FAO TRADE POLICY TECHNICAL NOTES
on issues related to the WTO negotiations on agriculture

No. 13 TRADE POLICY SIMULATION MODELS: Estimating global impacts of agricultural trade policy reform in the Doha Round

CONTENTS

1 Introduction

There has been a recent proliferation of simulation modelling[1] exercises attempting to quantify the potential economic gains from further liberalization of agricultural trade, and in doing so, seeking to inform the current Doha Round of multilateral trade negotiations. This paper[2] seeks to contribute to a better appreciation of what the results of simulation models actually mean, and the extent to which they can be used to inform debates relating to trade policy reform.

The paper begins, in section 2, by discussing the role of economic modelling in informing trade related debates, outlining the basic approaches taken in the types of models commonly used, and reviewing the main indicators that they generate in the context of the information required by policy makers and negotiators. Section 3 then discusses key messages that are often predicated on the model results. This discussion highlights some of the main reasons for differences in model results and explains several limitations in the messages that they have commonly been used to support.

Sections 4 and 5 then consider the main drivers of the model results. Section 4 explains "what" the nature of the reforms modelled is (i.e. the scenarios modelled) and why this often differs from what is "on the table" in the negotiations. It then explains the difficulties faced by analysts by examining "how" liberalization scenarios have been modelled – a key observation is that the scenario modelled is often driven to a greater extent by the structure and limitations of the model framework than by the issues of direct interest to policy makers and negotiators. Section 5 then explains some of the fundamental assumptions used in simulation models, and which play a major role in determining the magnitude of the results generated under the different scenarios. Key amongst these are assumptions relating to the employment of resources, the structure and degree of market competition and the way in which bilateral trade flows are allowed for and predicted. Finally, section 6 concludes by suggesting how several of the issues and problems highlighted in the preceding sections might be addressed.

2 Why are quantitative models used to investigate the impact of trade reforms?

The reform of trade policies usually involves a reduction[3] in government intervention to support domestic production and export of tradable goods (both exportables and import substitutes). Such reform is generally predicated on the understanding that reductions in policy-induced distortions in a sector will allow a country to shift resources towards the production of those goods that it can produce most efficiently, and in doing so, achieve a more optimal allocation of its resources. For there to be an overall positive effect, the benefits derived from such efficiency gains must outweigh any negative consequences that the reforming country may face as producers

[1] The models discussed in this paper include partial equilibrium and general equilibrium simulation models that have been used to quantify the impact multilaterally agreed reforms in a multi-country/ multi-commodity context.

[2] This paper benefits from extensive discussions at an Informal Expert Consultation on Global Trade Modelling, held at FAO, Rome on 7-8 July 2005.

[3] Trade policy reform does not necessarily imply a reduction in overall levels of support, but can result in a change in the nature of support, for example, towards more decoupled forms of support.

and consumers adjust their production and consumption activities.

Policy makers are interested both in the immediate impact of reforms on specific sectors, for example whether the sectors will become more susceptible to external shocks following reform, and the longer term impacts of reform as reflected for example in employment generation. Of interest to policy makers is not only the extent to which the benefits of reform might outweigh the losses at the national level, but also what segment of the population would experience these gains and losses. And, as importantly, how in turn this will be reflected in a range of key economic and social indicators.

In a simple world of two or a few countries producing two or a few products, the effect of reforms to border policies may be conceptualized and traced through relatively easily. However, when multiple countries with vastly different levels of technological development, different resource endowments, different levels of market distortions and widely different sets of preferences, are negotiating complex sets of reforms in multilateral fora, it becomes very difficult to determine where the gains and losses will fall, let alone their relative magnitudes. This is due in part to difficulties in predicting the outcome of the multiple interactions that will occur within and between interconnected sectors of the economies.

Quantitative models attempt to capture these complexities through numerical estimates of a policy change based on a set of postulated relationships which summarise the complex interactions among multiple factors. The rationale for the use of models is that they provide a consistent way to evaluate and compare alternative economic policies, to confirm policymakers' judgments or to alert them to potentially unintended consequences of their implementation or reform[4].

In the context of global agricultural trade, models have various potential uses including: (i) demonstrating how specific reform packages impact on different countries/commodities, (ii) making the case for further liberalization, (iii) use in dispute settlements and (iv) use in determining appropriate levels of compensation in arbitration, both in cases of challenges to trade restrictions, such as WTO incompatible import regimes, and also where government transfers e.g. export subsidies are deemed to be injurious. Although not unrelated to the last two uses, discussion in this paper is confined to the use of simulation models under (i) and (ii)[5].

[4] See Piermartini and Teh (2005) who provide a concise explanation of key constructs of CGE models.

[5] The use of models to support uses (iii) and (iv) is dealt with in detail in the recent WTO World Trade Report (WTO, 2005).

2.1 How is the impact of reform measured?

Critical to the usefulness of models is not just their ability to generate accurate results, but how well aligned the information that they can provide is with the types of insights required by policy makers. Most models use an estimate of net consumer welfare as the principle indicator for assessing the impact of policy change. However, while the welfare measure provides a useful indicator for comparing the relative efficiency of different policy options, it may not be the indicator that is in the forefront of policy makers' minds. The variety of concerns of policy makers and negotiators and possible elements in their objective functions are illustrated in Box 1. Indeed, the dominance of the welfare measure in reported model results has contributed to a growing divergence between the usefulness (and ease of use) of these results and the information actually needed by policy makers and negotiators[6].

2.2 What types of models are used?

The simulation models considered in this paper represent a particular approach to estimating the impact of trade reforms. Simulation models are used for *ex ante* analysis, i.e. to inform policy makers as to what the future impact of a policy change or a "shock" might be. Approaches that use *ex post* models can also provide information about the likely future impact of a policy change, but the two approaches serve different purposes. *Ex post* modelling studies are generally based on econometric analysis of past data and attempt to establish statistically the change in an indicator resulting from a change in a policy variable. Once this attribution is established, the model can be used to estimate the potential impact of a future policy change on the basis of the past relationship.

The data needs of *ex ante* simulation models are less demanding than econometric models as there is no need to determine statistically, from time series or cross sectional data, the cause and effect relationship. However, these models still require behavioural parameters to be specified, for example, those relating to supply and demand elasticities. Typically, the values of these parameters are assumed. Thus such models are synthetic in nature, as compared to the econometric models, where such parameters are estimated on the basis of historical data.

Ex ante simulation models differ with respect to their structure, temporal dimension and level of disaggregation, as well as in the type and level of indicators that they can generate. This subsection briefly highlights the key differences.

[6] UNCTAD (2003).

Box 1 – What indicators are policy makers interested in?

In considering whether and how to change policies, decision makers must balance a wide variety of concerns, reflecting national economic and social objectives. In relation to agricultural trade policy reform, these concerns include the following:

Balance of Payments effects

The Balance of Payments (BoP) reflects the credit and debit transactions of a country with other countries and with international institutions. A key component is the current account, which comprises visible trade (merchandise exports and imports) and invisible trade (essentially service sector activities). The contribution of agriculture to the merchandise trade balance can be significant in both developed and developing countries. The visible trade balance can be affected by the imposition of, or reduction in, import tariffs or quotas or the expansion/restriction of exports. Reform of trade policy can significantly affect both the BoP and a country's ability to control it.

National demand management and fiscal concerns

The pattern of public expenditure in many developing countries is strongly affected by their ability to raise revenue from the merchandise sector. Often, agricultural border policy represents the most effective mechanism for raising revenue in countries where other sectors are relatively small, and where the administrative costs of revenue raising through direct taxation could be prohibitive. Government revenue loss from tariff reduction is therefore a significant concern of policy makers.

Employment impacts

Employment is another critical issue for policy makers, since in many developing countries, agriculture employs a significant proportion of the labour force, and the complex interrelations between agricultural labour and agricultural production, as well as between agriculture and other sectors, can make the determination of employment impacts particularly problematic.

Poverty reduction and food security (Millennium Development Goals)

The primary macro economic and employment indicators are likely to impact on the goals of poverty reduction and improved food security, where the agriculture sector has a key role to play. However, the linkages between indicators of trade openness and indicators of poverty, and more notably food security, are complex and whether there is an established positive relationship is hotly contested in the literature.[1]

Non-trade concerns e.g. environment, food safety

At the same time, many developed countries are more concerned with environmental conservation and food safety than with farm incomes or agricultural trade balances. Intuitively, a relaxation of border controls and associated increases in trade raises the possibility of a higher degree of disease transmission. Although some models have been used to assess the relationship between trade openness and environmental impact, the literature is ambiguous as to the impact, which tends to be highly context-specific.

Prices

Although subsumed within a number of objectives, the prices of agricultural goods for both producers and consumers are important policy indicators. The prices of imported goods relative to the prices of a country's exports are an important determinant of a country's BoP and Gross Domestic Product. In interpreting the results of models, care must be taken in establishing which prices are being referred to. For example, an average "world" price increase can reflect very different price increases between countries. Within countries, there can be wide variation between relative changes in producer, consumer, import and export prices.

Welfare

The measurement of welfare reported is usually an estimate of the change in income that would be equivalent to the impact of the policy change (the Equivalent Variation (EV)) i.e. how much income would need to be given to (or taken from) the representative households to achieve the same welfare change as the policy reform. This welfare measure investigates welfare change in terms of compensation possibilities, i.e. if the gains offset the losses, it would be possible for the gainers to compensate the losers and still remain better off than they were. It does not imply however that this compensation needs to take place. The measure is therefore useful in avoiding the need for analysts to make value judgments concerning the distribution of gains and losses.

However, apart from its illustrative power in demonstrating the net gains from a reform, the indicator is not particularly useful in assisting the trade-offs between different objectives facing the policy maker. At a minimum, welfare components for individual countries, such as the producer surplus and net government gains/losses should also be highlighted rather than simply using a net welfare measure.

[1] See FAO (2003) where the linkages between trade stance and food security status are examined in detail.

- *Model type*

A broad distinction is often made between Partial Equilibrium (PE) and General Equilibrium (GE) model frameworks. These frameworks should not be seen as strict alternatives. They have particular uses in different situations and comparable solutions in terms of the main indicators generated.

Partial equilibrium models investigate the impact of changes within certain sectors of the economy on those sectors. They range from single sector-single country models through single sector-multi country models, for example the ARKANSAS Rice model[7], Goreux's cotton model[8], the University of Wisconsin's Dairy model[9], to multisector- multi country models, for example OECD's AGLINK, UNCTAD/FAO's ATPSM and FAO's COSIMO.

By contrast, Computable General Equilibrium (CGE) models attempt to account for effects of reform in, and on, the wider economy. They can also be single country, regional or multi-country[10], but are essentially concerned with determining how changes in resource allocation within and across sectors contribute to increases in welfare through improvements in allocative efficiency. This is not possible within the PE framework because cross price effects in markets are largely ignored, as are overall resource (e.g. land, labour, capital) limitations and budget constraints.

In this paper, as illustrated by the selection of models in Appendix Table 1, the focus is upon PE and GE models that incorporate multiple products and multiple countries[11].

- *Level of country and commodity disaggregation*

The models listed in Appendix Table 1 differ widely in terms of their level of disaggregation both with respect to the number of commodities that are separately modelled and to the number of countries or regional groupings. The GE models increasingly make use of the Global Trade Analysis Project (GTAP) database, with commodities and regions aggregated in different models to a greater or lesser extent.

The level of country disaggregation has major implications for the interpretation of model results as it will determine which countries appear as winners or as losers from the reforms. In many models, the countries of Sub-Saharan Africa are aggregated into one or two groups, typically a few key countries and the "rest of SSA". As discussed below, aggregation in this way can hide possible impacts in terms of the distribution of gains and losses.

To a certain extent, UNCTAD/FAO's ATPSM model, through substantial disaggregation overcomes this problem, but there is a trade-off in terms of policy specificity: using a large number of countries means that a simple tariff equivalent representation of policy must also be used.

- *Degree of policy specification.*

As Appendix Table 1 suggests, policy specification tends to be more detailed in PE models, allowing more detailed calculation of the impacts on commodity prices; different types of producers and hence livelihood concerns and potential employment effects; and more informed guidance on the detail of specific reform in commodity sectors. By contrast, the general equilibrium approach is more simplified in terms of policy representation. The issue of policy specification is discussed further in Section 4.

- *Elasticities*

The behavioural relationships in simulation models are generally specified in explicit supply and demand functions which depend on a set of elasticities. Several types of elasticities need to be specified in simulation models. A key difficulty for analysts is determining what the value of the supply elasticities[12] used in the models should be. As noted in Appendix Table 1, elasticities are determined in a number of ways and the precise rationale for the values used is difficult to trace. An example of the different elasticities used in four PE models is provided in Figures 1 and 2 which present the supply and demand elasticities for rice by country and by model respectively.

Figures 1 and 2 show that there is a significant range in specified elasticities around the average values for each country. It also shows that models tend to be fairly consistent in their over or under estimation. For example the Food and Agricultural Policy Research Institute (FAPRI) estimates are almost always the highest for supply elasticities.

[7] Wailes (2004).

[8] Goreux (2003).

[9] Cox *et al* (2005).

[10] A further distinction is in the temporal dimension of the models, with increasing use of dynamic GEs. Section 5 discusses some of the pros and cons of the dynamic structure.

[11] The paper does not examine the use of gravity models in trade modelling. For an explanation of their functionality and a review of their use, see for example Piermartini and Teh (2005).

[12] Trade elasticities are discussed in detail in Section 5.

Figure 1 Supply (area) elasticities for rice used in various models

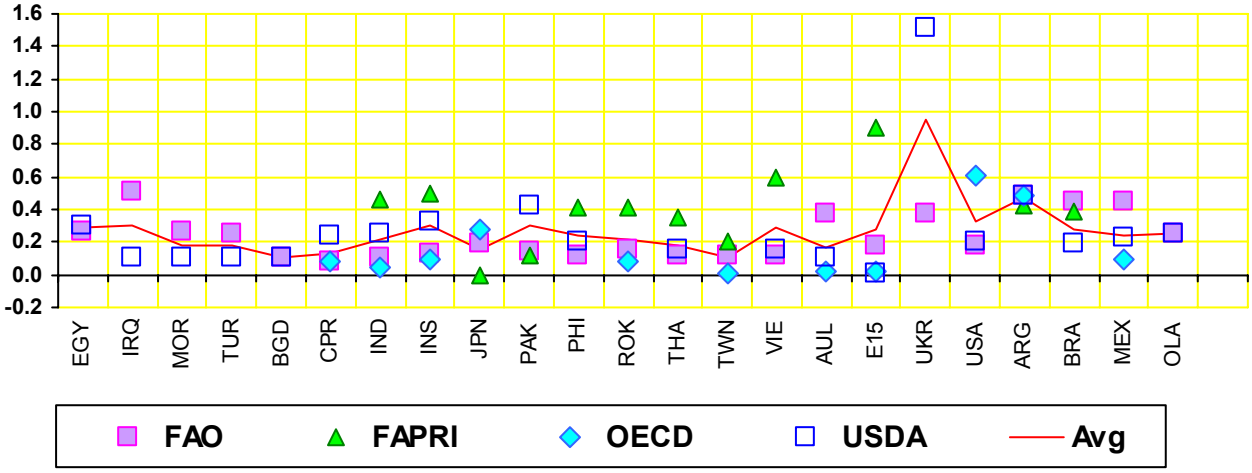
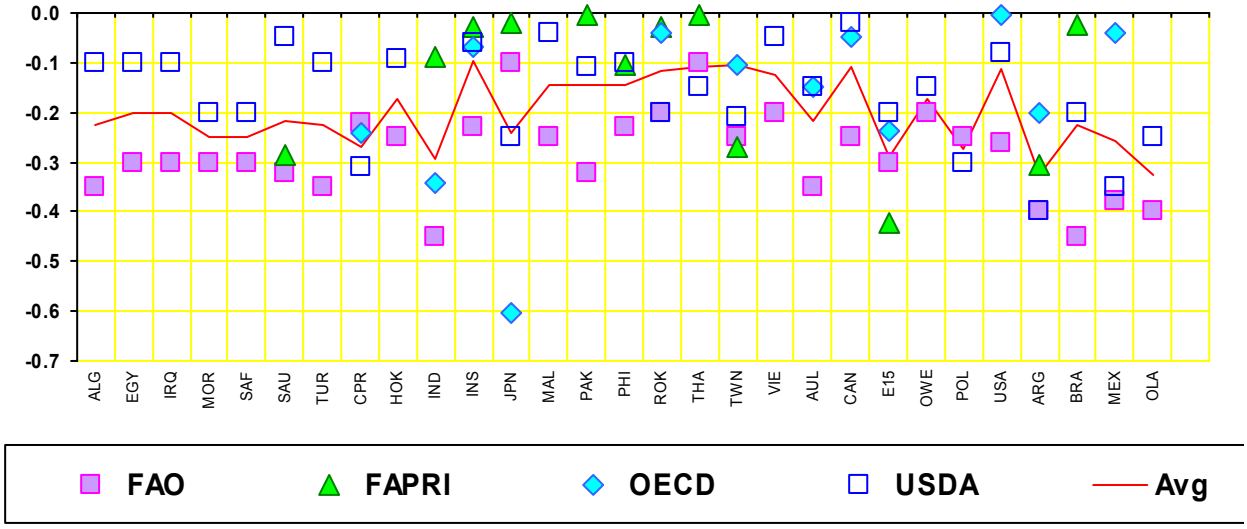


Figure 2: Demand price elasticities for rice used in various models



Many studies use historical data to estimate the supply response, but often producer responsiveness may change over time due to significant technical and macro-policy changes in certain agricultural exporting countries[13]. In addition, the peculiarities of the agriculture sector with its susceptibility to climatic conditions, changes in supply response to infrastructural improvements or deteriorations, macroeconomic policy, and exchange rate movements, often confound attempts to determine a realistic parameter value.

2.3 What indicators do models generate and how should they be interpreted?

The PE and GE models serve different, but complementary purposes. In terms of estimating the global welfare effects of a package of policy reforms, the GE which captures allocation effects, may be adequate – but for many of the issues of interest to negotiators, global welfare is not the key issue and specificity is needed. For example, in the Doha Round the significance of potential impacts on the individual sectors is critical as evidenced in discussion of sensitive and special products.

- *What indicators do the PE models generate?*

At their simplest level, PE models can be conceptualized as the interaction of supply and demand in a single market. For example, reform of a protectionist border policy through the removal of a tariff will result in a reduction in the

[13] In most modelling platforms, elasticity estimates are not updated regularly. See for example Piermartini and Teh's (2005, p.29) reference to GTAP 5.

domestic price. In turn, the model will have representative producers reducing production by an amount determined by a specified supply elasticity, and representative consumers increasing their consumption according to a specified demand price elasticity. A new equilibrium will be achieved in which imports will expand to fill the increased deficit between domestic production and domestic consumption. This simple example gives rise to a number of key indicators:

- Price change
- Production change
- Consumption change
- Trade effect in terms of import and export volumes or values
- Government revenue gain or loss
- Change in producer surplus
- Change in consumer surplus
- Net efficiency gains/losses (sum of changes in producer and consumer surplus as well as government revenue).

In the simple model it is assumed that the increase in imports does not affect the world price, the small country assumption. Hence the new price is simply the former price minus the tariff. Note that while the results from PE models can be aggregated across commodity markets to calculate, for example, changes in food import bills, they cannot be added across commodities to produce a welfare measure comparable to the GE measures discussed below.

- *What indicators do CGE models generate?*

A CGE model is a set of equations linked to one another by accounting identities and market equilibrium conditions. The link between endogenous variables such as prices, quantities and wages, and exogenous variables such as tariff levels, is shaped by the structure of the model (the number of equations and functional forms) and by the numerical values of a set of parameters (technology parameters, elasticities etc)[14]. A policy reform is introduced as a change to a policy variable, and the model simulates a new equilibrium on the basis of representative consumers and representative producers optimizing/maximizing their utility (subject to an income constraint) and their profit functions respectively.

The CGE model will solve for a set of prices that produce a market equilibrium where the demand in each market is equal to the supply in that market. This ensures that the country produces as much of the goods and services demanded by the households as it can, given the available resources. Opening to trade allows consumers (households) to obtain more with their given income because the prices of some products available from some other countries are lower than those determined domestically. This frees up domestic resources to move out of the production of these goods into the production of goods in sectors in which the country holds a comparative advantage. It is these shifts in resources and in prices that determine the extent of gains or losses that a country will face. Each different policy set will give a different equilibrium, which can then be compared.

- *Interpreting the indicators*

The CGE models can generate similar indicators to the PE models, but often the primary indicator reported is the measure of net welfare change[15]. At the same time, the authors of model based papers seldom fully explore or explain how a given change in welfare has arisen. The determinants of the welfare measure in the CGE model are varied, and so are the potential explanations as to how the model's results have been generated. This has critically important ramifications for the interpretation of results.

In welfare terms, how well off a policy change makes a country depends on what the change does to its national income and on the effect of the policy change on prices and hence the purchasing power of that income. At a basic level, the real income (or welfare) effect of trade liberalization comprises a number of key components, the most important of which are: (i) the change in efficiency or resource use as resources shift between sectors, and (ii) the change in the terms of trade facing a country/region as the relative prices that they receive or pay change.

Several papers[16] have explained how one component of welfare, national income, can be broken down into contributions from primary factors, net indirect taxes and technical changes. This breakdown is then used to categorize determinants of change in national income: endowment; technical change; and allocative efficiency. In static models with full employment of resources, the allocative efficiency effect is likely to be the most important of these determinants, but in dynamic models and in models with flexible resources, endowment and technical change effects can become as or more important.

The gains from allocative efficiency are realized when market distortions are removed; these accrue mainly to the liberalizing country or region. But although reform is generally supported on the basis of such efficiency gains, these are not

[14] UNCTAD (2003).

[15] Indeed, Fane and Ahammad (2003) suggest that "estimating the welfare effects of policy reforms is probably the single most important application of CGE models".

[16] e.g. Fane and Ahammad (2003).

always the most important in driving the welfare results.

National welfare is also affected by changes in relative prices resulting from reforms. These changes are reflected in the terms of trade (ToT) effects which result from changes in a country's export prices relative to its import prices. The ToT effect is critically important in the interpretation of model results because the net effect of multilateral agricultural reform varies across countries in large part due to the composition of exports and imports of the different commodities and the price sensitivity of these products to liberalization.

Most developing countries are importers of commodities which currently have the highest levels of domestic support globally, i.e. those produced in OECD countries, and for which the price impacts of global trade liberalization are likely to be greatest[17]. These countries also tend to be producers and exporters of primary commodities which are not so heavily supported by OECD country policies. It is therefore not surprising that most studies predict that the majority of developing countries will face a deterioration in their agricultural ToT following these types of global reform.

A number of studies are now reporting a disaggregation of the two main components of the total welfare change. The following examples taken from UNCTAD (2003) are illustrative.

Table 1 Decomposing welfare gain by component and by region

Country /region	Total welfare gain ($US million)	Terms of trade effect ($US million)	Allocative efficiency effect ($US million)
China	964	-379	1 387
South Asia	361	-205	599
North America	3 613	3 046	520
Sub-Saharan Africa	226	-197	437
TOTAL	21 547	-45	21 629

Source: UNCTAD (2003)

Although the total welfare gains reported in the UNCTAD study are positive for all regions, the signs of the terms of trade effect differ, as do the relative importance of the terms of trade and efficiency gain effects. Of the sample regions in Table 1, only in North America (a major exporter of the temperate crops expected to benefit from an increase in price) is the terms of trade effect positive, and here it is dominant, accounting for about 85 percent of the expected welfare gain. In the other regions the terms of trade effect is negative. In China, the deterioration in the terms of trade has a partial offsetting effect, but in Sub-Saharan Africa (SSA) the effect is very significant, offsetting almost half of the efficiency gains.

Nevertheless, the majority of studies suggest that all regions will gain from reform, implying that the efficiency gains dominate at the regional level. Net exporting countries that liberalize can gain for two reasons (a) their terms of trade improve if they are exporting commodities for which the prices rise relative to the prices of their imports (generally not the case for developing countries) and (b) the efficiency gains.

While net-importing countries suffer a terms of trade loss, these can be offset by the efficiency gains, although this may be questionable if their factor mobility is constrained. In either case, but particularly in the case of a net importer, if the ToT effect is sufficiently negative, then liberalization makes the country worse off. Indeed as some studies are now suggesting[18], reductions in domestic support and export subsidies in Organisation for Economic Co-operation and Development (OECD) countries can lower welfare in net food importing countries for this reason.

- *Some problems of interpretation*

A further difficulty in interpretation arises from the way in which the models solve for a new equilibrium. To allow changes in bilateral trade flows to be estimated, most models adopt an Armington structure which is briefly explained in Box 2 and addressed in detail in Section 5.

One of the assumptions of this approach is that each country can influence its own ToT. The realism of this is questioned[19], particularly with respect to Net Food Importing Developing Countries (NFIDCs) whereby models show an increase in welfare in response to liberalization in spite of rising import prices.

The Armington structure can also affect the proportion of a country's welfare change that is due to its own liberalization and the part that is due to liberalization by the rest of the world. Again, this result is largely model-driven. For example, if the ToT effects are large and negative in consequence of a country's own liberalization, it is possible that these welfare losses will be more than offset through liberalization by the rest of the world. This goes against the argument that the majority of the gains are to be had through own liberalization[20].

[17] Charlton and Stiglitz (2004).

[18] e.g. UNCTAD (2003), Bouet *et al* (2004), Bureau *et al*, (2005).

[19] Tangermann (2005).

[20] See Tokarick (2005), who suggests that liberalization by developing countries may cause a deterioration in their terms of trade to such an extent that it offsets any efficiency gains.

Box 2 – A non-technical introduction to the Armington approach

The Armington approach is discussed in detail in Section 5, which investigates a number of fundamental model assumptions. However, because of its pervasive effects on trade model results and the many references to the Armington approach throughout this paper, this Box provides a short summary of the rationale for the approach and a brief explanation as to how it functions.

For reasons of tractability, global trade models cannot investigate the impact of reform at the tariff line level – there are simply too many products to incorporate. Models therefore work with aggregate product groups such as dairy and coarse grains. This poses a problem in that countries are likely to both export and import a product when it is aggregated at this level. For example, a country may export wheat but import wheat flour, import skim milk powder but export cheese and so on. However, neoclassical economic theory only allows for a country to be an importer or exporter of an homogenous product, not both.

To resolve this problem, the product is differentiated on the basis of the producing country. Wheat produced by country A is treated as a different product from wheat produced by country B, or by any other country. This allows a country to export and to import wheat (i.e. to have a different trade position on different lines within the wheat aggregate). To achieve this in a model, an Armington structure is imposed, as detailed in Section 5.

Two points are worth highlighting at this stage:

(i) A key set of assumptions that must be made in adopting the Armington approach relates to the elasticities that are assigned to each country for each product group, allowing substitution of domestically produced product for imported product and differentiation between country of origin.

(ii) In adopting the Armington approach, the model is implicitly assuming that each country can influence the product price that it receives/pays by altering its level of trade. For example, the price that a country receives for an exported product will fall as the country increases its exports of that product in response to the initial price rise. As a result, the ToT can deteriorate. Conversely, as exports of a product fall, for example as production contracts, or as domestic demand increases, the price received per unit of the export increases, leading to an improvement in the ToT.

Another example of the danger of misinterpretation is provided by the Sub-Saharan African (SSA) example, where the region is very heterogeneous and the welfare gains relatively small and of questionable significance. For example, the ToT gains to some SSA countries through the removal of cotton subsidies by some OECD countries could offset any losses that they face due to higher food import prices. Although not all SSA countries will benefit from increased cotton prices or increased volumes of cotton exports, the combination of ToT and efficiency gains across all countries might allow for a positive message related to liberalization in that region.

The discussion above brings back into focus the difficulties in interpreting aggregate results. Policy makers are interested in the impact of global trade reforms on their own economies, *not* as to how they affect "global" or even regional welfare.

3 How are global trade models used and what are their key messages?

In forming conclusions from model results, the various GE exercises have tended to generate similar messages to each other. This is not only because of their similar structure, but because they focus on one aspect of the results – welfare.

The following list provides typical examples of inference of the gains to be had by further reform:

- *Significant gains*: reform generates global annual gains in excess of a hundred billion dollars
- *High costs of a Doha failure*: anything that does not get close to the 100 percent liberalization scenario will not deliver real gains
- *All will gain*: the gains will be roughly equally shared between developed and developing countries, but higher in developing countries when viewed as a proportion of their GDP
- *You liberalize, you gain*: developing countries gain more from reform of their own policies than from increased market access to developed countries
- *Agriculture sector liberalization is important*: gains from agricultural reforms are disproportionately high given its low share of global GDP, mainly because higher levels of protection exist than in the manufacturing sector, or because the service sector is not included in the model simulation.
- *Market access is key*: the gains from increased market access far outweigh those from reductions in the use of domestic support.

An implicit message from such conclusions is that developing countries should participate fully in the Doha round "rather than invoking SDT to

avoid reform"[21] i.e. that they should more fully open their markets to imports. On the other hand, some recent papers[22] qualify this view and cast doubt on the most quoted results, suggesting that not all countries are gainers from liberalization, indeed that most gains are concentrated in OECD and developed country Cairns Group members.

At the same time, the types of conclusions and messages listed above tend to be strongly supported by some model results. This paper considers how much confidence users should attach to the messages supported by these results. In particular it asks:

- What do we mean really by global gains of $x billion annually?
- Will the gains really be shared equally, and will all liberalizers gain?
- Is market access in agriculture the key contributor to the gains?

3.1 Billion dollar gains – what are they and who will benefit?

The purpose here is not to systematically and comprehensively review the numbers generated by contemporary models[23], but to look at the range of numbers and the trends in the numbers over time, in an attempt to isolate the reasons for the differences in results generated by different model applications.

Reviews of modelling exercises often focus on comparing models that run scenarios of 100 percent liberalization. In part this is due to the difficulty of comparing models that have run quite different "WTO" scenarios. It is however recognized that a key driver of the results is obviously the scenario being run, and this is discussed in detail in section 4.

As might be expected from economic theory, all of the GE simulations produce overall global welfare gains:

- Pre-2005, models which presented results for 100 percent liberalization of agricultural support and trade policies tended to generate annual global welfare gains in the range $100 billion to $200 billion.
- Those studies that report gains for 100 percent liberalization in all sectors (essentially agriculture and manufacturing) tend to report welfare gains in the range $260 to $365 billion, hence the conclusion that approximately half of the gains are from agricultural liberalization (even though it is a small sector globally). Simulations of trade reform in agriculture tend to produce the greatest variance in results.

The model results reported above are for static gains, i.e. ignoring the possibility of productivity improvements etc. Dynamic models tend to give higher gains. There are, however, distinct differences between the studies in the magnitudes of the generated results for a number of reasons:

- *Reduced ambition in models*

Welfare gains are generally overestimated before a negotiating round and diminish over the course of the negotiations. The Uruguay Round provided one of the first opportunities for the use of CGE models to simulate the effects of multilateral trade negotiations, with much higher gains in the earlier estimations than during or after the completion of the negotiations. Although modelling is more disciplined now, and modellers have access to better data and techniques, the numbers are still being used to support the case for reform without practitioners satisfactorily accounting for differences in model approach and parameters.

- *Comparing different endpoints*

Where a number is reported, it is generally reflective of the gains to be had by a specific year, and these endpoints are not the same in each model. Particularly problematic here are results from dynamic models. Such models incorporate productivity increases over a period of say, 10 years, and report an annual gain for a given year in the future, 2015 for example. Given that money has a time value, a sum available in 10 years time is worth less than the same sum available in the current period. To be comparable with other results, these numbers must therefore be discounted back to a common base year. As is well known, however, the choice of the discount factor can also significantly affect this comparison of results.

- *Using different datasets*

The numbers reported above are all from models that used the GTAP 5 database, which reflects the 1997 situation. But significant liberalization has occurred since 1997 and China has now joined the WTO. The remaining opportunities for liberalization are therefore much smaller.

The World Bank's LINKAGE model has been used to underpin many of the Bank's publications and messages related to the impact of global trade reform. Recent updating of the model to incorporate the new GTAP 6 database has resulted in significant reductions of the values generated and in changes in the distribution of gains and losses across countries. As a result, the dynamic model estimates of annual welfare gains from 100 percent liberalization by 2015 have changed very significantly.

[21] Anderson *et al*., 2005.

[22] e.g. Tokarick 2005; Francois (2003) and Bouet *et al* (2004).

[23] This has been done in numerous papers e.g. FAO, (2005a) UNCTAD (2003).

Using the GTAP 5 database, the model estimated gains of $413 billion in 2015 (note that this is equivalent to $215 billion relative to a 2001 economy, when the value is discounted back from 2015). Using GTAP 6, but without preferences included, i.e. essentially accounting for reforms between 1997 and 2001, the aggregate gain in 2015 falls by about 8 percent to $380 billion. But using the GTAP 6 baseline to reflect the existence of preferences and the inclusion of China in the WTO, the gains in 2015 fall to $287 billion, a reduction by 30 percent from the GTAP 5 based analysis[24], and only $160 billion when discounted back to 2001 values.

- *Differences in parameters*

A key distinction between models that use the same database and similar levels of country/commodity aggregation lies in the assumptions relating to parameter values. For example, a lower Armington elasticity will, by definition, lead to a proportionately lower impact. In general, low Armington elasticities will lead to large terms-of-trade effects, but a higher elasticity as used in, for example, the World Bank's model, will tend to suppress the importance of these effects, giving greater prominence to efficiency gains.

Differences in results may also be due to differences in assumptions about resource mobility. For example, assuming low land mobility essentially negates any gains to developing countries in which the agriculture sector is dominant. These and similar assumptions are examined in detail in Section 5.

Some modellers e.g. Bouet *et al* (2004) are critical of the excessive optimism in the messages generated by some of the contemporary modelling exercises. They suggest that levels of protection are not precisely measured; that the complexity of domestic support is not accounted for; and that there is too high a level of aggregation. In addition, they note that not all markets are distorted to the same extent, giving the example of the highly supported sugar and beef sectors as opposed to the "freer" coffee and cocoa sectors. Their study finds significantly smaller gains than most other studies and does not find that all countries gain from liberalization of agriculture sector support and protection.

3.2 To what extent is market access the key?

The premise that gains through reductions in border protection greatly exceed the gains from reductions in domestic support is based on the welfare metric[25]. Such results are used to suggest that negotiating efforts should focus on tariff reductions.

But in terms of other metrics this conclusion does not necessarily hold. Results from a Doha simulation in Bouet *et al* (2004) do indeed suggest this outcome, but in terms of total agro-food prices, the Doha simulation leads to an increase of 2.8 percent in the aggregate agricultural price, three quarters of which is contributed by reduction in domestic support. At the commodity level, the ranking is relatively consistent with domestic support reductions being dominant except for sugar where a positive increase from export subsidy elimination offsets a negative impact of tariff reduction.

With respect to export values, tariff reductions have the dominant effect in all regions, except for the poorest countries, where domestic support reductions make the greatest contribution. In terms of the impact on returns to labour, Bouet *et al* suggest, for SSA at least, that changes in agricultural labour are derived primarily from domestic support reductions.

The point here is not to dispute the fact that tariff reductions may well, in some circumstances, generate greater net gains relative to reductions in other types of support, but to caution against playing down the potential impacts of reductions in domestic support and export subsidies. A key message that can be based on the analysis of Bouet *et al* (2004) is that the effects of domestic support reduction and export subsidy elimination are not negligible in comparison to tariff reductions, if viewed on the basis of the non welfare metrics.

4 Scenarios – modelling proposed policy changes in agriculture

The discussion above is based on estimates of the impacts from full liberalization. Of course, no-one expects this scenario to result from the current Doha round negotiations, although the two scenarios are often conveniently confused in the use of model results. A false, and widely held, perception is that modellers are modelling the precise package under negotiation, but this is rarely the case. There is surprisingly little economic analysis of the precise consequences of potential trade agreements on participant countries[26]. In moving the debate from simply making the case for further reforms to investigating the potential impact of the current round of negotiations, which will fall far short of full liberalization, a key issue is how well the models actually reflect potential trade policy reforms.

In this section the difficulties of determining what the reduction commitments are likely to imply and how modellers attempt to operationalize their scenarios is considered. Often "what" is

[24] van der Mensbrugghe (2005).

[25] See e.g. Hoekman, Ng and Olarreaga (2002).

[26] Charlton and Stiglitz (2004).

modelled is determined by "how" it can be modelled, i.e. what is feasible in the modelling framework, although PE approaches are generally more able to model the specificity of a package of policy reforms and can be used to confirm or challenge the GE results. The difficulties of determining what scenario to model and how to model it are discussed below.

4.1 Market access

In attempting to estimate the impact of tariff reductions, modellers are faced with a number of issues, including how to determine the nature of tariff reduction; whether cuts in bound tariffs will, under a given formula, result in a reduction in applied tariffs; and how to deal with the fact that whilst reductions will be made at the tariff line level, the products in the models are specified at a much higher level of aggregation.

- *Which tariff reduction formula?*

Five main formulae or approaches have been discussed in the WTO context[27]:

- The Uruguay Round (UR) formula, which requires the negotiation of an average percentage reduction in tariffs over a number of years with the flexibility of a smaller minimum reduction for individual tariff lines;
- The Swiss formula, a harmonizing formula where a much narrower gap between high and low tariffs is achieved;
- The Banded approach, which categorizes tariffs into a number of bands on the basis of their initial values and applying the UR formula, but using different average and minimum cuts in each band;
- The Blended approach, which separates products into three groups subject to a different type of cut using a different formula;
- The Tiered approach which characterises products according to the height of their initial tariff. Linear cuts are applied in each tier, with tariffs falling into higher tiers being subject to higher rates of reduction.

Although the precise nature of the reduction formula is not yet clear, modellers have attempted to simulate the effect of tariff reduction. Often this has indeed been done by applying a linear cut across all tariffs in a certain band. However, the application of the types of formulae under discussion could play out quite differently. For example, the UR formula can result in some lines being cut significantly and others only minimally, a big difference from a model assumption of the same percentage reduction across all lines. Modellers can assume that countries will protect their highest applied tariffs, but given the flexibility intrinsic to this formula, this is not guaranteed.

- *Cuts to applied or bound tariffs?*

Until relatively recently, models have attempted to estimate the impacts of liberalization on the basis of significant reductions in the applied duties. Although not particularly insightful given that cuts are made to bound tariffs in the WTO context, this provided some idea of the likely effect of constraining reforms. Now that analysts have better access to bound, applied, and preferential tariff rates, the issue is one of how to model the application of the reduction to the bound rate and the extent to which this will require a cut in the applied tariff.

In one of the more recent applications[28], cuts to the bound tariffs, differentiated by tariff band, are simulated to demonstrate how the applied tariffs in the model are affected. They use the following scenario for the tariff cut:

- For developed countries, tariffs in excess of 90 percent are cut by 60 percent; tariffs between 15 and 90 percent are cut by 50 percent and tariffs less than 15 percent are cut by 40 percent.
- For developing countries, tariffs in excess of 120 percent are cut by 40 percent; those between 60 and 120 percent by 35 percent, those between 60 and 20 percent by 30 percent and those less than 20 percent by 25 percent.

Applying this scenario results in some interesting cross-regional differences in effective tariff cuts. In all cases, the cut in the average applied tariff is less than 10 percent, with cuts by the United States of America, SSA and the Rest of the World (RoW) being less than 1 percent. This compares with Anderson *et al* (2005) who run a more ambitious scenario where higher percentage cuts to bound tariffs are applied in each tier generating tariffs cuts in high income countries of 8.4 percent and in developing countries of 12.5 percent.

- *What level of product aggregation?*

An additional issue, exemplified in the case of the Tiered formula is that the tariff profiles of products or countries will not coincide with aggregations in models. Whilst some models have now achieved the HS6 level of disaggregation, decisions as to the configuration of tariff cuts will be taken at tariff line level[29] .

It is difficult to capture the effect of reductions at the tariff line level for reasons of tractability, i.e. to have a model defined at this level. One option could be to run the tariff reduction simulation at

[27] FAO Trade Policy Technical Note No.2 (2005b) provides more detailed explanation of the different formulae.

[28] Bouet *et al* (2004).

[29] see FAO Trade Policy Technical Note 2 (2005b).

tariff line level, and then aggregate up to the product category definitions. However, in this case, the profile of products falling within each tier would not coincide with the aggregations in models, because there is not a match between products and tariff lines.

A further issue concerns the treatment of ad-valorem equivalents (AVEs): although there is now a WTO accepted methodology, it is not clear that this is the same methodology that has been used in the modelling databases. A "wrong" AVE conversion formula could introduce a bias in the estimated results.

- *Addressing non reciprocal trade*

It is clear that whatever the final WTO agreement, it will contain the option for less than full reciprocity, and as such there will be discriminatory trade policies and associated commitments. This could arise through the existence of preferential tariffs where applied cuts vary not only by sector but by trading partner.

- Preferences

  Existing preferential tariff rates through reciprocal and non-reciprocal schemes are now much more fully reflected in databases although their operation is not necessarily reflected. Even though the GTAP 6 database, for example, contains preferential tariff rates, it is generally assumed that perfect competition between traders in the two sets of countries (recipients and providers), results in an equal sharing of the rent. In reality the shares accruing to each party are often unknown, and it may be that developing countries receive a smaller share of rents and hence their potential gains could be overestimated.

- Tariff rate quotas

  In GTAP 6, the tariff applied on a Tariff Rate Quota (TRQ) commodity depends on the extent to which the quota is filled. In this situation, where a TRQ is not binding and there is a preferential agreement in place, the preference, and the impact of its removal, may not be accounted for in the estimated welfare change. Several other models assume that the TRQs are filled. Similar issues arise with respect to production quotas.

A final point relates to whether tariff levels truly reflect levels of protection. On average, developing country tariffs tend to be higher than developed country tariffs, yet it is commonly held that developed country agriculture sectors are far more significantly protected as a result of non-tariff measures. As a result, there is a disconnect between the messages delivered on the basis of the models with respect to developing countries gaining more significantly from tariff reductions.

Consequently such messages engendered by the models can give a misleading picture. A key issue here is the treatment of non tariff barriers (NTBs), which tend not to be incorporated in most models, and whether in these circumstances differential tariff levels are good proxies of trade flows – in other words, whether trade flows would occur as predicted if tariff barriers fall.

4.2 Domestic support

Similar questions face modellers tackling the issue of reductions in domestic support. They include the following: what will the level of effective cut be for different countries, how will countries respond by changing policies, will the reconfigured policies really lower production and trade distortion, and how will a *de minimis* cut affect the use of domestic support policies by developing countries?

- *Will real cuts be achieved?*

The degree of flexibility over a number of parameters that is implicit in the WTO July 2004 framework agreement makes the treatment of domestic support in models potentially more difficult than that of market access. In the absence of modalities, it is problematic to determine whether countries will effectively have to make a cut, and the extent to which it will be different between countries under a tiered approach to reduction. It is also not possible to conclude at this stage, what an overall reduction in trade distorting support will mean for each country's individual policy set given uncertainties over the levels of exemptions for various types of support. Given the flexibility intrinsic in the framework agreement, and the widely differential set of policies across countries, a situation could arise where there are commitments to significant nominal cuts in domestic support that in practice will not require countries to make significant changes to their policies[30].

- *How is policy represented?*

The treatment of different policy types and, more specifically, changes in the way that support is provided, is problematic in models, where policy distortions are often defined simply as price wedges, the size of which is reduced following a reform, reducing the relative price incentive to producers in the previously supported sector.

Walsh *et al* (2005) note that in the standard GTAP model, agricultural support is represented in two ways:

- a market price support (MPS) component, which is modelled via border protection rates. This approach has the problem that a reduction in import tariffs implies a

[30] See FAO Trade Policy Technical Note No. 5 (2005c) on Domestic Support for further discussion of this issue.

proportionate reduction in domestic prices and ignores the possibility of "water" in the tariff and the possibility that a reduction in the bound tariff rate will not therefore necessarily bring about a domestic price reduction.

- a non market price support component derived from the OECD Producer Support Estimate and allocated to output subsidies, intermediate input subsidies, land based payments and capital based payments, again in the form of wedges. There are questions relating to the distribution of support to these different factors, and to the treatment of non-OECD countries for which a PSE is not available.

The same authors highlight significant differences between the GTAP database and WTO notifications, which could significantly affect the results in GTAP based models.

In the OECD PEM model, PSE data are decomposed according to the OECD criteria for receiving payment (MPS, payments based on output, payments based on input use). Each category of PSE is mapped to a price wedge in the relevant market, such that all policies may be implicitly included, although it is not possible to determine the impact of a specific policy reform because an aggregate wedge is used for each category of the PSE.

- *How is decoupled support treated?*

In addition to the uncertainty about the extent of real cuts, a key decision point for modellers is the treatment of decoupled payments. Many GE models assume that the production effect of a decoupled payment will be zero or, at best, minimal. For example, Walsh *et al* (2005) refer to Frandsen and Jensen (2003) who implement the decoupling of direct payments by transferring these payments into a uniform payment to agricultural land that is not linked to production. By contrast, Bouet *et al* (2004) model direct payments as a payment to self employed labour with the effect of this payment on production levels depending upon assumptions made about labour market mobility in the model closure.

The general assumption in CGE models that direct payments are minimally trade distorting contrasts with a number of PE models which use supply response coefficients suggesting that decoupled support accounts for up to 30 percent of the impact of market price support – anything but a minimal distortion[31].

It is by no means clear that output will always fall with a shift away from coupled support payments, not just because of asset fixity in the sector, but due to structural change and the associated dynamic efficiency gains, as the more efficient producers are able to increase their scale and achieve productivity gains. The suggestion is that a potential shake out in an industry could mean that an assumed supply elasticity used in the model could be significantly different from the actual responsiveness and that this could result in a significant overstating of the production reduction effect of decoupling support payments.

To adequately incorporate the likely effect of reform, explicit individual modelling of main policy instruments would need to be adopted rather than use of synthetic indicators such as the price wedge. For example, a shift to the Single Farm Payment (SFP) in the EU is not simply a case of a reduced price wedge since modelling this policy requires a link with farm level decisions. In this case, the producers will need to decide whether to enter the programme or not through their adherence to cross compliance requirements. As with the difficulty of determining which tariff lines a country may reduce and by how much, modellers are faced with the difficulty of constructing a model that will accurately determine how producers decide whether or not to "accept" a support payment. The degree of product aggregation in most GE models is simply too great to be able to cope with such requirements.

4.3 Export competition

Although modelling expected reductions in export subsidies may on the face of it appear relatively simple, analysts are still faced with the difficulty that countries can choose how to meet either the value or volume commitments – if one is binding, a choice can be made by the country to alter the per unit subsidy level to cope with this. As such, reductions to export subsidies may not be as constraining as assumed in some models.

The other components of export competition, export credits, STEs and food aid, have not been adequately represented in models, primarily because the absence of data has made assumptions regarding the potential impacts of their reform highly speculative. Additionally, it is not yet clear which aspects of these components will be disciplined and to what extent[32].

4.4 Modelling all three pillars together

To complicate matters further, there are commitment interlinkages between all three pillars and it is not realistic to consider reforms under each pillar in isolation, as is reported in some papers.

[31] See FAO Trade Policy Technical Note No.5 (2005c) for further discussion on this issue.

[32] FAO Trade Policy Technical Note No.4 (2005d) on Export Competition explores these issues in more detail.

- Within a country, an increase in market access will affect the level and type of domestic support that can be provided.
- Between-country interlinkages exist when one country's trade liberalization affects others' commitments. Here there is a possibility that models will overstate the extent of reform.

In running Doha scenarios, it is clear that decisions need to be taken as to how a nominal agreement will translate in reality. As the negotiations proceed, much of the detail will be written into Schedules, which could help to clarify whether and how key policies will be affected. For example, even if a binding reduction in the Aggregate Measure of Support (AMS) is agreed to, it is unlikely to result in an equiproportional reduction in AMS across all commodities There may still be grey areas following an agreement on modalities and it will be important to determine how changes might play out for specific commodities. The key problem is that of endogeneity (i.e. strategic behaviour), for which assumptions are needed about choices that will be made.

5 Fundamental issues in trade modelling

In understanding the values generated by trade models and in assessing the scope for retargeting global trade models to providing more relevant information, it is necessary to consider what is driving the results over and above the scenarios run. In essence, what fundamental assumptions made, and approaches taken, might need modification to produce results in which users can have greater confidence.

Different models generate different results and give different insights and it is typically the data and assumptions that are important in this respect. By definition, results generated by models are contingent upon a number of simplifying assumptions.

As stated by Charlton and Stiglitz (2004), "the standard argument that trade liberalization makes all countries better off is predicated on a set of assumptions that may not be satisfied in many developing countries: full employment, perfect competition, perfect capital and risk markets. In many developing countries, unemployment is high and markets imperfect, so trade liberalization may have different effects to those anticipated in simple models".

In this section, the following core assumptions are considered:

- Full (or fixed) employment of resources
- Perfect competition
- The homogeneity/heterogeneity of products, including assumptions about products differentiated by source or exporting country – the Armington assumption.
- Further issues related to dynamics and data.

5.1 Why assume full employment of resources?

In most models, full (or at least fixed) employment of labour (and other resources) is assumed. This is not because analysts firmly believe this to be the case, but because for a model to reach a solution, certain assumptions must be made as to how a model "closes". For a solution to be reached in a model comprising *n* equations and *m* variables, the number of equations should equal the number of endogenous variables. The implication of this is that to allow closure of the model, the value of *m-n* variables needs to determined exogenously. In global trade models the labour market is particularly relevant and problematic.

At its simplest level, the labour market can be characterized by one equation, where the demand for labour equals the given supply of labour in equilibrium. However, this equation relies on two variables, the amount of labour demanded and the wage rate. In deciding which variable will be endogenous and which will be exogenous, the analyst faces the choice as to whether to assume (a) a labour market with full employment or (b) a labour market with involuntary unemployment.

If the first is selected, then the wage rate is endogenously determined, and if the second, the wage is fixed exogenously and the amount of labour determined within the model[33]. Selecting option (a) i.e. fixed resources, can help to ensure that the model achieves a sustainable outcome (in terms of the countries' deficits), and for that reason is often the closure rule selected. However, in the context of understanding the impacts of trade reforms this assumption is problematic because:

(a) it overstates the consumer gain and understates the producer loss

Full employment (or a fixed level of employment) does not describe most countries' recent experience, and explains how the full employment assumption may skew model results towards consumer impacts[34]: when relative prices fall, consumers gain through access to cheaper goods and services, but producers lose by virtue of a fall in their wage rate. But the full employment assumption means that producers will not become unemployed but will find employment in another activity and their loss will be limited to the differential in wage rates. Since there is no such limitation on consumer impacts, the fact that

[33] Piermartini and The (2005).

[34] Ackerman (2005).

consumer benefits often dominate the results may simply be a modelling artifact.

(b) if the interest is in the employment effects of policy reform, the model is largely irrelevant.

Trade policy is generally seen by policy makers as a source of change in aggregate employment. In the presence of unemployment, trade liberalization may move workers from low productivity protected sectors into unemployment and this impact would not be captured in the models.

Evidence suggests that in developed countries, workers displaced by trade reform may be older, less skilled, and/or live in remote locations and therefore less mobile. In developing countries, where the immobility of labour is generally much greater, the problem is compounded by the fact that trade often moves workers in or out of underemployment in agriculture and in petty trading. An assumption of flexible employment (fixed wage) may be more realistic since it allows for the employment of unemployed labour to increase with the demand for consumer goods.

Even if the assumption of fixed employment is retained, many models could incorporate more realistic fluctuations in aggregate employment. For example, by using parameters to constrain the mobility of labour in developing country agriculture, whilst allowing it to be higher in developed countries, and in the manufacturing sector[35].

5.2 Perfect Competition

Assumptions about market structure and scale economies are important in determining how large the gains from agricultural liberalization will be. Often, the effects of perceived market imperfections are captured in models in a broad brush fashion by inferring an assumption about the returns to scale. Agriculture, because of its atomistic structure, is assumed to be characterized by constant returns to scale (CRS), but manufacturing may be assumed to have increasing returns to scale (IRS).

In models where the returns to scale assumption differs across sectors, e.g. CRS agriculture and IRS manufacturing sectors, agricultural liberalization tends to produce small gains and even losses. In contrast, CRS-only models tend to show that the largest welfare gains come from agricultural liberalization.

It has been suggested that the former result occurs in model simulations for developing countries, because the agriculture sectors expand due to better access to OECD markets, causing resources to be drawn away from their industrial sectors. The latter contract and therefore the ability to exploit scale economies is reduced, which can outweigh the welfare effects of agricultural expansion. Unexpected negative welfare effects are in part due, therefore, to the presence of scale economies in some sectors. Essentially, if liberalization leads to specialization and expansion of primary export CRS sectors, this is often inferior relative to policy induced expansion in IRS sectors. In the latter case, the traditional gains from liberalization are magnified by additional opportunities to utilize economies of scale[36].

The case for laissez-faire supported by most global trade models is, however, based on the assumption of perfect competition, with CRS assumed across all sectors. However, if in reality there is a situation of IRS characterized for example by oligopoly, theory suggests that government intervention may be optimal. This contention is also consistent with the extensive historical experience of successful agricultural-led development behind high tariffs and with active government intervention. A more appropriate focus for analysts would be assumptions about the efficiency of factor markets and supply side rigidities that characterize developing countries in particular, and the absence of which in models may lead to overestimation of the impacts from trade policy reform. Similarly, assumptions regarding risk and uncertainty, which are likely to become more relevant with the increased volatility facing previously protected producers following tariff reduction, need to be better incorporated. In cases of higher volatility, negative supply response has been observed in subsistence farm production[37]. Again, this is likely to be more important in developing countries, where access to risk management instruments is limited, and its omission may lead to overestimates of gains in the model results.

[35] Keck and Piermartini (2005) in investigating the impact of Southern African Development Community (SADC) reform, run both a full employment and an alternative closure of fixed wage rate for unskilled labour, allowing the quantity of labour supply to adjust. They find that the welfare effects are larger with the alternative closure, but with allocative efficiency gains more dominant than ToT effects. The endowment effect also becomes important as labour is drawn into employment.

[36] Francois *et al* (2003).

[37] Dorward *et al* (2004).

5.3 Product differentiation and the Armington assumption

Neoclassical economic theory makes the assumption that each product is homogenous regardless of its country of origin. In other words, consumers are indifferent as to which firm in the economy produces the product, or indeed which country produces it, as they cannot distinguish between them. As such the price they pay per unit of the product is identical. The assumption implies that there would be one "world" price for each product which would vary by country only as a result of transport costs and trade barriers. It also implies that every country would be either an importer or exporter of the product, but not both.

However, to maintain tractability in global trade models, it is not possible to divide total trade into more than a relatively limited number of products. Treatment of products as aggregates in the models clearly means that the product lines making up each product aggregate are very heterogeneous. But, treating the product as heterogeneous means that the model approach must allow each country or region to have a set of demand functions for the traded products. There would also be a supply schedule for each product produced by that region. The "world" price for a given product aggregate would be calculated as the weighted average of prices across these countries/regions. However, this approach still causes tractability problems given the number of countries and products involved.

Many models therefore adopt the Armington approach which simplifies further by reducing the number of price variables[38]. To allow changes in the pattern of trade, Armington models use elasticities to introduce a form of product differentiation. They assume that each activity produces one good that is homogeneous domestically, but imperfectly substitutable with imported goods. The model works by first allowing a change in the proportion of domestic to imported good on the domestic market following an expansion/contraction in the aggregate supply, and in a second step, by allowing a change in the shares of different sources of imports in the new total import volume.

Elasticities are used to reflect the extent to which an imported good is substituted for a domestically produced good (or vice versa), or to which imports from different sources (foreign exporters) are substituted for one another as the relative price of the good changes. Assuming that products are differentiated by country of origin helps to overcome the problems associated with the perfect competition assumption listed above. The Armington model therefore usefully accommodates two-way trade (bilateral trade flow) allowing imports and exports within the same product category or sector.

However, a number of fundamental issues[39] have been raised questioning the use of the Armington approach since changes in the values of the two sets of elasticities can significantly affect model results, and for which there is little empirically based research as to their actual magnitudes:

(1) Dealing with zero or low base flows

A key problem is that predicted trade flows following trade reform will be contingent to a large extent on the flows in the base period. This implies that large Armington elasticities would be required to generate a significant change in the levels of imports and exports. However, when applied to small initial levels of imports, even large assumed elasticities still lead to small increases in trade flows.

The Armington model also locks in the trade pattern in the base to the extent that trade reversals (i.e. shifts from net importer to net exporter status or vice versa) are not possible. This also implies that for countries having no exports to a particular country in the base year, it is not possible for those countries to start exporting to that country even though they may be competitive under the new regime.

(2) How large should the trade elasticities be?

A second issue is the size of the Armington elasticities. The elasticities are key determinants of overall level of welfare gains in the GE models in particular, of which as explained in Section 2, ToT changes are one of the two main components. Each country is a unique supplier of its differentiated product, so the price of its export will depend on the amount demanded on the world market. If a country exports more, its export price falls. Therefore because of the Armington assumption, changes in trade policy can induce significant ToT effects in the model.

Higher elasticities dampen the ToT effects and increase both trade and real income gains more than proportionately when the elasticities are increased. Conversely, lower elasticities reduce gains more than proportionally. In the World Bank studies, increasing elasticities by 50 percent[40] results in a greater than 50

[38] Thomas (1988).

[39] There are also a number of more theoretical assumptions that must be made in adopting the Armington such as marginal rates of substitution between any two products in the same aggregate being independent of purchases of products from other aggregates and that the relative amounts of products in an aggregate depend only on their relative prices (Thomas, 1988).

[40] Recall that the World Bank LINKAGE model assumes Armington elasticities that are on average 30 percent

percent increase in real income globally, (improving the global gains in the Bank's model from $287 billion to $438 billion in 2015) and a greater than 75 percent increase for the developing region, effectively by dampening the negative ToT effects in these regions. At the individual country level, the variation can be greater. For example, in Mexico the welfare gains are $0.9 billion using the assumed elasticities, but fall to negative $1.2 billion with a 50 percent reduction in the elasticities, or increase to $3 billion with an increase in the elasticities. The proportional impact on trade flows can be even greater (van der Mensbrugghe and Beghin, 2004).

Clearly, the models are highly sensitive to this assumption[41], particularly where ToT effects are significant in relation to the potential allocative gains. But trade models use widely differing assumptions about the values of these elasticities. Studies typically fall into one of three categories: those that use low elasticities (1-3), e.g., the standard GTAP applications; those that use a middle range (3-6), e.g., the World Bank; and those that use a high range (20-40), e.g. the Harrison-Rutherford-Tarr model[42].

Econometric evidence on the size of these elasticities is problematic, but has tended to suggest that the elasticity of substitution between domestic and imported product is relatively low (i.e. in the range 1-2) and that between exporting regions is about twice that level. However, this evidence is downplayed by others who suggest that such a low elasticity will lead to implausible ToT effects, which would suggest that high tariffs can be optimal!

(3) How homogenous are products?

A third issue is the realism of the assumption of perfect homogeneity according to country of origin. Anania (2001) notes that if goods produced in different countries are not perfect substitutes, then the Armington assumption may represent reality, but if imperfect substitutability does not occur, then it will overestimate the removal of protection. In this respect, Bouet *et al* (2004) suggest that agricultural goods are often relatively homogenous and that Armington elasticities tend to overestimate the degree of differentiation of goods according to origin, since it may be difficult for an individual country, particularly a developing country, to really influence the price received for its exports (or the price paid for its imports) and hence its own terms of trade.

The increased prevalence of standards also raises questions as to the extent to which a product can be differentiated by supplier – if a product meets the standard, it is likely to be little differentiated from other imports meeting the same standard, and indeed imports from different origins may be more similar to each other than they are to the domestically produced good.

Given the sensitivity of models to the Armington elasticity assumed, and the lack of evidence in support of the assumed value, alternative approaches have been attempted. It is not clear what the alternative to this assumption might be given that it is very parsimonious, a key attribute where there is a dearth of available data on the required variables needed to construct import demand and export supply equations.

Alternatives, such as spatial models, tend to be programming models which require greater levels of detail in the data used. One alternative approach to the Armington may be to introduce bilateral trade by having separate explanatory relationships for the exports and imports to a country depending upon whether it is a net exporter or importer (different elasticities) (as followed in a version of the ATPSM). This would allow prediction as to how much the import or export volumes adjust to a change in the relative price and make it easier to investigate the issue of trade diversion, a particular problem, for example, if looking at the elimination of preferences.

5.4 Further issues

- *Dynamics vs statics*

As noted in Section 2, an increasing number of dynamic models are now being used. These specifications bring to bear another set of assumptions regarding growth processes, parameter values and closures. Proponents suggest that the dynamic models are less abstract than the static models and allow for the phasing in of shocks and for an investigation of the speed of adjustment. But others argue that the assumptions regarding the sequencing of policy changes can be significant and are generally not well accounted for. The hypotheses about productivity and trade are also argued not to be robust to small changes in assumptions[43]. It is argued that reliance on additional effects (e.g. dynamics and trade facilitation effects) to generate the additional welfare gains is problematic.

Where such models may be useful is that in the main, comparative static specifications do not incorporate adjustment costs. The shift from one

higher than those in Hertel and Keeney (2004), and which in agriculture are 75 percent higher.

[41] van der Mensbrugghe and Beghin (2004).

[42] Harrison, Rutherford and Tarr (1997).

[43] Ackerman (2005).

sector to another is not frictionless and is more difficult in developing countries. There is growing empirical evidence on adjustment which suggests that the ability to adjust is country specific[44]. This could be better incorporated into models.

- *Data*

As noted throughout this paper, data is critical in both operationalizing scenarios and in making assumptions about producer response, trade elasticities, etc.

On market access, the data sets upon which GE models in particular are based are becoming increasingly similar, as increased use of the ever expanded GTAP platform is observed, and the sharing of tariff datasets e.g. MACMAP's applied HS6 2001 data which covers most bilateral tariffs becomes more apparent. Bound tariff databases are becoming more fully comparable, incorporating AVEs etc, although there are still many limitations to the use of these databases as discussed for example in the FAO Trade Policy Technical Note on Market Access (FAO 2005).

But there is less convergence in terms of policy data sets required to model more fully the effects of reform to domestic support. The OECD monitoring and evaluation reports which have good documentation of policies may be a useful starting point. WTO Notifications should also become more user friendly with a shift to electronic notification.

6 Addressing the problems

Because the results generated by modelling exercises during the Uruguay Round were often taken at face value by policy makers and negotiators, the "failure" of that Round to "deliver" the estimated gains has caused some potential users to become at best wary, and at worst highly sceptical, of the results being generated by contemporary models pertaining to the current round.

This scepticism has created an interesting paradox whereby the models are still being criticized for generating unrealistic estimates of the net aggregate gains from reform, but at the same time are increasingly unable to produce results that are suggestive of significant and clear cut gains from further liberalization. The magnitudes of welfare gains predicted, when expressed as a percentage of global GDP often appear insignificant and the results are often particularly ambiguous about the effects on the more vulnerable countries or regions, notably Sub-Saharan Africa.

To a certain extent, the paradox and the debates around it have detracted from the central issue of what the models can actually tell us and what they can't. This paper has raised a number of issues both for the model developers and for the users of the results, and in particular for the messages that can be inferred from such modelling exercises. It has considered some of the numerous determinants of model results and the reasons why the results vary so widely and why they may be highly inaccurate and indeed misleading in their interpretation. Modellers suggest that the numbers should not be taken at face value, rather that the direction and relative magnitudes of effects should provide the guidance. But evidence suggests that the modellers themselves are ignoring this rule, contributing to the increasing lack of credibility being attached to model results.

So can the limitations be overcome and can credibility be re-established? Two main lessons can be drawn from this review: (a) the need to refocus global trade modelling exercises to provide information on the indicators of particular interest and (b) that the validity of the types of values generated and the application of simulation models to address the issue of global trade reform requires more thorough investigation.

6.1 More useful information

- *Better indicators*

As outlined in Box 1, policy makers and negotiators are not simply concerned with whether a given reform produces a net welfare gain over and above the alternatives. Arguments for/against different forms of intervention therefore need to be made in more pragmatic style, with the use of models to inform debate, rather than to try to convince users that reform is needed.

As wide a range of indicators of interest should be addressed as possible, and more weight given to the qualification of results in the papers. This needs to be reflected in the style of writing, with a better justification of the metrics reported. The metric for success is broader than welfare change, and analysts should present numbers on several issues i.e. welfare, employment impacts, fiscal impacts, and associated budgetary sustainability. In many cases, this would not necessarily undermine, but could help the case for reform, if it is indeed justified.

As well as a change of emphasis in the metric, there is a need for greater disaggregation of results and analysis. In models with a high level of regional aggregation, losses through higher import prices tend to be offset by welfare gains in other countries in the region – the balance is critical to the result and it is not possible to say that there are no countries that lose when models are aggregated across countries. Greater regional

[44] See e.g. Fernandez de Cordoba and Laird (2005) and Blandford and Hill (2005) on adjustment in developing and developed countries respectively.

disaggregation is important in allowing identification of the winners and losers[45].

However, the key issue in the use of simulation models is not simply about improved transparency and better explanations of the model results in terms of the indicators presented, but the numerous technical difficulties and subjective assumptions that confound the generation of realistic insights.

- *Improved scenario design*

Section 4 has reviewed a number of difficulties in determining what scenarios to run and how to run them. A challenge for modellers is how scenarios can be more realistically configured. In determining the impact of reduced levels of protection, a key first step is to build improved information on the actual levels of protection, as opposed to use of tariff levels. This is especially needed to determine the potential impacts of reform on developing countries, particularly where significant proportions of the agricultural output are non-tradables, where the products concerned have few trade opportunities, and for which applied tariffs do not accurately reflect protection.

- *Improved approaches*

Section 5 reviewed three critical sets of assumptions integral to the chosen model approach:

- *Employment*

Generally, model closure in labour markets in GEs is through full employment. This paper has shown that this assumption (a) can produce counter intuitive results as labour resources are pulled out of sectors that would not be expected to contract in reality, and (b) is often unrealistic given the prevalence of surplus labour in many economies. A more realistic closure may allow a flexible labour market to be reflected, but at the least, both a full and a flexible employment scenario should be run.

- *Armington*

The Armington structure of the models is required to allow bilateral trade in products that are highly aggregated. However, the assumption and associated elasticity values can play havoc with the model results and with their interpretation. This limitation needs to be more fully acknowledged and explained.

- *Competition*

The CRS/IRS approach to incorporating imperfect competition may not be optimal. Analysts may do better to focus upon incorporating the effect of the prevalence of market failures and associated high transaction costs that reduce the likelihood of efficiency gains being realized following reform.

6.2 Model validation

The key role that the three fundamental assumptions examined in Section 5 can play in determining the magnitude and direction of estimated results is obviously problematic where models are attempting to simulate an equilibrium position in the future. Validating the results of *ex ante* studies can help to determine the realism of the estimated results and greatly increase the confidence that users attach to the insights that are generated.

More systematic model comparison would be a further option. Interaction between organizations using PE models already happens in informal meetings. The goal is not harmonization of the models, as this could propagate errors, but competition between institutions with respect to the performance of the models rather than the data. Research networks could also be established on, inter alia, modelling specific policies in specific countries.

In terms of improving the assumptions, there is a need for more informative use of sensitivity analysis and a role for greater use of ex-post assessment based on analysis on the ground in order to validate assumptions concerning resource flows; labour markets; price transmission; the Armington approach; market competition etc.

Sectoral Partial Equilibrium models could also be used to test the robustness of results to assumptions about, inter alia, price changes, supply and demand elasticities, etc.

6.3 Alternative approaches

- *Alternative modelling approaches*

Simulation models are a set of equations, often purported as a true representation of reality, while reducing complexity to one or two key variables. They have been demonstrated to have a number of critical weaknesses. In some cases, modellers are not aware of, or do not put much weight on, these weaknesses in their analyses.

Econometric models may provide a better approach. These models generally estimate multi-country, multi-commodity trade linkages with structural excess supply and demand equations. Econometric time series based models provide statistical estimates of key structural relationships and parameters such as quantity and price linkage and closure equations, and supply and demand price response elasticities. But even these models have limitations in terms of technical econometric problems, data difficulties and associated analyst-introduced biases in assumptions.

[45] There are advances in this respect. For example, the ATPSM now covers 161 countries, allowing better identification of winners and losers.

- *Non modelling approaches*

Lessons from similar trade agreements can provide useful insights, for example, from the case of European Union enlargement, where losses were expected for some groups of individuals in some regions. Safety nets and compensation mechanisms were established in recognition that not all can gain from reform and to obviate negative impacts for poor regions. With the exception of trade preferences, there has been little discussion of compensation or adjustment assistance in the WTO context, even though the EU experience suggests that insights into the potential losses, and mechanisms for offsetting these losses, need fuller discussion.

Final comment:

Although a number of difficulties in the use of simulation models and in the interpretation of their results have been highlighted, the aim of this paper is not to discredit trade modelling per se. Rather, it is to caution both users and modellers with respect to the limitations and dangers involved in using simulation model results to inform debates or negotiations regarding the benefits of further liberalization. It is not clear that all countries or regions will gain from global trade liberalization as is commonly portrayed.

Therefore, the key messages of this paper are:

(a) That modellers need to more fully explore and explain the reasons as to why the results that they generate are of the magnitude and direction estimated. It is not sufficient to simply present results, state that they appear consistent with prior expectations, and use them to build a case for full and significant liberalization of trade policy . Rather than helping developing countries, this could hinder their development.

(b) That alternatives to simulation models need to be more actively pursued. Results of simulation models should not be taken as the only, or even dominant, source of information: alternatives exist both in the form of other types of models and in reviews of similar experiences of trade policy reform, which can better reveal how countries and regions may actually fare in a new global trade context.

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APPENDIX TABLE 1 – Basic facts about key contemporary global trade models

Model	No. of Commodities/ Sectors	Number of Countries/ Regions	Model type	Model Structure	Policy representation	Determination of elasticities
ATPSM (UNCTAD and FAO)	36	161+ Rest of World (ROW)	Partial Equilibrium	Non spatial. Imports and exports specified allowing estimation of trade flows. Model solves by: (i) assuming that exports change in fixed proportion to changes in supply or (ii) using an Armington version where the change in imports is determined by changes in relative prices.	Limited specificity. Uses tariff equivalent wedge.	Mainly from FAO's World Food Model (WFM).
AGLINK (OECD)	32	12 + ROW	Partial Equilibrium	Net trade. Doesn't allow estimation of trade flows in both directions.	High specificity for certain policies: US marketing loan rate, EU intervention prices, remainder in form of wedges.	Estimates from collaborators, (such as EC, ERS, Ag Canada); literature and experts.
PEM (OECD)	6	6 + ROW	Partial Equilibrium	Net trade. Factor demands and supplies.	PSE data are decomposed according to their criteria for receiving payment.	Review of studies by Abler & Salhofer. Also uses stochastic parameters.
CAPRI (University of Bonn 2005)	40	40 regions/ countries in 18 trade blocks.	Regionalized programming model for EU embedded in a global spatial commodity PE model.	Spatial model (bilateral trade flows) based on Armington assumption on demand side.	Detailed policy representation. Explicit on EU intervention stock changes, subsidized exports and bilateral tariffs and preferential trade agreements (TRQs).	Parameter estimates are not calibrated. Aggregated up from HS6 definition.

Model	No. of Commodities/ Sectors	Number of Countries/ Regions	Model type	Model Structure	Policy representation	Determination of elasticities
COSIMO **(FAO 2005e)**	17	52	Partial Equilibrium world agricultural model	Non spatial. Builds on OECD's Aglink model to extend country and commodity space.	Same Aglink policy specifications in addition to detailed India and South Africa policy modules. A wedge is used to represent other policies.	Use available estimates from the literature / WFM, FAPRI, USDA.
FAPRI **(e.g. Fabiosa *et al* 2005)**	17	20 (results reported for)	Multimarket Partial Equilibrium	Non-spatial, Armington structure.	Detailed policy representation of key policies.	Not specified
World Bank LINKAGE **(e.g. Anderson et al, 2005; van der Mensbrugghe, D and J. Beghin, 2004)**	22 sectors, 15 of sectors are agricultural	23 regions [1]	CGE	Dynamic (1997-2015) based on GTAP structure. Armington structure	Price wedges	CRS assumed. Labour is perfectly mobile across sectors.
UNCTAD	6 sectors	12 regions	CGE	Standard static GTAP with perfect competition and CRS. Armington structure.	Price wedges	CRS assumed. Labour is perfectly mobile across sectors.
IMF	55 commodities	66 regions	CGE	Static, based on GTAP5 Armington structure.	Price wedges	CRS assumed. Labour is perfectly mobile across sectors.
GTAP **(e.g. Hertel and Keeney, 2005)**	87 commodities	57 regions	CGE	Static, based on GTAP5 Armington structure.	Price wedges	CRS assumed Labour is perfectly mobile across sectors. GTAP elasticities
MIRAGE **(CEPII e.g. Francois *et al* 2003, Bouet *et al* 2005)**	17 sectors	16 regions	CGE	Francois *et al* use GTAP 5.2 Bouet *et al* use GTAP 6 Armington structure.	Price wedges	CRS agriculture/ IRS manufacturing in Francois *et al.* Elasticities from GTAP

[1] The sectoral/ regional coverage is expanded to 27/25 in Anderson *et al* with 13 agricultural sectors.

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