *butter, cheese, skim and whole milk powder*
$_i$: *raw milk*
$_j$: *beef and veal*
$_k$: *feed crops*
$_l$: *liquid milk*

A common approach used to model supply response in the fruit sector is to model acreage and yield separately (Marzouk, 1972; Roosen, 1999). While price expectations are used to model acreage, current year's price and climate conditions are used generally to determine the yield. The approach used to model domestic supply in the fruit sector in the LTEM focuses on the allocation of apples and kiwifruit between fresh and processing use, so focuses on the fresh yield. A CD function is used to model the supply in these sectors and is specified as a function of current year's price and a trend which proxies the technological advances such as better cultivation technique, better care etc, equation A3. Because the emphasis is not on the acreage decision of farmers no lags in prices (expectations) are included as explanatory variables (Voorthuizen et al., 2002).

$$qs_{ma,k} = g_{a,k0}\, pp_{ma,k}^{\;g_{a,k}}\, tr_t \,; \qquad a_{a,k} > 0 \qquad \text{A3}$$

$_{a,k}$: *apples and kiwifruit*

In order to analyse the effects of the production quota in the dairy sector, the supply function is respecified to include an exogenously determined policy variable that constraints the total domestic production at the maximum quota level, equation A4. The production quota, pq_{mi}, becomes a decision variable for the solution algorithm, which becomes binding if the calculated equilibrium quantity in the mathematical solution procedure is greater than or equal to this quota amount. A mathematical MIN function integrated to the supply equation is used for this purpose. With this method the production quota amount becomes binding if the calculated equilibrium qs_{mi} is greater than the pq_{mi}, and the model is pushed to choose pq_{mi} as the solution value. If the calculated equilibrium qs_{mi} is less than the pq_{mi}, then the model continues with the calculated qs_{mi} as the solution amount.

$$qs_{mi} = MIN((a_{i0}\, shf_{qs}^{\;1}\, pp_{mi}^{\;a_{ii}}\, pp_{mj}^{\;a_{ij}} \prod_k pc_{mk}^{\;a_{ik}}),\, pq_{mi}) \qquad \text{A4}$$

The variable shf_{qs}, in equation A4, proxies the supply side shift factors, and is commonly used in PE trade models such as GAP (Salomon, 1998a; 1998b), GLS (Tyers and Anderson, 1986), SPEL (Henrichsmeyer, 1990), WATSIM (Lampe, 1998). This is used in most modelling exercises to simulate the effects of land set-aside policy (although not active in this study) by shifting the supply curve downward/upward by changing it exogenously at the determined policy level from 1.

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. Domestic demand is assumed to adjust simultaneously to price changes. The variables per capita income and population are exogenous to the model, and the interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities.

As the produced raw milk is consumed and exhausted in various forms of dairy products, the domestic demand for raw milk is not modelled in the LTEM, instead the demands for dairy products are modeled endogenously at the country level. The aggregate domestic demand relationship for dairy products is given by equation A5[vi]. In this equation domestic demand for liquid milk, qd_{ml} is defined as a function of consumer prices of the own *(pc_{ml})*, substitute and complementary commodities *(pc_{mh})*, per capita income *($pinc_m$)* and population growth rate *(pop_m)*. The exponents reflect the related elasticities. The cross-price demand elasticity (? $_{lh}$) with respect to prices of other raw milk products is positive, since these products are assumed to be gross substitutes with liquid milk. The elasticity of demand with respect to income (? $_{l2}$) and population growth (? $_{l3}$) is also expected to be positive. In order to analyse the effects of demand side shifters other than income and population growth, the demand function is respecified to include an exogenously determined shift factor (shf_{qm}) which is given the value 1 initially, equation 6.

$$qd_{ml} = d_{l0} shf_{qm}{}^{1} pc_{ml}{}^{d_{ll}} pinc_m{}^{d_{l2}} pop_m{}^{d_{l3}} \prod_h pc_{mh}{}^{d_{lh}} ; \quad d_{l1} < 0 ,\ d_{l2} > 0 ,\ d_{l3} > 0 ,\ d_{lh} > 0$$

A5

The demand for apple and kiwifruit is modeled at final consumption level, which covers fresh fruit production only. The demand is specified as a function of own-price, per capita income and population growth.

Stocks. The stocks are explicitly modelled in the LTEM framework based upon the inventory demand theory (FAPRI, 1989). The determinants of the stock demand are the transaction and speculative motives, which respond to the quantity of production or consumption, and to the consumer prices. In the dairy market it is assumed that raw milk is stocked in the form of butter, cheese and skim milk powder. The behavioral equation for stock demand is given as in equation A6. In this equation ? $_{h1}$ represents the elasticity of stock demand with respect to the quantity of supply, and is assumed to be positive. The coefficient ? $_{h2}$ represents the consumer price elasticity of the stock and is expected to be negative. In the LTEM stocks are not modeled in apple and kiwifruit markets.

$$qe_{mh} = j_{h0} qs_{mh}{}^{j_{h1}} pc_{mh}{}^{j_{h2}} ; \qquad j_{h1} > 0 ,\ j_{h2} < 0$$

A6

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 change from the previous year, ? qe_m, therefore it is 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 $_t$). Since it is assumed that all produced raw milk is utilized in the form of processed products, raw milk is not traded. The net trade identity for the liquid milk and fruit sector is given in equation A7, and other dairy products are presented in equation A8.

$$qt_{ml} = qs_{ml} - qd_{ml}$$
A7

$$qt_{mh} = qs_{mh} - qd_{mh} - \Delta qe_{mh}$$
A8

Prices. The domestic producer (pp_m) and consumer prices (pc_m) in the LTEM are determined by the trade price (pt_m) of the related commodity and country border policies that affect domestic prices (tp_m and tc_m) and transportation costs (tc), which are assumed to be zero. Equations A10 and A11 present this price transmission mechanism, which consists of protection, $tp_{mh,l}$ and $tc_{mh,l}$, and stabilization $(WDp_{h,l}/ex_m)^{? ?}$ components (Tyers and Anderson, 1986), for all the products in the LTEM framework. The trade price of a commodity in a country is determined by the world market price of that commodity, equation A9. The variable ex_m is the nominal exchange rate and the parameter $?_?$ shows the price transmission elasticity. The price transmission elasticity shows how much a change in world prices is transmitted to the domestic market, of which the effect is referred to as the stabilization component. If a country for example is applying a fixed-price policy for a certain commodity then $?_?$ takes the value of 0, or instead if there is a completely free market policy then $?_?$ equals 1. Border policies such as per unit import tariffs (or taxes) and export subsidies and taxes are incorporated in the price transmission mechanism through the use of commodity based price wedge variables, $tp_{mh,l}$ and $tc_{mh,l}$, which differentiate the domestic and trade price of the commodity. When there are no border 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 A10 and A11.

$$pt_{mh,l} = \left(\frac{WDp_{h,l}}{ex_m} \right)^{e_t}$$
A9

$$pp_{mh,l} = pt_{mh,l} + tp_{mh,l} + tc = \left(\frac{WDp_{h,l}}{ex_m} \right)^{e_t} + 0 + 0$$
A10

$$pc_{mh,l} = pt_{mh,l} + tc_{mh,l} + tc = \left(\frac{WDp_{h,l}}{ex_m} \right)^{e_t} + 0 + 0$$
A11

In the LTEM, various domestic producer and consumer support and subsidy measures in the dairy market are incorporated in the price transmission mechanism as ad-valorem distortions[vii] which form a price wedge between domestic and world prices. These measures include direct payments ($sd_{mh,l}$), input subsidies ($si_{mh,l}$), general services expenditures ($sg_{mh,l}$), and other market subsidy payments ($sm_{mh,l}$) to the producers, and a consumer market subsidy ($cm_{mh,l}$). Equations A12 and A13 show the $pp_{mh,l}$ and $pc_{mh,l}$

which are extended with ad-valorem domestic and border policy measures in which *tc* is assumed to be zero. Thus all quantifiable policies affecting dairy prices are included in the equations above.

$$pp_{mh,i} = pt_{mh,i} + tp_{mh,i} + tc + sd_{mi} + si_{mi} + sg_{mi} + sm_{mi}$$

A12

$$pc_{mh,i} = pt_{mh,i} + tc_{mh,i} + tc + cm_{mh,i}$$

A13

The intervention price in the dairy markets is incorporated in the LTEM in the solution procedure through the mathematical MAX function. In the new producer price function, which is respecified in equation A14, the intervention price, $mp_{mh,,l}$, becomes a decision variable and becomes binding if the calculated equilibrium $pp_{mh,l}$ is less than the $mp_{mh,l}$. When $pp_{mh,l}$ is less than $mp_{mh,l}$ the model is pushed to choose $mp_{mh,l}$ as the solution value. If the calculated equilibrium $pp_{mh,l}$ is higher than the $mp_{mh,l}$, then the model continues with the calculated $pp_{mh,l}$ as the solution price level.

$$pp_{mh,i} = MAX((pt_{mh,i} + tp_{mh,i} + tc + sd_{mi} + si_{mi} + sg_{mi} + sm_{mi}), mp_{mh,l}) \; ; \qquad tc=0$$

A14

A productivity change, such as an increase in the productivity of maize in a GM adopting country, is reflected through the exogenous change in the shift variable (shf_{qsg}) which is equal to 1 initially. If for example, a 10 percent increase in the production of maize is assumed as a result of a reduction in the use of factors of production, then the shifter becomes equal to 1.00 + 0.10 = 1.10, and causes a parallel downwards shift in the supply curve. As a result, a decrease in the price of GM-maize is expected because of the excess supply created in the domestic market, and this lower price feeds back into the supply function of GM-free maize, as GM and GM-free components are substitutes.

$$qsg_i = a_0 shf_{qsg}\, ppg_i^{a_1}\, pp_i^{a_2} \prod_{j=1}^{2} ppg_j^{a_j}$$

1

The demand for GM grains (oilseeds, maize, wheat and coarsr grains) in the LTEM is disaggregated into feed and food demand. The feed demand for GM maize (for example) is specified as a function of own consumer price, consumer price of GM-free maize, consumer prices of the other substitute GM feed products, and the supply amount of GM raw milk (-subscript *k* is used to denote raw milk). The food demand for GM maize is specified as a function of own consumer price, consumer price of the GM-free maize, consumer prices of the other GM substitutes, per capita real income and population. Similar functional forms and behavioral relationships are also used to reflect the feed and food demand response for GM-free maize, in which the consumer price for GM-maize also appears as a substitute product in consumption to GM-free maize.

Table A1: Country and Commodity[1] Coverage

Countries	*Commodities*	
Argentina-AR	Wheat	Raw milk
Australia-AU	Coarse grains	Liquid milk
Canada-CA	Maize	Butter
European Union (15)-EU	Oilseeds	Cheese
Japan-JP	Oilseed meals	Whole milk powder
Mexico-MX	Oils	Skim milk powder
New Zealand-NZ	Apples	Beef
United States of America-USA	Kiwifruit	Sheepmeat
Rest of World-RW		

[1]: Each commodity is included as GM and GM-free components.

Table A2: Policy Variables/Parameters and Non-Agricultural Exogenous Variables in the Main LTEM Framework

Policy Variables-Domestic Market	*Policy Variables-Border*	*Non-Agricultural Exogenous Variables*
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		
Producer general services		
Consumer market subsidy		

[i] See http://members.aol.com/vorecon/vorsim.html.
[ii] In addition, the ability to include agricultural input markets endogenously and to treat commodities as imperfect substitutes (in other words to include bilateral trade relationships) with some effort may make PE frameworks more attractive.
[iii] There are 126 equations for each country and in total there are 2142 equations.
[iv] The list of non-agricultural exogenous variables are given in Table A2.
[v] See Fair (1984) p. 29, Kehoe (1991) p. 2058, and Wooldridge (2002) for more explanation on Newton's global algorithm.
[vi] The demand for other dairy products (qd_{mh}) other than liquid milk is specified by using the same functional form and the same behavioural relationships that are in qd_{ml}.
[vii] As introduced in the methodology of producer and consumer subsidy equivalent (PSE and CSE) measures, Cahill and Legg (1990).