ABSTRACT

This paper presents preliminary findings of an analysis using a version of the Global Trade Analysis Project (GTAP) model that has been modified by the OECD Secretariat to incorporate key features of the OECD's Policy Evaluation Model (PEM).

The most recent version of the GTAP[1] model is taken as the starting point from which refinements to the agricultural supply side are added. First the production technology has been significantly improved to include a new land allocation system developed in the most recent version of the PEM. Second, a more realistic production technology is introduced that models substitution between farm-owned and purchased inputs. These modifications are crucial to fully exploit the information in the PSE database. Third, factors of production are segmented between agricultural and non-agricultural uses. Finally, to ensure consistency with the PEM, the revised model has been validated by calculating the relative impact of various agricultural policies.

2. INTRODUCTION

Policy reform simulations in a sector as complex as agriculture often require a variety of different models. Consistency between the different approaches is important. The assumptions about economic behavior should be transparent and similar in spirit across the different models. The focus of this paper will be on the way OECD agricultural policies are represented in GTAP. This is important to preserve consistency relative to existing PEM analysis, in particular with respect to the issue of decoupling.

This analysis builds on previous work by Hertel and Keeney (2003) that incorporates model refinements to the agriculture sectors in GTAP. Our specific contribution is a more complete representation of agricultural land markets. Specifically, the heterogeneity of agricultural land will be modeled using a structure similar to that found in the PEM. This is a necessary requirement if we are to analyze agricultural policy reform that shifts emphasis from commodity specific policies to those that target more broadly defined categories of commodities. This issue is at the heart of debate on "decoupling". Agricultural policies in some OECD countries contain instruments that are less targeted at specific products through output market interventions, but are instead based on the idea that the farmer should receive a direct income support with minimal impact on his production decisions. In practice, this is achieved through payments linked to land holdings (and animal head).

Decoupled payments are considered to be eligible for inclusion in the green box. However this is currently being discussed in trade negotiations under the auspicies of the Doha Development Agenda (DDA). Area payments, such as the EU single farm payment, are considered by some policy makers to be decoupled. In contrast, commodity specific programs, such as cotton support in the US which was found illegal by a recent WTO panel ruling, are under international pressure for reform because they are considered to be significantly production and trade distorting. Clearly the evaluation of output- and trade effects of re-instrumentation hinges crucially on the supply response to the policy changes. Farmer's land allocation decisions occupy center stage in this question.

[1] GTAP model version 6.2, September 2003.

3. POLICY EVALUATION MODEL (PEM)

The Policy Evaluation Model (PEM) is a partial equilibrium model of crop and dairy markets. It provides a stylised version of existing and hypothetical agricultural policies in participating OECD countries[2]. The results provide useful information to policy makers about the *relative* effects of market price support and various kinds of budgetary payments. The sensitivity of the results to assumptions about the elasticity values or price responsiveness of supply and demand for inputs have been analysed in detail and also provide important information for policy makers. The main purpose of the PEM is to provide a closer connection between measurement of support as defined for the Producer Support Estimate (PSE) and quantitative analysis of the impacts and distribution of such support.

A partial equilibrium model of the farm sector elaborated in Gardner (1987) provided the basic analytical structure for the PEM crop and milk models. First developed by Hicks to study issues in labour economics, the model has been widely applied in general economic policy analysis. An important precedent to its application in agricultural policy analysis was in an analysis of housing and urban land economics by Muth. The development of the model for analysis of agricultural price supports is generally credited to Floyd. Its application for the PEM follows most closely applications found in Atwood and Helmers (1998), Gunter *et al.* (1996), and in Hertel (1989).

The type of analysis undertaken using this modelling framework has become known more generally as 'equilibrium displacement modelling' (Salhofer and Sinabell, Piggott, Cahill). In this framework, commodity supply is usually represented in terms of an aggregate production function and the associated factor demand and factor supply functions. Commodity demand and supply equations typically relate quantities and prices at the farm level, although several of the applications in the literature involve modelling sector-wide policy and market linkages (Alston). Normally, the functional relationships in the model are approximated with equations linear in elasticities and percentage changes in quantities and prices.

In constructing the PEM, three main sets of assumptions were required: 1) those relating to the basic structure of supply and demand response, 2) those relating to the underlying data and the elasticities, and 3) those relating to the primary incidence of support measures on prices and quantities.

The basic framework was developed in a pilot study carried out by a work group including representatives from the OECD Secretariat and representatives from each included region as well as other interested member countries. This working group made use of consultants who provided estimates of important model parameters through a systematic review of relevant studies available in the academic literature. This working group also relied on important contributions from the Ministries of participating countries, who provided significant information and analysis in all parts of the model development process.

The PEM provides a stylised version of existing and hypothetical policies for selected OECD countries. The results provide useful information to policy makers about the *relative* effects of market price support and various kinds of budgetary payments. This permits conclusions to be drawn about the relative marginal impacts on the selected indicators such as production, trade, price, and farm income.

[2] Participants review results of their own country module, and provide data and/or parameters. Current participants include Canada, the European Union (15), Japan, Mexico, Switzerland, and the United States.

4. INCORPORATING PEM INTO GTAP

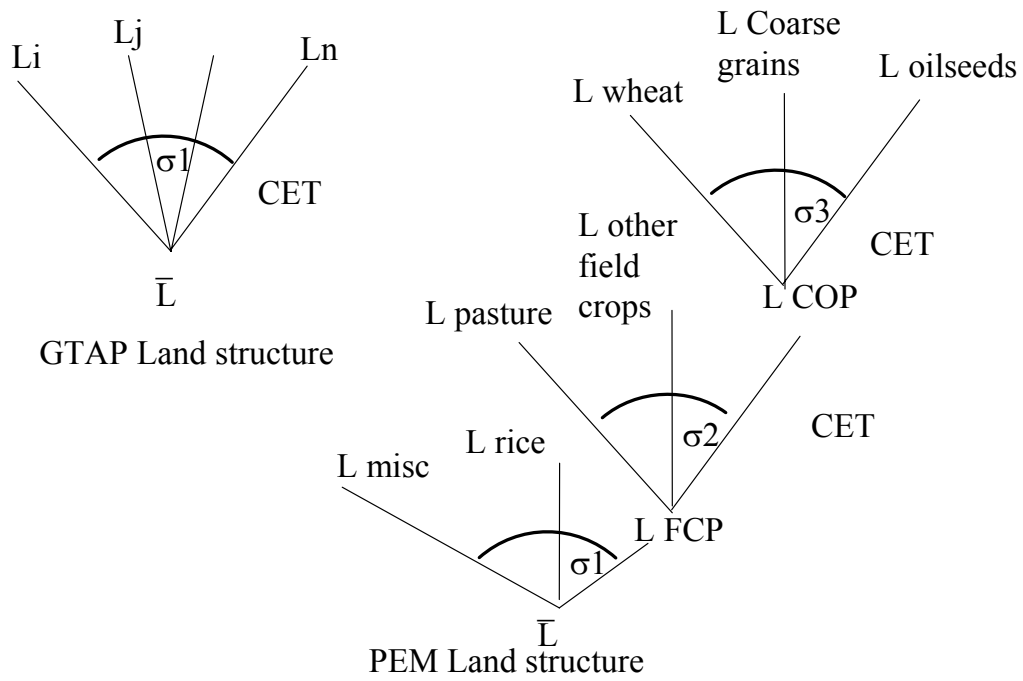
The standard version of GTAP represents land allocation that assumes various types of land are imperfectly substitutable[3]. That is, land is imperfectly mobile across alternative uses. PEM has a similar structure but with more detail. Implementing this structure of land allocation into GTAP is motivated by the need to more accurately model land use decisions, and to be consistent with the supply response in PEM.

The revised model (which we will refer to as GTAPEM) covers several types of land more or less suited to various crops. The crops include wheat, coarse grains, oilseeds, rice and other agricultural uses. The transformability of land between different uses is an empirical question. The parameters used in the PEM model were derived from consultant reports (Abler 2000, and Salhofer 2000) produced during the pilot phase of model development. These reports provided best estimates and acceptable ranges of estimates for own and cross-price elasticity of demand based on a review of the literature. Appendix A outlines the procedure used to incorporate these elasticities into the GTAPEM.

4.1 Land Allocation System

PEM distinguishes different types of land in a nested 3-level CET structure[4]. The difference can be seen in Fig.1, where the GTAP structure is on the left and PEM is on the right.

Figure 1- Land Allocation Tree for Standard GTAP and PEM



The lowest nest assumes a constant elasticity of transformation between 'Miscellaneous agricultural land' (vegetables, orchards etc.), 'Rice' and the group 'Field crops and pastures' (FCP). The transformation is governed by the elasticity of transformation σ_1. The FCP group

[3] Note that GTAP allows for non-agricultural land uses as well as agricultural land use. PEM is strictly confined to agricultural land. See Appendix for full description.

[4] This is a relatively recent feature of PEM. Earlier versions had a 2-level structure.

is itself a CET aggregate of Pastureland, the group 'Cereal, Oilseed and Protein cropland' (COP) and other field crops that (cotton). Here the elasticity of transformation is σ_2. Finally, the transformation of land within the upper nest, the COP group, is modelled with an elasticity σ_3.

In this way the degree of substitutability of types of land can be varied between the nests. It captures to some extent agronomic features. In general it is assumed that $\sigma_3 > \sigma_2 > \sigma_1$. This means that it is relatively easier to change the allocation of land within the Cereal, Oilseed and Protein group, while it is more difficult to move land out of this group into a lower nest, such as into vegetables.

4.2 Factor Substitution

A theoretically sound model of producer behaviour is essential for analysing the impact of policy changes. One of the key innovations of the PEM over other PE models is a detailed representation of factor markets – farm owned primary factors (land, labour, capital) and purchased intermediate inputs – and the ability to directly model the impact of various PSE categories of support.

Factor demand in the standard GTAP model is modelled as a two level process. Primary factors are a CES aggregate of labor, capital, land and natural resources which are combined in fixed proportions with intermediate inputs (Leontief). That is, there is no substitution between intermediate inputs and primary factors of production, while substitution between primary factors is possible. This assumption, common in many computable general equilibrium models, is often used because it reduces considerably the number of parameters required. However, in the context of this analysis, this assumption is too unrealistic. For example, farmers have shown considerable potential for altering the rate of chemical fertilizer in response to changes in the relative price of fertilizer to land.

In GTAPEM, substitutability between purchased farm input intermediates, and between the aggregate intermediates and farm-owned inputs is explicitly modelled. The parameters are calibrated to elasticities of substitution taken from the PEM model (Hertel and Keeney 2003).

5. SEGMENTED FACTOR MARKETS: AGRICULTURE/NON-AGRICULTURE

If labour were perfectly mobile across domestic sectors, we would observe equalized wages throughout the economy for workers with comparable endowments. This is clearly not supported by evidence. Wage differentials between agriculture and non-agriculture can be sustained in many countries (especially developing countries) through limited off-farm labour migration (Harris, Todaro 1970). Returns to assets invested in agriculture also tend to diverge from returns to investment in other activities.

To capture these stylized facts, we incorporate segmented factor markets for labour and capital by specifying a CET structure that transforms agricultural labour (and capital) into non-agricultural labour (and capital). This specification, already introduced into a special version of GTAP by Hertel and Keeney (2003), has the advantage that it can be calibrated to available estimates of agricultural labour supply response.

We separate market-clearing conditions for agriculture and non-agriculture and thus have separate market prices for each of these sets of endowments. The economy-wide endowment of labour (and capital) remains fixed, so that any increase in supply of labour to manufacturing has to be withdrawn from agriculture, and the economy-wide resources constraint remains satisfied. The parameters of this function are calibrated to fit estimates of

the elasticity of labour supply reported in OECD (2001). The same procedure is applied to capital.

6. MODEL VALIDATION

A key objective in this analysis is to integrate into GTAP the capacity to model agricultural policy in a manner consistent with the OECD's Policy Evaluation Model (PEM). Therefore, model validation is necessary in order to evaluate the extent to which this goal has been achieved. In addition, a comparison will be made with the standard version of GTAP.

6.1 Comparing GTAPEM and PEM

This section first describes the process of model validation used in the PEM. This is followed by a summary of some results obtained when the same principles are applied to the revised GTAPEM model.

Several factors influence the degree to which production levels respond to changes in policy. It has been observed that different countries will have different output responses to changes in market price support. In PEM, the reasons for these differences can be due to differences in:

i) elasticity of supply,
ii) other elasticities in the model, especially the elasticity of export demand, and
iii) initial level of support.

One way to control for these 'country effects' is to use a reference category of support to compare only relative effects of the various support measures across countries. Market price support[5] is chosen as the reference support category for this purpose. Although this procedure does not completely eliminate all the country effects it does help focus attention on differences that are of more immediate interest.

The relative impacts of different policies (impact ratios) are calculated using a compensating expenditure approach. That is, the indicator of interest is constrained to be constant in the model while the expenditure level of a particular policy is reduced by a nominal amount. Market price support expenditure (the numeraire) is the endogenous variable that adjusts so that the constraint on the indicator holds. For example, if reducing payments based on historical entitlements by USD 100 million reduces farm welfare by USD 90 million, how much market price support must then be added to increase farm welfare by 90 million? Suppose the answer is USD 200 million. The impact ratio is then USD 200 million/USD 100 million = 2, indicating that historical entitlements are 2 times as effective in transferring welfare to producers than is market price support. This is, in essence, the same approach used by Cahill (1997) and Moro and Skokai (1998) in their studies on the relative effects of crop support measures for the European Union.

Comparable calculations have been performed with the amended GTAP model to test whether the two approaches provide similar responses to policy interventions. The calculations with

[5] OECD indicator of the annual monetary value of gross transfers from consumers and taxpayers to agricultural producers arising from policy measures creating a gap between domestic producer prices and reference (world) prices of a specific agricultural commodity, measured at the farm-gate level. In principle, this indicator should have a minimum value equal to border support as defined in the GTAP database, but may be larger due to other factors that hinder market access.

GTAP simulate for each of the six OECD focus countries in this study, and the aggregate rest of OECD region, a change in each of four policy instruments.

The policy change consists of a 10% reduction of the current ad valorem equivalent of support in 2001 for the following: i)border support, ii)output subsidies, iii)factor payments and iv)intermediate input subsidies. Each of these 28 simulations yields, amongst other things, a change in farm revenues (market revenues plus transfers from government) and a change in farm income. The ratio of the farm income calculation over the farm revenue calculation gives an income impact ratio for each of the policy instruments.

Table 1 reports the indicators thus obtained. The ranking of policy instruments is similar to the ranking obtained from PEM (OECD 2001). The most income efficient transfer is through payments linked to (farm-owned) factors of production, such as area payments. On average 90% of every unit of revenue increase through factor payments translates to additional farm income. In contrast, of the subsidies on intermediate inputs into farming only 20 percent ends up in the farmer's income. The remainder is lost to other agents, notably input suppliers.

Table 1- Range of income impact ratios GTAPEM

	max	min	average
Border support	0.6	0.3	0.4
Output support	0.5	0.2	0.3
Factor payments	1.0	0.8	0.9
Intermediate input	0.3	0.1	0.2

Note: defined as ratio of change of farm income to change of farm revenues inclusive of subsidy. Max and min values reflect country differences.

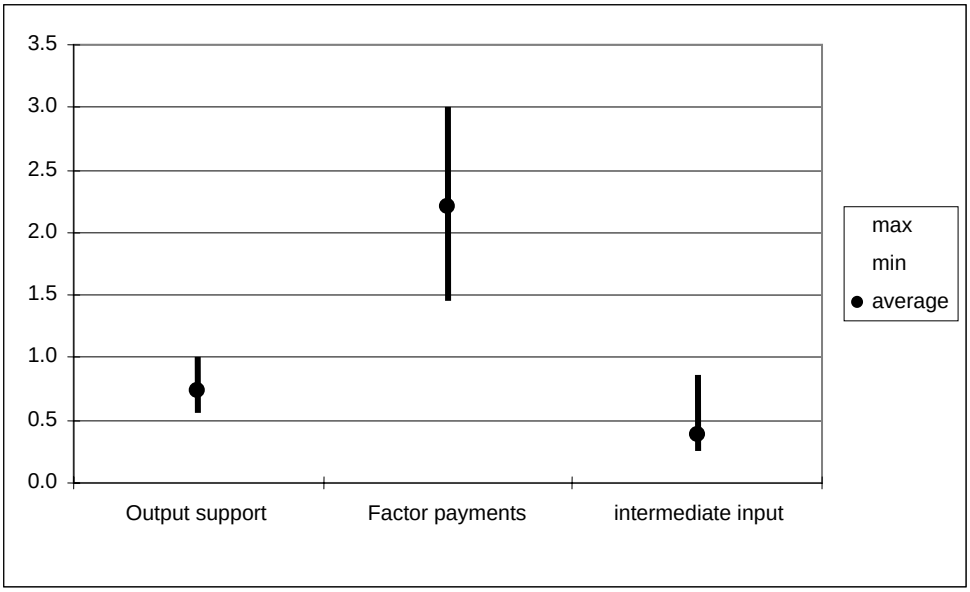
In some cases, there is considerable variability among countries. This reflects factors specific to each country as expressed in the original PEM parameters. These factors constitute the assumptions and "initial conditions" necessary to properly calibrate a model for policy simulation. The existence of this sort of variability may limit the generality of findings but should not be interpreted as a limitation of the underlying model. Indeed, it is precisely because there are measurable differences between countries in, for example, the initial level of support, that a simulation model may be helpful in quantifying relative effects of policy changes. That is to say, that to the degree that differences in estimated policy effects are due to objectively measurable differences among countries, our capacity to quantify them should be seen as source of richness in the model.

Tables 2 and Figure 2 present the same information, but normalized with respect to border support, and hence comparable to the figures presented in OECD (2001). Although there are some differences in the values of the ratio, the ranking of instruments is the same across the two models. Future work will include impact ratios for production, trade, and prices.

Table 2- Range of income impact ratios GTAPEM

	GTAP Ratio	PEM Ratio
Border support	numeraire	numeraire
Output support	0.75	1.34
Factor payments	2.25	2.24
Intermediate input	0.5	0.84

Figure 2 - Range of impact ratios GTAPEM, border support = 1.0



6.2 Comparing GTAPEM and GTAP

This section compares GTAPEM with the standard GTAP model. Since our main interest and our main contribution (compared to Hertel & Keeney, 2003) lies in the more refined modelling of land allocation we shall concentrate on the land market. To this end, we design two sets of simulation experiments, each of them simulated with the amended GTAPEM model and the standard GTAP model (version 6.2, September 2003). The database for the experiments is the pre-release 6.0_1 of the GTAP database (25 November 2003).[6]

The first experiment focuses on the effects of policy changes that directly act upon the rental price of land in the Cereals-Oilseeds-Protein complex (COP). Specifically, we reduce the price wedge that exists between the user (i.e. farmer) price of land and the market price of land.

The second experiment focuses on the output market, and reduces the price wedge between market prices and the producer prices of COP commodities in OECD countries. Hence, it reduces that portion of agricultural support that is fully coupled to production.

Before describing the experiments in detail, it will be useful to discuss the nature of the 'shocks' administered to the model, as this will help to understand the results. In each region the price linkage equation for land used in each (land-using activity) is:

$$P_{li}' = T_{li} * P_{li} \qquad (1)$$

Where P_{li} 'denotes the subsidy-inclusive price of land used in production activity *i*. This is the price that guides the farmer in and the land owner in his decisions on land allocation. The

[6] Since its circulation in November 2003, some significant areas for improvement of the agricultural trade protection data have been identified by the database developers. The version used here does not yet incorporate the changes that have been carried out since. However, the nature of our experiments (measuring relative rates of impact) is such that this does not greatly affect results.

price P_{li} denotes the market price of land in activity *i*, and T_{li} denotes the *power of the subsidy.* The power of the subsidy, (or tax) is defined as one plus the ad valorem rate of the subsidy τ_{li}. $T_{li} = (1 + \tau_{li})$. Hence, if T_{li} is less than one, we have a subsidy (the farmers sees a lower price that the market price) and if it exceeds one, we have a tax.

Using lower case letters to denote percent change, the above price linkage equation becomes in linearized form:

$$p_{li}' = t_{li} + p_{li} \qquad (2)$$

6.2a Land subsidy reduction

The experiment consists of reduction of the ad valorem rate of the subsidy on land used in COP activities by 10% in OECD countries only. The ad valorem equivalent of the area payments is quite substantial in some OECD member countries. In this case a 10% reduction of the rate of subsidy coincides with a very substantial reduction of the power of the subsidy, and direct price effects will be sizable. In addition, the price effects will vary across countries and crops, as the size of the initial subsidy differs. A simple example may illustrate this.

According to our database the ad valorem equivalent of all the subsidies given to wheat land in the EU equals 92%, while that in the USA equals 79%. Table 1 shows the size of the change of the power of the subsidy, i.e. the percent change t_{li} required to reduce the rate of the subsidy by 10%. It is evident that the 'shock' needed to effectuate that adjustment is quite large in both model regions. If the market price were constant in equation (2), which it is not, the EU wheat farmer would witness a direct increase of the price of land by more 115%, while the wheat farmer in the USA would face an increase of almost 40%. Hence, even if the reduction in the rate of the subsidy appears to be a modest 10%, we can expect substantial changes to the effective price land users face.

Of course, the market price of land is not constant, but adjusts to a new equilibrium value in response to the demand and supply forces. Exactly what portion of the shock will be fall on land users (farmers) and what portion will fall on land-owners depends on elasticities of demand and supply of land.

Table 3- Illustration of shock calculations

	subsidy rate %	Power	New subsidy rate % (10% reduction)	Required % shock to power	New power
	τ^o	T^0	τ^1	T	T^1
EU	-91.7	0.08	-82.5	110	0.17
USA	-79.4	0.21	-71.5	40	0.29

Land markets

Table 4 shows the difference of results between the GTAPEM and the GTAP model for the land subsidy reduction experiment. Drawing the attention to the bottom two rows of the table, we observe that the results for the average change of the (real) price of land are very comparable between the models. They are also of a substantial size, with drops of more than 30% in the EU, more than 10% in Canada and the USA and small changes in Japan, Mexico and the aggregate Rest of OECD.

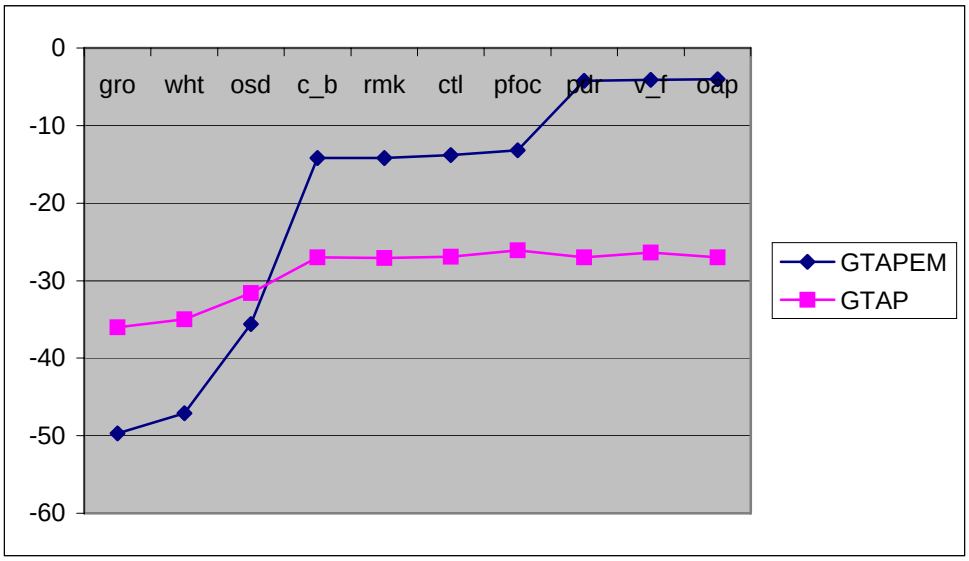
However, the distribution of effects across activities differs enormously. The GTAPEM apportions a relatively larger share of the fall in market pries to the land used in COP activities, as indicated by the negative signs in the rows for Wheat, Coarse grains and Oilseeds. Since the standard GTAP model does not take into account the limited reallocation of land between the broad groups of activities defined in our 'land tree', it simulates the incidence of the shock to be spread out more evenly.

The GTAPEM, however, specifies limited substitutability between branches in the tree, and hence the COP land cannot move as easily to other activities in response to the drop in subsidies. Consequently, COP production will change somewhat, but the effect will mainly materialize in lower market prices for COP land (and higher prices to be paid by the land user).

Table 4- Percent point difference GTAPEM-GTAP, market price of land

	CAN	EU1	ITA	JPN	MEX	USA	rOECD
Paddy rice	4.9	23.0	25.0	0.4	2.1	6.5	1.3
Fruits/vegetables	5.3	22.4	24.5	0.4	1.9	6.7	1.4
Sugar cane/beet	2.4	13.0	13.4	0.4	1.9	4.9	1.3
Plant fibers/other crops	3.0	13.1	12.8	0.5	2.3	5.4	0.7
Wheat	-3.2	-12.0	-19.0	-2.0	-2.3	-6.5	-0.7
Coarse Grains	-2.7	-14.0	-3.8	-2.7	-3.8	-3.9	-1.3
Oilseed	-3.7	-4.4	5.8	-4.6	-2.3	-0.5	-0.1
Cattle/sheep	3.0	13.0	13.1	0.5	1.9	6.1	1.3
Raw milk	3.1	13.1	13.2	0.4	1.9	6.1	1.3
Other animal products	6.1	23.0	25.1	0.4	1.9	7.1	1.3
Real average factor price land GTAPEM	-10.7	-33.1	-34.4	-0.2	-4	-11	-0.7
Real average factor price land GTAP	-10.5	-33.2	-35	-0.5	-3.5	-11.1	-1.5

Figure 3 – Distribution of land prices in the EU, land subsidy experiment



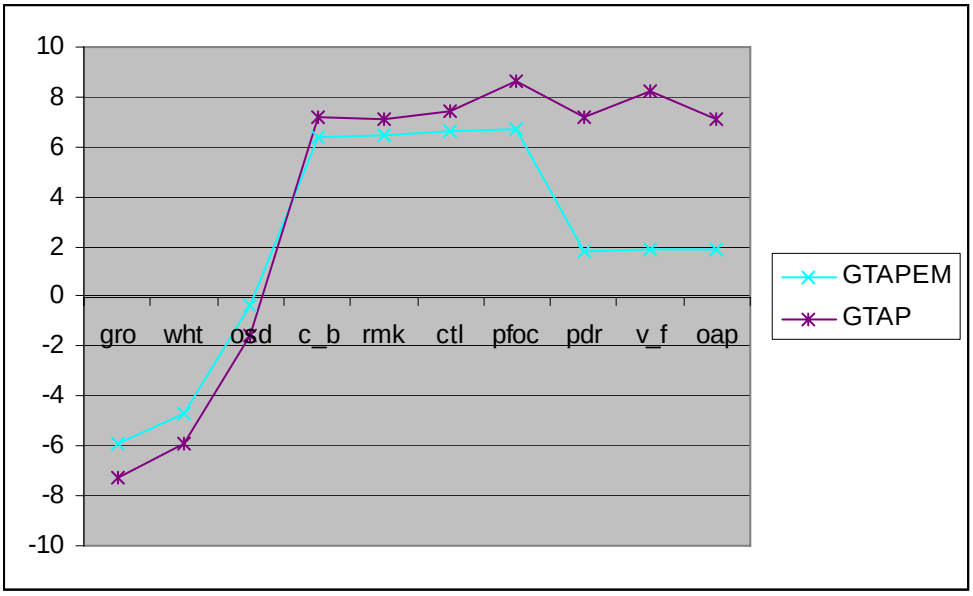
The distribution of incidence is illustrated in Figure 3. The order of crops in the figure follows the nested structure of the land allocation tree described earlier. In GTAPEM, the more inelastic supply of land at the top level of the tree (gro, wht and osd) leads to steeper price decreases compared to standard GTAP. Taking the example of the EU, note that about half of the initial shock to the power of the subsidy for COP land is transmitted to lower land prices in the COP sector. In the second nest, land prices decline less compared to standard GTAP because COP land is less easily transformable from the top level to the second level. Finally, in the lowest level, the impact is even lower than in the second level.

Impact on land use

The alternative modeling of land markets has a marked impact on simulated land use response. Although the price drop is highest in the COP nest, the land use response is more moderate compared to the standard GTAP model, as land can less easily be used to produce other products. Within the COP-nest the response also differs, as illustrated for the EU in Figure 4. As the initial area payments are highest in wheat, we find the most pronounced response in this sector, and some grains land is shifted to less heavily subsidized oilseeds production.

Most of the land taken out of COP production is used for other field crops and pasture, while the shift to miscellaneous crops is limited. This represents a marked difference with the standard GTAP model, which reallocates COP land more or less equally to alternative uses.

Figure 4: Distribution of land use changes in EU, land subsidy experiment



Output effects

The output results in the COP sector between the two models are very similar. The size of output adjustments in the COP sectors in OECD countries is of the order of magnitude of -1%, hence supporting the notion that land-based payments have a limited effect on output (OECD 2003). Although the size of the output drop is very comparable between the two model versions, it is interesting to note that the mechanisms involved are quite different.

The drop in demand follows a rise in supply prices for COP products resulting from the reduction of land subsidies (leading to rising unit cost). In GTAPEM the rise of the farmer's price for land is smaller, and the drop in the market price for land is bigger, compared to standard GTAP. This is a direct result of the elasticity of land supply being smaller in GTAPEM. Consequently, the impact on unit cost and on supply prices for COP commodities is less pronounced in GTAPEM. This would point to a somewhat dampened demand effect on the domestic markets and on export markets as compared to standard GTAP. However, we observe similar output responses across the models. So, there must be something else going on.

The main driver for the fall in COP output in GTAPEM is the reduced demand for intermediate use in food processing and in feed use for the livestock sectors. The key to understanding this is the substitution between intermediate inputs and the substitution between farm-owned and purchased inputs introduced in GTAPEM. The standard GTAP model assumes complementarity between the value-added aggregate and intermediate inputs, and furthermore assumes that all intermediate inputs are used in fixed proportions. This implies a rising intermediate demand by all sectors outside COP as those expand production at the same time as COP output declines. In GTAPEM, on the other hand, producers have the possibility to shift away from COP intermediate inputs, and to some degree substitute them with other inputs. Hence, this leads to a smaller demand for COP products.

In summary, we have two countervailing effects that drive the differences in output response to reduced land subsidies. First, the lower elasticity of land supply in GTAPEM implies a smaller rise in land user's prices, which translates to a smaller rise in unit cost and supply prices. Hence, the final demand in domestic and foreign markets reacts less sharply (at the same elasticities). Second, the substitutability between inputs in GTAPEM allows users to

shift away from COP inputs, resulting in decreased demand of COP commodities for intermediate input use.

Outside the COP sector, we find a different output response in the 'miscellaneous' crops category that follows closely land use response.

6.2b Output subsidy reduction

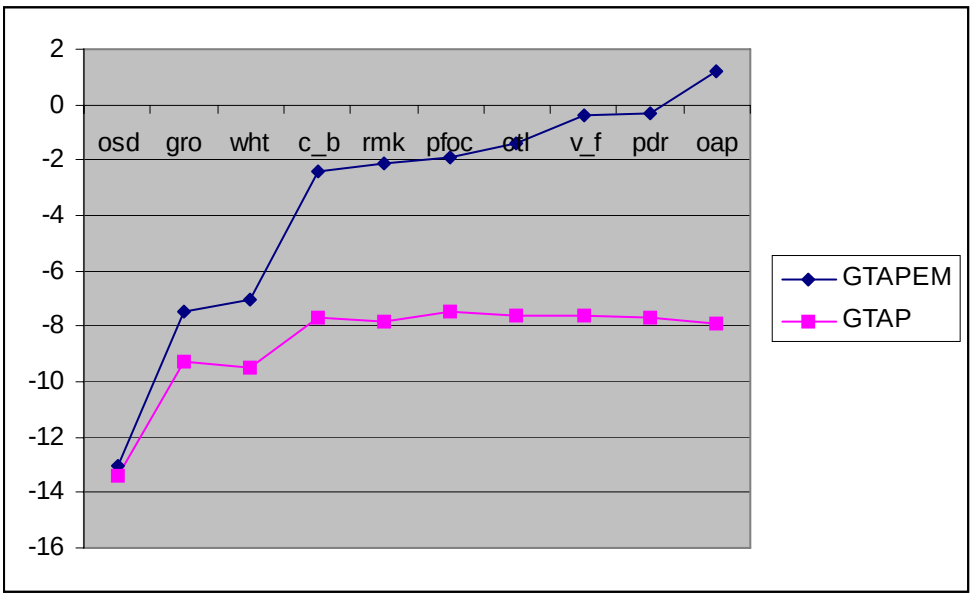
This experiment also reduces a price wedge, but this time between the producer price of the product and its market price. Again we concentrate on the COP commodities in OECD countries. Given that many payments to agricultural producers are already partially decoupled from production, our database shows only small initial distortions.

We administer an equal 10% rise to the power of the output tax equivalent across all COP commodities and all OECD regions. Hence, even if its initial size is one –implying the absence of a distortion- we increase it to a higher number.

The reduction of the output subsidy – or increase of an output tax- directly acts upon the market price of the end product and therefore creates incentives to move away from consuming and producing the commodity in question. This experiment is prototypical for policy changes that affect output market prices, such as for example trade liberalisation.

The output response of GTAPEM is not much different from that of standard GTAP. Both yield a relatively large drop in output of the commodities directly affected by the policy shock, and rather little indirect effects on other sectors. However, as in the previous experiment, the impact on the distribution of land prices is more concentrated on the COP crops in GTAPEM compared to standard GTAP. This is illustrated in Figure 5.

Figure 5– Distribution of land prices in the EU, output subsidy experiment



CONCLUDING REMARKS

In validating GTAPEM we have undertaken a number of simulation experiments to find out if there are major differences in policy implications obtained from the new model as compared to either of its 'parents'. That effort is still underway but, to date, there seem to be almost no differences of any real policy relevance between PEM and GTAPEM. A key indicator for the PEM is *relative* transfer efficiency – the estimated transfer efficiency of different categories of support measures relative to that of market price support. Estimates of this indicator obtained from GTAPEM are, with one minor exception, the same as those obtained with the PEM. The work still to be done here is to generate comparisons of *relative* production or trade impacts of different support measures.

Estimates of supply elasticities for non-OECD countries are not available from PEM. The "guesstimates" used in this study should in principle be an improvement over the standard single parameter of transformation used in GTAP. However this is a hypothesis that would need to be verified with real estimates –something that is beyond the scope of this specific project, but clearly an important area for future research.

Comparisons of GTAPEM and GTAP results also lead to few surprises. The main differences seem to be in the implications for the distribution of welfare changes among different categories of agricultural activity. GTAP and GTAPEM produce nearly identical estimates aggregate effects of a given policy change but there can be significant differences in the 'mix'. These latter differences seem mainly due to the more refined system of land allocation in GTAPEM - an issue still being studied.

In conclusion, the inclusion of more detailed supply modelling of agriculture makes a difference in policy evaluation. Specifically, the supply elasticity of land has a direct implication for the incidence of land subsidies. The main contribution of this paper is to highlight the need for more detailed land market in modelling crop supply response. The

modifications introduced in this paper address frequently voiced criticisms that GTAP has limited ability to capture crop specific supply response in agriculture.

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APPENDIX A: Calibration of Land Supply to PEM Elasticities

The parameters in GTAPEM have been calibrated to land supply elasticities used in the PEM model. Elasticity of supply for land can be written as a function of the transformation parameter in each nest and the share of land for each use. As land use shares are known constants, this leaves the choice of the three CET parameters as the determinant of the matrix of own and cross-price elasticity for land.

For rice land, a member of nest 1 (the highest), its own-price elasticity is

$$\varepsilon_{rr} = \sigma_1 \cdot (1 - sr_r),$$

where sr_r represents the share of rice in all land. As this is the highest level CET function, this equation is the same as for any single CET function; the own elasticity is equal to the transformation parameter times one minus the share. The cross-price elasticity is defined as

$$\varepsilon_{rw} = -\sigma_1 \cdot sr_w,$$

the negative of share of wheat land times the transformation parameter for nest 1.
For wheat land, a member of nest 3 (the lowest), its own price elasticity is

$$\varepsilon_{ww} = \sigma_3 \cdot \left(1 - \frac{sr_w}{sr_{n3}}\right) + \frac{sr_w}{sr_{n3}} \cdot \sigma_2 \cdot \left(1 - \frac{sr_{n3}}{sr_{n2}}\right) + \frac{sr_w}{sr_{n2}} \cdot \sigma_1 \cdot (1 - sr_{n2}),$$

where sr_w is the share of wheat in all land, sr_{n3} is the share of the lowest nest in all land, and sr_{n2} is the share of the second nest in all land. The ratio sr_w/sr_{n3} is therefore the share of wheat in nest 3. This can be seen as an extension of the result for a single CET function, where to the single function formula is added a share of the impact of all the higher nests. That is, a change in the price of wheat will bring an adjustment of land for wheat within not only its nest, but between nests as well.

The cross-price elasticities for wheat, with respect to price of coarse grains (same nest), price of pasture (prior nest), and rice (top nest) are as follows:

$$\varepsilon_{wc} = -\sigma_3 \cdot \frac{sr_c}{sr_{n3}} + \frac{sr_c}{sr_{n3}} \cdot \sigma_2 \cdot \left(1 - \frac{sr_{n3}}{sr_{n2}}\right) + \frac{sr_c}{sr_{n2}} \cdot \sigma_1 \cdot (1 - sr_{n2}),$$

$$e_{wp} = -\sigma_2 \cdot \frac{sr_p}{sr_{n2}} + \frac{sr_p}{sr_{n2}} \cdot \sigma_1 \cdot (1 - sr_{n2}),$$

$$\varepsilon_{wr} = -\sigma_1 \cdot (1 - sr_r).$$

Having only three degrees of freedom means that it is practically impossible to recover exactly the original elasticity matrix. A decision rule was used where σ_1, σ_2, and σ_3 were chosen to produce an average value of the own and cross-price elasticities for all wheat, coarse grains, and oilseeds and the own price elasticity for rice equal to the average values for these specified in the consultant reports.

This approach leaves free all other elasticities, for which estimates were not included in the consultant reports, and also allows in some cases specific own or cross-price elasticities to fall outside of the range specified in these reports. This is a necessary trade-off for having the

more formalized structure of land allocation. This rule results in the following equations for the CET parameters σ_1, σ_2, and σ_3:

$$\sigma_1 = \frac{\varepsilon_{rr}}{(1 - sr_r)},$$

$$\sigma_2 = \frac{\bar{\varepsilon}_{ii} + 2\bar{\varepsilon}_{ij} - \frac{\varepsilon_{rr}}{(1 - sr_r)} \cdot \left(\frac{sr_{n3}}{sr_{n2}} - sr_{n3} \right)}{1 - \frac{sr_{n3}}{sr_{n2}}},$$

$$\sigma_3 = \bar{\varepsilon}_{ii} - \bar{\varepsilon}_{ij}.$$

This approach to choosing the values for the σ's has the virtue of being true to the estimates provided in the consultants' reports, but is not an unambiguously best choice. In particular, it makes no attempt to set reasonable limits on the net elasticity of important land groupings. These net elasticities are major determinants of the production impacts of some policies[7].

[7] The value of σ_1 is of particular importance in determining the net elasticity. The other main factor in determining this net elasticity is the value of miscellaneous land (essentially fruits and vegetables).

APPENDIX B - Country and Commodity Aggregation

COUNTRY AGGREGATION

ANZL	Australia New Zealand						
CAN	Canada						
EU1	European Union less Italy						
ITA	Italy						
JPN	Japan						
MEX	Mexico						
USA	Usa						
rOECD	r. OECD =	Czech	Hungary	Korea	Poland	Slovak	
		Switzerland	Turkey	Norway, Iceland, Lichtenstein*			
BRA	Brazil						
MWI	Malawi						
LIEXP	Vietnam	India	Zimbabwe	Zambia	**Malawi**	Mozambique	
LIAEXP	Tanzania	Uganda	R. SSA				
MIEXP	R. Andean	Argentina	Uruguay	**Brazil**	Botswana	Chile	**Hungary**
MIAEXP	Sri Lanka	Colombia	C. Am	R. Sam	FSU	R. Sacu	
MIFEXP	Indonesia	Thailand	Peru	Morocco	Malaysia	**Turkey**	
LIIMP	Bangladesh	O. Safrica	S. Africa	R. SEasia			
LMIIMP	China	Philippines	R. MidE	R. Nafrica			
UMIIMP	**Mexico**	Venezuela	**Poland**	R. CEEC			
ROW	Rest of the world						

Bold	Not included here, but used in another definition
	*cannot be split out

LIEXP	Low income Net exporter primary agriculture and processed food
LIAEXP	Low income Net exporter primary agriculture and Net importer processed food
MIEXP	Mid income Net exporter primary agriculture and processed food
MIAEXP	Mid income Net exporter primary agriculture and Net importer processed food
MIFEXP	Mid income Net importer primary agriculture and Net exporter processed food
LIIMP	Low income Net importer primary agriculture and processed food, potentially self-sufficient
LMIIMP	LowMid income Net importer primary agriculture and processed food, potentially self-sufficient
UMIIMP	LowUp income Net importer primary agriculture and processed food, potentially self-sufficient

APPENDIX B - Country and Commodity Aggregation - CONT

COMMODITY AGGREGATION

	Paddy
pdr	rice
v_f	Vegetables ,fruits and nuts, pulses
c_b	Sugar cane/beet
pfoc	Plant fibers and other crops (flowers, coffee, tea, spices, etc)
wht	Wheat
gro	Coarse grains
osd	Oilseeds
ctl	Bovine cattle, sheep and goats, horses
rmk	Raw milk
oap	Non-ruminants (pigs, poultry, eggs, etc)
mil	Dairy products
sgr	Sugar
cmt	Ruminant meat (beef, sheep)
omt	Non-ruminant meat (pork, poultry, eggs)
ofod	Other food (seafood, vegetable oils/fat, processed fruits/veg, processed rice, beverages/tobacco, etc.)
mnfcs	Manufacturing, Fisheries, Forestry, Coal, Oil, Gas, Mineral
svces	Services
cgds	Capital Goods