Computable General Equilibrium Modelling of the Common Agricultural Policy

by

George Philippidis

A thesis submitted to the University of Newcastle upon Tyne
for the degree of Doctor of Philosophy

No portion of the work referred to in this thesis has been submitted in support of an application for any other degree or qualification from this or any other University or Institute of learning.

September 1999

CONTENTS

Page

Page

Page

Page

Page

Page

ACKNOWLEDGEMENTS

First and foremost I would like to thank Lionel Hubbard for his supervision, expert guidance and perhaps most of all, his 'calming influence' over the period of this research. I would also like to acknowledge the department of Agricultural Economics and Food Marketing, who were always receptive to my cries for help. I am also indebted to the Ministry of Agriculture, Fisheries and Food (MAFF) for providing funds for much of the duration of this work.

I also recognise the support of my family, particularly my parents, who have always given me encouragement. Finally, I would like to thank my friends, whose constant jibes spurred me on to completion of this thesis.

Computable General Equilibrium Modelling of the Common Agricultural Policy

ABSTRACT

With improvements in computational facility over the last twenty years, there has been a burgeoning of Computable General Equilibrium (CGE) applications in the trade literature. Indeed, CGE is seen as one of the most important recent developments in empirical trade research, with its inherent ability to measure the inter-sectoral and regional resource redistribution effects resulting from liberalisation.

In constructing a multi-region CGE trade model, one is faced with the arduous task of collecting input-output, trade and support data which must be mutually consistent with the market clearing conventions of the model framework. Alternatively, one can resort to using an existing CGE database. This research follows the latter approach and draws on the work conducted by the Global Trade Analysis Project (GTAP) which was established in 1992. In its entirety, the GTAP consists of several components:

1. A fully documented, publicly available, global data base.
2. Software for manipulating the data.
3. A global network of researchers with a common interest of multi-region trade analysis and related issues.
4. A consortium of national and international agencies providing leadership and a base level of support for the project.

In this thesis, the focus is on employing the CGE approach to re-investigate the costs of the European Union's Common Agricultural Policy (CAP). Moreover, this research identifies two particular features of CGE modelling of the CAP which remain under-explored. First, the majority of studies characterise CAP support solely through tax and subsidy data underlying the model structure. Evolutionary developments in CAP support, predominantly under the MacSharry reforms, has rendered this approach somewhat ineffectual in attaining a 'true' cost figure. For example, in the case of de-coupled support (area compensation, headage payments), using a *direct* measure such as an output subsidy is a less than ideal treatment. The other issue which is under-

developed in the CGE literature on CAP liberalisation is the incorporation of imperfect competition in many of the downstream food (i.e., food processing) and non-agricultural sectors of these models. Moreover, the notion of varietal diversity to food buyers in global markets, which represents an important decision variable in both final and intermediate consumer behaviour, is also largely overlooked.

Results of the research presented here suggest that under CAP abolition, the EU-15 gains 0.54% of GDP, with gains to the UK and EU-14 of 0.90% and 0.29% of respective GDPs. The EU-15 gains are similar to the more recent estimates of CAP costs in the literature. Increasing ‘varietal effects’ within the UK leads to larger EU-15 gains of 0.57% of GDP from CAP abolition. Other experiments on firm concentration levels and conjectural variation effects are also conducted. Results from these experiments suggest a wider range of costs associated with the CAP.

Chapter 1

The Economic Costs of the CAP

The inception of a *common* market was the result of a desire amongst a nucleus of western European countries to catalyse a political and economic union following the resolution of the second world war. From this ideology, the Common Agricultural Policy (CAP) was born, targeted at curing balance of payments and food shortage problems resulting from the war effort, as well as offering the benefits of further political integration.

However, successful though the policy was at achieving greater EU food security, the CAP also faced ‘internal’ pressures for reform. Critics argued that the policy penalised poorer consumers (due to high internal food prices), encouraged inefficient production, benefiting larger farmers disproportionately to small farmers (since support was based on production levels) and led to oversupply (due to technological change). Moreover, the CAP was also under external pressure to comply with world trade policy restrictions, ratified under the auspices of the General Agreement on Tariffs and Trade (GATT).[1]

Thus, the somewhat turbulent experience of the effects of CAP support on EU internal and world markets has been a subject of intense debate amongst academics and policy makers alike. As a result, there have been numerous attempts by academics and policy makers to quantify the costs of the CAP.

This chapter examines some of these attempts and in so doing discusses the nature of CAP costs. Section 1.1 uses a partial equilibrium schematic framework to highlight some of the cost concepts involved. Section 1.2 compares Partial Equilibrium (PE) and Computable General Equilibrium (CGE) approaches and briefly assesses their relative merits and drawbacks. Sections 1.3 and 1.4 present a chronological survey of empirical estimates of CAP costs and show how model applications have been affected by changes in economic and political developments surrounding the CAP. Moreover, some interpretation of model structures and results is offered along with, where possible, comparisons and conclusions. Section 1.5 presents a caveat to this analysis in the form of the distributional issues underlying the costs of the CAP. Section 1.6 summarises and concludes on the empirical costs of the CAP, as well as providing a new perspective on the costs of the CAP which will be discussed in subsequent chapters.

1.1 A Simple Theoretical Analysis of CAP Costs and Benefits

> *"there is no such thing as an absolute cost. The cost of anything can only be measured in terms of what has to be given up to achieve it, that is, the cost relative to some alternative"* (Buckwell *et al.*, 1982, pp39).

This statement of opportunity cost is true of all of the empirical estimates that follow. The 'alternative' most commonly used is that of complete agricultural liberalisation within the EU, i.e., abolition of the CAP.

The simplest way to undertake an examination of the effects of CAP-type price support on domestic welfare is through the use of a single-good PE analysis, although many of the assumptions underlying the model limit its use. Demekas *et al.* (1988) highlight these shortcomings which are discussed in section 1.2.

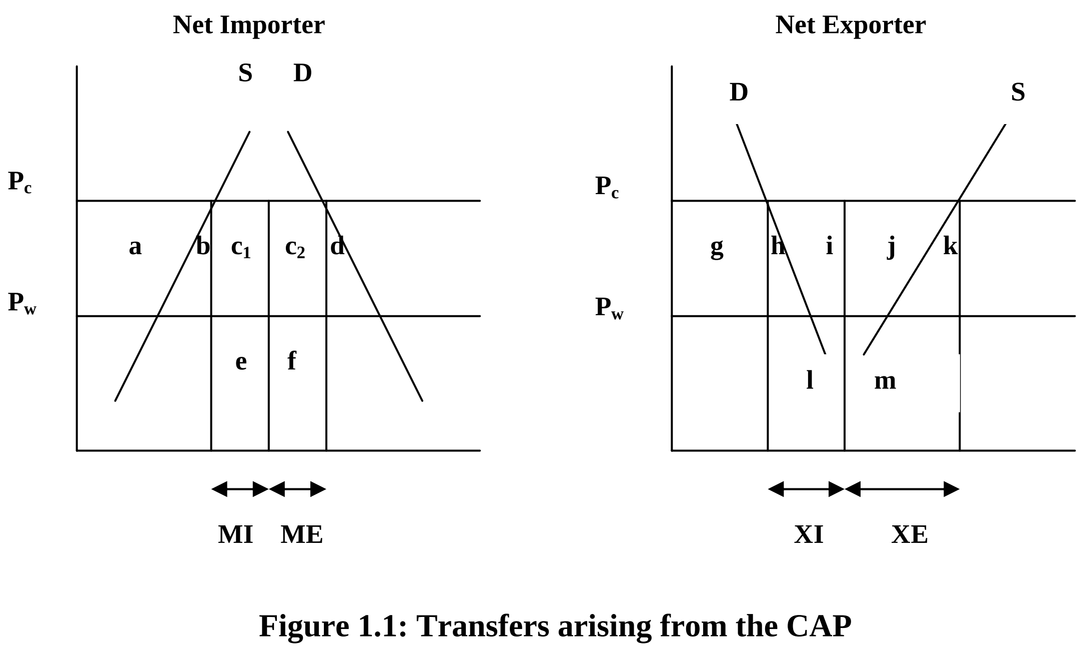


Figure 1.1: Transfers arising from the CAP

A PE single commodity representation (Buckwell *et al.*,1982) of a two-country community including community preferences and common financing is presented in

[1] Now superseded by the World Trade Organisation (WTO).

figure 1.1, where the world and internal prices are given as P_w and P_c respectively. Moreover, Imports and exports have been disaggregated into intra- (MI; XI) and extra- (ME; XE) community trade, where extra-community and intra-community trade are valued at world and common (internal) prices, respectively. This price differential is due to *community preference*, where trade between partners within the EU is free from any 'external' trade barriers. The analysis also includes the role of *common financing* of CAP market support, which is characterised by export subsidies. Moreover, levies on extra-EU imports are paid into the FEOGA account.[2] The accompanying transfers of income are presented in table 1.1.

	Net Importer	Net Exporter
Trade Flows:		
1. Export receipts		l+m+h+i+j+k
2. Import payments	c_1+e+f+c_2	
3. B. of agric T. (1+2)	-(c_1+e+f+c_2)	l+m+h+i+j+k
Budgetary Flows:		
4. Export refunds		j+k
5. Import levies	c_2	
6. Net FEOGA expenditure to each region (4+5)	-c_2	j+k
7. Total community expenditure	-c_2+j+k= Z	
8. VAT contributions (α7)	-(αZ)	-(1-α)Z
9. Bal. of FEOGA payments(6+8)	-(c_2+αZ)	j+k-(1-α)Z
Welfare Effects: The Costs of CAP abolition		
10. Producers	-a	-(g+h+i+j)
11. Consumers	(a+b+c_1+c_2+d)	g+h
12. Taxpayers	(αZ+c_2)	(1-α)Z-(j+k)
13. Overall welfare	(b+c_1+2c_2+d+αZ)	-(i+2j+k)+(1-α)Z
14. Net overall welfare	(b+d+h+k)	

Table 1.1: Transfers in a Two Country Community
(Adapted from Buckwell et al. 1986)

Thus, the first two rows of table 1.1 show the total revenues from and expenditures on exports and imports within the community. The summation of these value flows for both member states is the *balance of agricultural trade*. The next three rows in the table

show the breakdown of the FEOGA budget, which are summed in row 7 under *total community expenditure* (Z) and split (row 8) into member state contributions by the share parameter α. Row 9 is the sum of rows 6 and 8, and shows the net contributory

[2] French acronym for the community budget.

position of the two countries. The net importer pays αZ to the common budget as well as handing extra-community import levy revenues over to the community. The net exporter receives income in the form of export subsidies, and contributes $(1-\alpha)Z$ to the community budget.

The final rows in the table examine the costs of the CAP compared to the alternative of free trade. The transfer of funds to producers from consumers and taxpayers under this policy scenario is a measure of the economic or resource costs of this policy. The taxpayer costs represent the effect of removing the net contributory positions each state holds under the CAP. Thus, in both regions, producers lose and consumers gain due to lower supply prices. The extent to which transfers of funds do not sum to zero reflects the inefficiency of the policy in supporting producers (in this case), and is known as the *dead-weight welfare cost* (row 14). Dead-weight costs (i.e., the gains from CAP abolition (b+d+h+k)) arise since subsidising agriculture draws resources away from other sectors where resources could be better employed. [3]

1.2 Partial Equilibrium vs General Equilibrium

Much of the literature on CAP costs throughout the 1970s and ‘80s was based on a partial equilibrium approach. However, it has been recognised that this approach does suffer from certain limitations (Demekas *et al.* 1988):

- PE treats the market for agricultural commodities as mutually exclusive from the wider effects of resource reallocations on factors of production in the rest of the economy (i.e. non-agricultural sectors).
- In economic terms, there are no cross-price elasticity effects, as the prices of goods/services in other markets are assumed fixed.
- The analysis assumes that the country is a price-taker (i.e., the 'small' country assumption) in the world market, such that changes in domestic production will have no affect on world prices.
- PE restricts attention to one (agricultural) sector. This often restricts the modeller to capture only one specific policy from a plethora of CAP support instruments, which in turn will bias welfare results.
- All demand is 'final' and does not capture the 'intermediate' nature of demands which characterises much of the agricultural sector.

[3] A useful discussion is given in Atkin (1993).

Demekas *et al.* (1988) highlight how the use of multi-country, multi-commodity models (Tyers, 1985; Anderson & Tyers 1988, 1993) can overcome some of these problems, although the resultant level of complexity can be significant. Moreover, it is stressed that,

> *'even a model of such sophistication....is essentially limited by the constraints of partial equilibrium methodology'* (Demekas *et al.*, 1988, pp118).

With the advent of more advanced computer software, as well as multi-region database syndicates, usage of CGE now dominates much of the current trade literature, including that pertaining to the CAP. Hence, CGE explores the ramifications of a policy change throughout the entire economy. By its very nature, this approach captures all interactions between agriculture and non-agricultural sectors which typically magnify the costs of a given policy compared to the partial equilibrium counterparts (de Janvry and Sadoulet, 1987; Hertel, 1992). Indeed, in some cases, PE and GE can produce *contradictory* results for the same scenario.[4]

Thus, it is widely agreed that to identify the detail of economy-wide relationships, CGE models are a clear advance on partial equilibrium. However, this advantage does come at the cost of a degree of pre-conditioning of the model results by parameterising (e.g., 'borrowing' elasticity values from the literature) or calibrating behavioural parameters to the existing data set. Thus, it is more difficult to know whether the results are a reflection of reality or symptomatic of model structure. Nevertheless, such an extension is entirely necessary if the modeller wishes to better approximate the full effects of policy changes which go beyond the 'first-round' effects of partial equilibrium studies.

1.3 Earlier Empirical Estimates of CAP Costs

There are several review papers offering good coverage on estimates of CAP costs throughout the 1970s and '80s, and it is not the intention here to identify each and every

[4] Anderson and Tyers (1988) predicted in their study of trade liberalisation under the Uruguay Round, that a fall in the economic welfare of the developing countries would follow liberalisation by industrialised nations due to the rise in international food prices, with consumer losses outweighing producer gains. The same scenario was conducted under CGE conditions (Burniaux and Waelbroeck, 1985; Loo and Tower, 1989) both of which showed welfare *gains*, due to the effects of the non-agricultural sectors. Noting the reconciliation of the structural differences between the model approaches, Anderson and Tyers (1993) reverse their initial estimates from a sizeable loss (1985 US $14bn) into a significant gain (US $11bn).

study over this period.[5] This section merely attempts to give a brief resume of the types of cost concepts measured and the range of estimates attained

Buckwell *et al.* (1982, pp59) present a summary of several early (1975-1979) partial equilibrium estimates of CAP costs, where each is measured against the alternative of nationally financed agricultural support at existing price levels without community preference. Although there is a large consensus between studies on which countries are the gainers and which are losers, there is a large margin of error in terms of the magnitudes of the results, largely because data discrepancies occur in terms of years used, commodity coverage varies and differences exist between model structures. It is therefore difficult to draw comparisons or conclusions.

Source	Countries	Model Structure	% of GDP
Morris (1980)	EC-9	PE	0.50
Harvey & Thomson (1981)	EC-9	PE	0.50
Buckwell *et al.* (1982)	EC-9	PE	0.50
Tyers (1985)	EC-9	PE	1.10
Roberts (1985)	EC-10	PE	0.30
Spencer (1985)	EC-9	GE	0.90
Burniaux *et al.* (1985)	EC-9	GE	2.70
Tyers *et al.* (1987)	EC-12	PE	0.27
Stoeckel & Breckling (1989)	EC-4[6]	GE	1.50

Table 1.2: Estimates throughout the 1980s of the dead-weight costs of the CAP

Table 1.2 presents the costs of the CAP in terms of the dead-weight costs of the policy as a percentage of GDP foregone. This statistic illustrates the relative inefficiency of the CAP in the total economy. All of the PE studies are multi-sector and have a broad level of CAP commodity coverage. It is clear that all the studies indicate a substantial cost to the EU from the CAP. Yet again, however, the variance of estimates is broad mainly due to methodological differences (e.g., PE vs GE) which makes comparisons difficult. The range of estimates vary from 0.27 to 2.7 per cent of GDP, where the larger estimates are given by CGE models which capture the extra multiplier effects of inter-

[5] For fuller coverage of all empirical studies (PE and CGE) on CAP costs, the reader is advised to consult Buckwell *et al.* (1982), Winters (1987), Demekas *et al.* (1988) and Atkin (1993).

[6] This application models the four biggest economies of the EU (Federal Republic of Germany, France, Italy and the UK) which account for 86% of total EU-10 GDP.

sectoral relationships within the broader economy, although as Atkin (1993) notes, even the smallest estimate (0.3% of GDP) represents a significant cost.[7]

1.4 CGE Estimates of CAP Costs in the 1990s

Although some CGE studies were still evaluating the impact of complete CAP abolition (e.g., Hubbard, 1995a, 1995b), political and economic developments in the 1990s pertaining to EU agricultural trade prompted a change of direction in much of the literature. Emphasis was no longer placed on complete abolition of CAP support, but rather on the impact of the 1992 CAP reforms and compatibility with GATT requirements (Blake *et al.* 1998, Weyerbrock 1998). Moreover, other important issues pertaining to European expansion (Frandsen *et al.* 1996, 1998, Herok & Lotze, 1998) have added a further dimension to CAP reform studies. A final point to note is that CGE model structures have evolved radically to better characterise the intricacies of the CAP.

Throughout the 1980s, CGE policy modellers contented themselves by approximating CAP protection, insulation and distortionary effects through exogenous *ad valorem* tariff/subsidy equivalents. However, more recent studies of the CAP have sought to provide a more detailed coverage of agricultural sectors, by introducing endogenous behaviour through the *explicit* modelling of CAP support instruments including set aside, direct payments on land and cattle, and budgetary effects (Gohin *et al.* 1996, Harrison *et al.* 1995, Weyerbrock 1998).

Some CAP related CGE studies have attempted to impose a specific time horizon to more realistically quantify the impact of CAP removal/reform. Frandsen *et al.* (1996), in studying European expansion of the CAP to cover eastern block countries, present a projected benchmark through to 2010, against which to compare CAP liberalisation scenarios, where their projections are based on estimates of productivity, endowment growth and population change.

A final consideration has been the advances made in CGE market structure. These studies not only characterise the standard efficiency gains of resource reallocations from perfectly competitive agricultural sectors, but also capture additional welfare

---

[7] Although efficiency gains from CAP abolition in the order of 0.5% of GDP are more usual (see Winters, 1987).

effects emanating from firm economies of scale, as well as utility effects from increased levels of varietal diversity.[8] Consequently, these CGE model structures typically lead to larger estimates of welfare gains from agricultural liberalisation.

Whilst a rich range of industrial organisational structures have been employed in applications pertaining to the effects of the Uruguay Round (see Francois *et al*. 1995, Harrison *et al*. 1995a, 1995b), enlargement of the EU (Baldwin and Francois, 1996) and European market segmentation (Mercenier, 1992), with the exception of Blake *et al*. (1998), *very little appears to be directed towards liberalisation of the CAP*. Table 1.3 presents a range of recent estimates based on CAP abolition/reform in a comparable form (% of GDP). All of the studies highlighted, bar one, are CGE in nature.

Using a partial equilibrium approach, the European Commission (1994) measures the economic inefficiency of the CAP as being just over 13.7 billion ecu, which translates as approximately 0.22% of EU GDP. Three of the member states (Denmark, Greece, Ireland) actually gain from the existence of the CAP compared with the policy alternative of CAP abolition, with the rest of the world continuing to protect and distort their farm sectors as before the Uruguay Round. As expected, this result is towards the lower end of the range of estimates presented, since this analysis implicitly ignores the cross market interaction effects that such a policy change can be expected to have elsewhere in the economy.

Source	**Model Structure**	**Market Structure**	**Countries**	**% of GDP**
Commission (1994)	PE	Perfect Comp.	EU-9	0.22
Harrison *et al.*(1995)	CGE	Perfect Comp.	EU-10	0.10
Hubbard (1995a)	CGE	Perfect Comp.	EU-12 as single	0.80

[8] 'Scale' effects emanate from movements down the average total cost curve with increases in firm output. Pro-competitive effects include this effect but also examine the simultaneous reduction of the mark-up price distortion. A fuller discussion is presented in chapter 6; This is a Chamberlinian concept commonly referred to in the CGE literature as the 'love of variety'. For further discussion see Spence (1976), Dixit and Stiglitz (1977) and chapter 3.

			region	
Hubbard (1995b)	CGE	Perfect Comp.	EU-12 as single region	0.14 -1.3
Folmer *et al.* (1995)	CGE	Perfect Comp.	EU-9	0.30[9]
Blake *et al.* (1998)[10]	CGE CGE	Perfect Comp. Imperfect Comp.	EU-12 as single region	0.42 0.44-0.53[11]
Weyerbrock (1998)	CGE CGE CGE	Perfect Comp. Perfect Comp. Perfect Comp.	EU-12 as single region	0.20[12] 0.40[13] 0.10[14]

Table 1.3: Recent estimates of the dead-weight costs of the CAP

Hubbard (1995a) uses a standard perfectly competitive, constant returns to scale Global Trade Analysis Project (GTAP) model. The Global Trade Analysis Project (GTAP) was established in 1992 and essentially includes a fully consistent global database with an accompanying model framework and software to operationalise the model. Hubbard uses the GTAP model to examine complete abolition of the CAP.[15] The model characterises labour and capital as perfectly mobile and land as agriculture specific, with the CAP represented using exogenous tariff wedges. Hubbard (1995a) compares the counterfactual CAP abolition scenario with the benchmark GTAP data, and predicts specialisation effects in non-agricultural sectors leading to EU welfare gains of 0.8% of GDP. Moreover, the removal of the CAP results in global gains of 0.4% of GDP. This 'standard' treatment sits well with (smaller aggregation) earlier studies predicting EU gains in the region of 0.5%. Using the same model specification, Hubbard (1995b) conducts a sensitivity analysis of the trade ('Armington') elasticities that determine the mix of imperfectly substitutable imported and domestic goods. A quadrupling of these elasticity values results in a range of resource costs from 0.14% to 1.3% of EU GDP.

Harrison *et al.* (1995) conduct an evaluation of the impact of the CAP on ten members of the EU-12 and a 'rest of the world' region.[16] The model uses a standard CAP

[9] This estimate is based on the MacSharry CAP *reform*.
[10] CAP *reform* including the full Uruguay Round reform package.
[11] This study employs a Cournot oligopolistic structure similar to that used in Harrison *et al* (1995a).
[12] CAP *reform* only.
[13] CAP and GATT reform plus further reductions in intervention prices for sugar and dairy to meet GATT requirements.
[14] CAP and GATT reform plus quantity controls required to meet GATT targets.
[15] The GTAP is essentially a consortium approach to the construction of a mutually consistent global database.
[16] The authors had no data on Greece or Luxembourg.

abolition scenario and is calibrated to time-series data running between 1974-1985. Counterfactual results can thus be interpreted as providing some measure of the historical impact of the CAP in each year. Thus, from each base year, the study examines different time horizon (short run (SR), medium run (MR) and long run (LR)) scenarios based on assumptions about factor mobility. In the LR scenario, all factors are mobile, with land characterised as agriculture specific. The MR scenario is the same as the LR, except that the authors capture the downward rigidity of wages by including Europe-wide unemployment. The SR scenario further assumes sectoral specificity of capital.

This study also captures the essence of the CAP more effectively by introducing endogenous behaviour into CAP policy instruments (i.e., variable import levies, support buying, export subsidies, community budget) compared to the 'traditional' approach of exogenous tax/subsidy wedges.

The LR model suggests that the abolition of the CAP in the earlier years (1974/'75) would have been detrimental to a number of member states at that time (France, Netherlands, UK, Denmark, Ireland), although for most countries these losses turn to gains in the later years, with an overall gain to the EU throughout the 1980s of only 0.1% of EU GDP. The principal beneficiaries of the CAP over the time period are the Netherlands and Ireland. The effects on the rest of the world are negligible.

While the range of welfare magnitudes in the MR is broadly similar to the LR, the distribution of gainers and losers is different. For some regions (Germany, Belgium) the gains from CAP abolition in the MR are much greater. Harrison *et al*. (1995) maintain that in these cases,

> *'elimination of the CAP.....reduce(s) surplus labour (in the benchmark) raising the welfare gain from liberalisation of product markets' (pp241).*

In other countries (UK, Italy), the reverse is the case, with the model predicting unemployment increases. Indeed, those nations whose non-agricultural sectors expand the least cannot employ as much displaced agricultural labour and their unemployment rates rise.

One clear pattern in the SR is that sectorally 'trapped' capital dampens the decline and rise in agricultural and manufacturing industries respectively following CAP removal, which might suggest smaller magnitudes in regional welfare gains. However, many EU regions' welfare gains are larger than in the LR and MR scenarios, and the variance of gains and losses across members is also greater, although the reasons for this are not clear.[17]

Folmer *et al.* (1995) look at the effects on the EU-9 of a reform scenario characterised by the elimination of all agricultural production, consumer and input subsidies, compensatory lump sum transfers for the reduction in production and export subsidies, the abolition of set-aside and the relaxation of sugar and milk quotas.[18] The reported resource cost estimate of 0.3% of EU GDP is lower than most estimates of reform of the CAP. This is because the CAP reform is only partial (i.e. not complete abolition). More interesting perhaps, is the fact that the authors estimate the MacSharry proposals to be broadly compatible with the Uruguay Round commitments, although further reductions in import tariffs are expected to be required.

Blake *et al*. (1998) study the combined effects of the 1992 CAP reforms and the UR package. Using a 17 commodity, 13 region aggregation of the GTAP database (1992 base year), the model includes special features such as agricultural specific factors, endogenous export subsidy behaviour, set aside and de-coupled compensatory payments.[19] A model variant characterising food processing sectors as imperfectly competitive is also used.

Blake *et al.* (1998) predict a welfare gain to the EU of 0.42% of EU GDP. This result may be smaller than expected due the dampening effects of specific factors, and endogenous export subsidy behaviour, where a 36% required reduction in export expenditure requires less than a 36% reduction in the exogenous subsidy rate (as is usually applied in other studies). Introducing imperfect competition into the food

[17] -0.7 to + 0.6 in 1985 compared to the same years for the Long Run (-0.4 to + 0.3) and Medium Run (-0.3 to + 0.8).

[18] Authors did not have enough data to include Greece, Spain and Portugal.

[19] 50% of each factor employed in agriculture is assumed farm specific. The returns on these factors is considered as farming income as opposed to returns on all factors in agriculture which is classified as agricultural household income (not necessarily accruing to the farmer).

processing sectors increases welfare gains by between 0.44 - 0.53% of EU GDP depending on the number of firms specified in the benchmark.[20]

Weyerbrock (1998) also assesses the policy effects of CAP and GATT reforms. This model is similar to Blake *et al.*(1998) insofar as CAP support instruments are explicitly modelled (set-aside, compensation and headage payments, CAP budget).[21] As well as estimating the welfare impacts of CAP reform, this study attempts to ascertain whether or not CAP reforms meet the GATT requirements. The main findings are that CAP reform alone results in a 0.2% increase in EU GDP in the long run. Contrary to Folmer *et al.* (1995), Weyerbrock (1998) predicts that CAP reforms will not meet many of the GATT commitments over the longer term. Although GATT internal domestic support targets are met, import rules and export competition criteria in the sugar and dairy sectors are violated under the 1992 reforms. Moreover, the CAP budget is increased by 32% as expenditure on headage premia, compensation payments and structural programs exceed savings on export and oilseed subsidy payments.

Based on this evidence, two further scenarios are considered comparing the relative merits of price support and supply management. The first scenario evaluates the welfare implications of CAP reform plus further reductions in EU intervention prices and elimination of intervention buying of dairy and sugar to meet GATT requirements. The second scenario represents a further tightening in cereal set-aside and dairy/sugar production quotas to meet GATT restrictions. The results show respective long run gains of 0.4% and 0.1% of real EU GDP. Weyerbrock concludes by confirming that price reductions are more efficient at curbing budgetary problems compared to quantity controls, since in the former scenario, dairy and sugar farmers are not compensated for intervention price reductions, whereas in the latter scenario, extra compensation must be paid on further cuts in land areas.[22]

As in Harrison *et al.* (1995), Weyerbrock employs further assumptions about wage inflexibilities and possible unemployment to characterise different time horizons. This leads to smaller resource movements in the EU and, contrary to Harrison *et al.* (1995),

[20] The smaller the number of firms the greater is the mark-up in the benchmark and hence the greater are the potential gains from CAP liberalisation.

[21] Conducting sensitivity analysis with set-aside levels, Weyerbrock (1998) predicts that if the EU sets aside 3-15% of its agricultural land, between 10,000 and 56,000 workers will leave the rural sector in the long run with farm output declines between 0.3% to 0.8%.

[22] The budget situation actually improves 11% from the base under further price reductions compared with an increase in budgetary pressure of 11.5% under further quantitative restrictions.

the welfare gains are smaller in these cases reflecting different assumptions about the workings of factor markets.

1.5 Distribution Issues

Before concluding this summary, a caveat is in order. All of the results presented indicate that the EU benefits from reform/abolition of the CAP. However, CGE models, whilst able to report on some of the income transfers between agents in the economy, pay very little attention to evaluating the distribution of welfare gains among different agents.

The convention in economic theory is to adopt the principle that the marginal utility of income is equal for all recipients.[23] Using this convention, the evaluation of losses and gains can be undertaken using the compensation principle, which states that if the gainers from the policy can compensate the losers and still be better off (or the potential losers cannot 'bribe' the potential gainers to retain the status quo, and still be better off than they would be with the policy change), then the policy is Pareto-improving.

Despite the mass of work quantifying the effects of the CAP in the 1980s and 1990s, the empirical literature of the *dispersion* of the gains to various agents in the economy is thin. Harvey (1989) attempted some preliminary analysis of the producer gain for the UK. On the basis of a land price model, he estimated that land prices were, on average, inflated by 46% due to the CAP, which in 1986 amounted to an increase of £655/ha. This amounted to £631m, which Harvey estimated as being 55% of the farming gain.[24] Thus, just over half of the support afforded to agriculture through the CAP manifested itself as land values and rents to the land owners, with the remainder (45%) distributed across factor and input markets to other factors of production used by the industry.

Renwick and Hubbard (1994) examine the distributional impacts on food consumers and taxpayers in the UK of changing from support prices to compensation payments and premia as a result of the 1992 reforms of the CAP. They find that high income households bear more of the taxpayer costs, whereas the consumer cost, when compared with income, falls more on lower income households. The move away from

[23] In other words a £ is a £ regardless from whom it comes or to whom it goes. However, the fact that many political systems in the West ascribe to progressive tax rates makes this theoretical assertion of the real world somewhat nonsensical.

[24] This inflation in land prices can be associated with a policy induced rent increase based on an estimated relationship between rents and land prices provided by Lloyd (1989).

support prices toward compensation payments and premia results in a shift in burden from consumer to taxpayer, which they conclude, will lead to an improvement in the relative position of low income households.[25]

1.6 Conclusions and Further Issues

Clearly, the evolutionary path of the CAP has sparked much debate amongst politicians and agricultural economists alike, which in turn has led the latter to quantitatively measure the effects of the CAP on producers, consumers, taxpayers as well as trade protection and distortion effects. Thus, this chapter reviews some of the main attempts to empirically estimate CAP costs, placing emphasis on studies employing PE and CGE frameworks. Whilst all the estimates converge on welfare *gains* resulting from CAP abolition/reform (at least in the long run), there is much debate on the 'true' figure.

Studies in the 1980s place estimates between 0.27% - 2.7% of EU GDP, although more recent estimates (1990s) suggest smaller gains of between 0.22% - 0.8% of EU GDP.[26] This is due, in part, to the treatment of set-aside and headage support which is no longer characterised as direct (i.e., output subsidies), but is now modelled through either lump sum transfers (Folmer *et al.*, 1995; Weyerbrock, 1998) or input subsidies (Blake, *et al.*, 1998, 1999). Moreover, the incorporation of special features such as specific factors helps to dampen the supply response of agriculture to changes in the level of support, resulting in smaller estimates of welfare gains from liberalisation scenarios. Finally, more recent CGE applications pertaining to CAP liberalisation (Blake *et al.* (1998) and Weyerbrock (1998)) focus on CAP *reform* vis-à-vis complete abolition.

Perhaps the main conclusion that can be drawn from the literature is that comparisons between models is, at best, problematic where the scope of model structures (e.g., elasticities, factor mobilities), data sets, commodity coverage and aggregation all have far reaching implications on welfare results.[27] For this reason, it is better sense to interpret CAP costs within a range of model estimates.

Although the measurement of CAP costs is not new from a research perspective, the principal methodology employed has changed dramatically over the last 15 years. The

---

[25] Welfare for households in the lowest quintile rises 2.5%, and falls for households in the highest quintile by 1%.
[26] This does not include the CAP reform studies.
[27] See Arce & Reinhart (1994) to see how aggregation affects welfare results.

development of multi-region computable general equilibrium (CGE) trade models allows modellers to capture a broad range of feedback effects between those trade policies under observation and their concurrent effects on key trading partners.

The discussion in section 1.4 showed that recent attempts to quantify CAP costs in the CGE literature led modellers to re-characterise CAP support within the model structure to keep in step with the shift in price support to direct payments. To this extent, the literature is still relatively new, and is constantly undergoing transformation in an attempt to keep up with what has come to be a radical decade in the evolutionary reform process of the CAP. One aspect of this study continues in this vein with significant commodity coverage of key CAP policy mechanisms within the model structure.

This research will also examine the impact of quality perceptions (predominantly in food products) by consumers based on region of origin. Very little CGE work has been done examining the role of variety, preferences and choice patterns, and the impacts of policy change on purchasing behaviour, trade patterns and regional welfare. Thus, this study examines the implications of CAP reform on consumer utility, where preferences are seen to be patriotic (although the model allows for different characterisations of purchasing behaviour). Evidence of this is readily observable in the ‘real world’ (e.g. Buy British campaigns) as well as within the food marketing and management literature. Moreover, certain productive sectors in this study are classified as imperfectly competitive, where producers are aware of their competitors and strategic conjecture and pro-competitive effects play an important role on welfare.

Some of the issues to be explored:

- How do the welfare results reported in this study (incorporating explicit modelling of CAP policies, imperfect competition and product differentiation) compare with estimates of CAP costs from the literature?
- Are welfare gains significantly improved/worsened when consumer preferences are characterised as more patriotic?
- How does the degree of consumer loyalty by consumers affect resource allocations between sectors? Trade flows?

- How important is the role of strategic conjecture by firms? To what extent do firm numbers affect welfare results?

Finally, the structure of the thesis is as follows: Chapter 2 examines the key issues in CGE model design and implementation. Chapter 3 discusses some of the imperfectly competitive trade theories within the literature, including the role of product perceptions and region of origin. Chapter 4 gives an overview of the standard Global Trade Analysis Project (GTAP) model and database. Chapter 5 discusses the specific aggregation used in the final version of the model employed in this study and details the modelling issues surrounding a full characterisation of, *inter alia*, the CAP and the Uruguay Round constraints. Chapter 6 gives a detailed discussion of the modelling issues pertaining to the incorporation of imperfect competition and hierarchical preferences within the model framework. Chapter 7 provides an analysis of the results and conclusions of the study. Chapter 8 summarises and concludes. A glossary providing a complete listing of all model notation is provided at the end of the thesis.

Chapter 2

Computable General Equilibrium Theory and Practice

Computable General Equilibrium (CGE) models use neo-classical behavioural concepts such as utility maximisation and cost minimisation to characterise the workings of the economy. Although these principles have long been recognised by economists, operational usage of large scale (multi-region) CGE models has only become more prevalent through improvements in computational facility.

Once the model structure is formalised and calibrated to a static data set, specific macroeconomic or trade policy scenario questions may be posed. The model responds with the interaction of economic agents within each market, where an outcome is characterised by a new set of interdependent equilibria. To ensure that the model obeys the Walrasian laws of general equilibrium, a large system of accounting identities are introduced to guarantee that households and producers remain on their budget and cost constraints respectively and that zero profits prevail in all production sectors.

The strength of the CGE approach lies in the ability to characterise all economic feedback effects not inherent in partial equilibrium studies; moreover, CGE models are able to explicitly incorporate support policy mechanisms (i.e., quotas). However, CGE models suffer from the complexities of data gathering and manipulation required to create a consistent data set. Such a high level of information on commodity detail precludes the use of time series data; moreover, unlike stochastic estimation techniques, there are no statistical tests to support deterministic parameter values.

The chapter begins with a detailed discussion of the more popular types of functional forms used in CGE analysis. This is followed by a simple stylised CGE model of a closed economy in section 2.2 which looks at the mechanisms behind the general equilibrium solution to a system of equations. The chapter also examines the issues of closure (2.3), calibration (2.4) and model solution methods (2.5). Section 2.6 concludes with a more detailed look at nesting, which forms the basis for the implementation of the Armington assumption. The Armington mechanism becomes the subject of further debate in chapter 3. Appendices are provided at the end of the chapter.

2.1 Functional forms

CGE modellers tend to favour the family of 'convenient' functional forms. In a similar fashion, the CGE trade model in this study uses Leontief, Cobb-Douglas (CD) and Constant Elasticity of Substitution (CES) functions. Importantly, within the final model structure, the use of *linearised* functions is favoured over the more familiar *levels* representations given in the following sections. With added sophistication in computer software, there is very little difference in levels or linearised model results (Hertel, 1992), although calibration procedures are simpler with linearised representations. A further discussion of linearisation is provided in section 2.5.3 and an illustrative example of a nested linearised structure is developed in appendix A.

2.1.1 Leontief Function

The Leontief function is the basis of upon the input-output approach to economic modelling. At the simplest level, the Leontief function assumes perfect complementarity between inputs (commodities) in the production (utility) function. In production theory, this

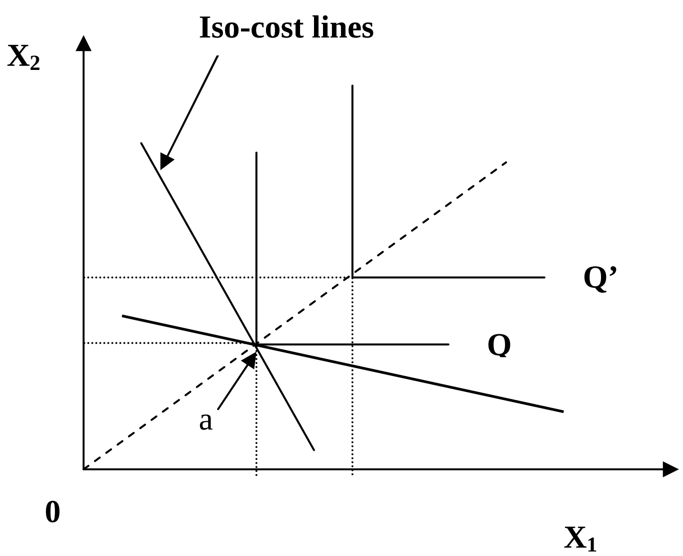


Figure 2.1: Leontief Isoquant

implies that there is zero substitution between inputs such that there is only one method of production for any level of output. The isoquant is thus 'L' shaped, as presented in figure 2.1. In the figure, the corner of the isoquants, Q and Q', represents the best point for the firm (industry) to operate at the specified outputs. All other points along the isoquants are sub-optimal since they employ more of one input (although not less of the other) to produce the same level of output.

In the case of 'n' inputs, the Leontief function is algebraically expressed as:

$$Q_j = \min\left[\frac{X_{1,j}}{A_{1,j}}, \frac{X_{2,j}}{A_{2,j}}, \ldots\ldots, \frac{X_{n,j}}{A_{n,j}}\right] \qquad \text{(LF.1)}$$

where it is assumed that the *minimum* number of units of *all* (intermediate) inputs $X_{i,j}$ required to produce an extra unit of output (Q_j), is given by the parameter $A_{i,j}$. This fixed relationship between output and each input implies constant returns to scale.

The nature of the function implies that to produce an extra unit of production, rational cost minimising producers will only employ the minimum number of input units, giving demand functions:

$$X_{i,j} = A_{i,j} Q_j \qquad \text{(LF.2)}$$

where demand for each input 'i' is a function of the fixed input-output parameter $A_{i,j}$. Note, that Leontief demands remain unaffected by changes in relative prices. This can be illustrated in figure 2.1 above, where changes in the slope of the iso-cost line running through optimal production point 'a' (along the ray), has no effect on input intensity.

The composite output price over all 'i' inputs (i=1…n), P_j, can be derived by assuming zero profits in industry 'j':

$$P_j Q_j = \sum_{i=1}^{n} R_{i,j} X_{i,j} \qquad \text{(LF.3)}$$

where

Q_j - Output in industry 'j'.

P_j - Output price in industry 'j'.

$X_{i,j}$ - Demand for input 'i' in industry 'j'.

$R_{i,j}$ - Price of input 'i' in industry 'j'.

Substituting expression (LF.2) and dividing by Q_j gives:

$$P_j = \sum_{i=1}^{n} A_{i,j} R_{i,j} \qquad \text{(LF.4)}$$

The Leontief function is a common specification in many CGE models. In this study, Leontief functions are chosen to characterise (zero) substitution possibilities between composite value added and composite intermediate inputs. In an agricultural context, it may be argued that such a treatment of producer behaviour is not realistic, where for example a farmer may use a different fertiliser application in response to a relative price change with respect to land. However, with a general lack of data on substitution possibilities between composites of this nature, most CGE applications favour the Leontief approach.

2.1.2 More advanced functions

The Cobb-Douglas (CD - Cobb and Douglas, 1928) and Constant Elasticity of Substitution (CES - Arrow *et al.*, 1961) functions are more advanced treatments of producer/consumer behaviour, as they allow substitution possibilities between inputs (commodities). Thus, the shape of the isoquant is smooth and convex with respect to the origin as presented in figure 2.2. Changes in relative input prices, denoted by movements in the iso-cost line, imply substitution between factors (commodities).

In the next two sub-sections, CD and CES production functions are assessed on three criteria:

(i) The response of short run output to variation in a single input, all other inputs held constant (marginal and average product).

(ii) The substitution possibilities of one input for another (applies equivalently to consumer theory)

(iii) The response of long run output to an equiproportional change in all inputs (returns to scale).

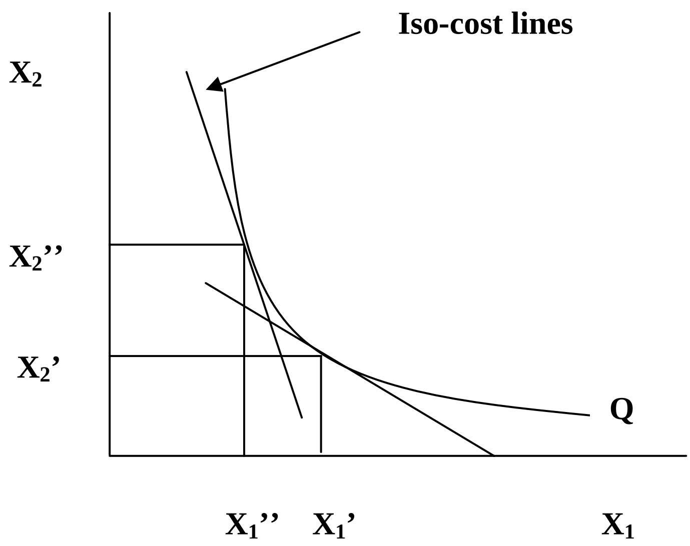


Figure 2.2: A Smooth Convex Isoquant

In the final model, input and commodity demands are Hicksian (compensated) with the exception of the top nest (see section 2.6 for a discussion on nesting) in the 'regional household' demand structure which is CD Marshallian (uncompensated). Hence compensated own- and cross- price elasticities are derived for CD and CES as well as the uncompensated income elasticity for CD.[1]

[1] Typically elasticities are partial equilibrium in nature since prices of other goods are assumed fixed.

2.1.3 Cobb-Douglas Function

A two input CD production function is of the form:

$$Q = AX_1^{\alpha} X_2^{\beta} \tag{CD.1}$$

where demands for input 1 and 2 are X_1 and X_2 respectively, Q is output, A is an efficiency parameter and α and β are elasticities. First order *partial* derivatives give short run marginal products:

$$\frac{\partial Q}{\partial X_1} \Rightarrow MP_1 = \alpha A X_1^{\alpha-1} X_2^{\beta} \tag{CD.2}$$

$$\frac{\partial Q}{\partial X_2} \Rightarrow MP_2 = \beta A X_1^{\alpha} X_2^{\beta-1} \tag{CD.3}$$

The average product (for input 1) is given as:

$$\frac{Q}{X_1} = AP_1 = AX_1^{\alpha-1} X_2^{\beta} \tag{CD.4}$$

Substituting (CD.4) into (CD.2) gives the relationship between marginal and average products:

$$MP_1 = \alpha AP_1 \tag{CD.5}$$

The production function must obey either concavity or strict concavity (see appendix B) to be consistent with the theory, which restricts the range of values that the parameters may assume in the chosen function (see appendix B).[2] As a result of these short- and long-run theoretical restrictions, Beattie and Taylor (1985) demonstrate that production functions exhibit three stages of production (see appendix C). Thus, CD functions which are restricted to strict concavity only exhibit stage II of production either with

---

[2] In theoretical terms, 'Short-Run' production functions must exhibit Diminishing Marginal Returns; 'Long-Run' production functions must exhibit some form of returns to scale.

respect to each factor (short-run) or with respect to scale (i.e., proportional changes in all inputs). Similarly, strict quasi-concavity in CD functions implies stages I or II with respect to either each factor or scale (see Beattie and Taylor, 1985, pp68-69).

The elasticity of substitution (σ) is a measure of the curvature of the isoquant and is given as the proportionate change in the slope of a ray to the isoquant, divided by the proportionate change in the slope of the tangent at the same point. For a two input production function:

$$\sigma = \frac{MRS_{12}}{X_2 / X_1} . \frac{d(X_2 / X_1)}{d(MRS_{12})} \qquad \text{(CD.6)}$$

The marginal rate of substitution (MRS) is the ratio of the marginal products, or the slope of the isoquant (Koutsoyiannis, 1979, pp73). Dividing (CD.2) by (CD.3) gives:

$$MRS_{12} = \left(\frac{\alpha}{\beta}\right).\left(\frac{X_2}{X_1}\right) \qquad \text{(CD.7)}$$

Expressed explicitly, (CD.6) is:

$$\sigma = \frac{\left(\frac{\alpha}{\beta}\right).\left(\frac{X_2}{X_1}\right)}{\left(\frac{X_2}{X_1}\right)} . \frac{d\left(\frac{X_2}{X_1}\right)}{\left(\frac{\alpha}{\beta}\right) d\left(\frac{X_2}{X_1}\right)} = 1 \qquad \text{(CD.8)}$$

In equilibrium, the marginal rate of substitution (slope of the isoquant) is equal to the ratio of input prices (slope of the iso-cost line), so that expression (CD.6) can be rewritten as:

$$\sigma = \frac{(R_1 / R_2)}{(X_2 / X_1)} \times \frac{d(X_2 / X_1)}{d(R_1 / R_2)} = 1 \qquad \text{(CD.9)}$$

Thus, a 10% increase in the factor (commodity) price ratio (R_1/R_2), leads to a 10% increase in factor (commodity) intensity (X_2/X_1). This implies that in CD functions, the cost (expenditure) shares are fixed.

It is also possible to measure the change in long run output (Q) with changes in scale (i.e. equiproportional change in all inputs). Thus, in the two input CD production function, assume that $X_2 = \vartheta X_1$ such that the ratio X_2/X_1 is constant with increases in scale, then the CD production function may be rewritten as:

$$Q = AX_1^{\alpha} X_2^{\beta} = A\vartheta^{\beta} X_1^{\alpha+\beta} \qquad \text{(CD.10)}$$

Thus, the elasticity of output with respect to proportional changes in inputs is given as:

$$\frac{dQ}{dX_1}\frac{X_1}{Q} = \alpha + \beta \qquad \text{(CD.11)}$$

where if:

$\alpha + \beta < 1$ - decreasing returns to scale

$\alpha + \beta = 1$ – constant returns to scale (CRS)

$\alpha + \beta > 1$ – increasing returns to scale

As α and β are constants, the elasticity of scale for the C-D function is also a constant, so it is invariant to changes in the level of output.

Standard CGE applications employ perfectly competitive structures, where each firm faces perfectly competitive input/factor markets as well as behaving competitively in its relevant output markets (i.e., takes prices as given). Moreover, constant returns to scale (CRS) is assumed, implying that long run average cost (TC/Q) is equal to long run marginal cost ($\partial TC/\partial Q$). Given the assumption of long run zero profits, output price equals average unit cost, as well as long run marginal cost (due to CRS), which is a key characteristic of perfectly competitive market structures (Koutsoyiannis, 1979).

When a production function does exhibit constant returns to scale then it is said to be ‘linearly homogeneous’. This relationship between homogeneity and returns to scale can be proven mathematically. Taking Cobb-Douglas production in an initial period as Q_0, multiplying each of the inputs by a scalar 'c' gives output in period Q_1:

$$Q_1 = A(cX_1)^{\alpha}(cX_2)^{\beta}$$
$$Q_1 = c^{\alpha+\beta}Q_0 \tag{CD.12}$$

where the new output level Q_1 can be expressed as a function of c (to a power $\alpha+\beta$) multiplied by the initial output, Q_0. The power of c is the *degree* of homogeneity of the function where linear homogeneity *in inputs* is established by restricting $\alpha+\beta$ equal to 1.

Minimising cost subject to the Cobb-Douglas function gives the first order conditions:

$$\frac{\partial L}{\partial X_1} = R_1 - \Lambda \alpha A X_1^{\alpha-1} X_2^{\beta} = 0 \tag{CD.13}$$

$$\frac{\partial L}{\partial X_2} = R_2 - \Lambda \beta A X_1^{\alpha} X_2^{\beta-1} = 0 \tag{CD.14}$$

$$\frac{\partial L}{\partial \Lambda} = Q - A X_1^{\alpha} X_2^{\beta} \tag{CD.15}$$

where R_i (i=1,2) are input prices, and Λ is the Lagrangian multiplier. Divide (CD.13) by (CD.14), rearrange in terms of X_2 (X_1), and substitute into (CD.15). Rearranging the resulting expression in terms of X_1 (X_2) gives CD Hicksian demands:

$$X_1 = \left(\frac{Q}{A}\right)^{\frac{1}{\alpha+\beta}} \left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} \left(\frac{R_2}{R_1}\right)^{\frac{\beta}{\alpha+\beta}} \tag{CD.16}$$

$$X_2 = \left(\frac{Q}{A}\right)^{\frac{1}{\alpha+\beta}} \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}} \left(\frac{R_1}{R_2}\right)^{\frac{\alpha}{\alpha+\beta}} \tag{CD.17}$$

Note that in consumer theory, there is no income effect in compensated demand functions.[3]

[3] Hicksian final demands are a function of utility and prices only.

Given the assumption of zero profits:

$$PQ = R_1 X_1 + R_2 X_2 \tag{CD.18}$$

it is possible to derive the composite output price, P. Substituting Hicksian demands (CD.16) and (CD.17) into (CD.18), simplifying and factorising for prices R_i gives:

$$P = Q^{\frac{1-(\alpha+\beta)}{\alpha+\beta}} A^{-\frac{1}{\alpha+\beta}} \left\{ \left[\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}} \right] R_1^{\frac{\alpha}{\alpha+\beta}} R_2^{\frac{\beta}{\alpha+\beta}} \right\} \tag{CD.19}$$

Assuming CRS (i.e. $\alpha + \beta = 1$), the composite output price, P, is linear homogeneous in R_i and zero degree homogeneous in output Q. Further, it can be shown that the underlying demands of a linearly homogeneous function are zero degree homogeneous in prices. Thus, for (CD.16) increasing the input prices by a scalar 'c' and factorising for 'c' gives the expression:

$$X_1^{t+1} = c^{\left(\frac{\beta}{\alpha+\beta}\right)-\left(\frac{\beta}{\alpha+\beta}\right)} X_1 \Rightarrow c^0 X_1 \tag{CD.20}$$

Thus, uniform increases in *all* prices by x% has no effect on the level of demand (i.e. no money illusion).[4]

Taking the demand for input (commodity) 1 as an example, Hicksian elasticities of demand are given as:

$$\frac{\partial X_1}{\partial R_1}.\frac{R_1}{X_1} = -\left(\frac{\beta}{\alpha+\beta}\right)\left(\frac{Q}{A}\right)^{\frac{1}{\alpha+\beta}} \left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} \left(\frac{R_2}{R_1}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)} X_1^{-1} \tag{CD.21}$$

[4] Homogeneity proofs can also be demonstrated in the case of other 'convenient' functions (i.e. CES, CET), although this is not demonstrated in the text.

cancelling terms gives:

$$\frac{\partial X_1}{\partial R_1}.\frac{R_1}{X_1} = -\left(\frac{\beta}{\alpha+\beta}\right) = -(1-\alpha) \qquad \text{(CD.22)}$$

provided α+β=1. Similarly, the Hicksian compensated own-price elasticity for input (commodity) 2 is:

$$\frac{\partial X_2}{\partial R_2}.\frac{R_2}{X_2} = -\left(\frac{\alpha}{\alpha+\beta}\right) = -(1-\beta) \qquad (\alpha+\beta=1) \qquad \text{(CD.23)}$$

Compensated cross-price elasticities are given as:

$$\frac{\partial X_1}{\partial R_2}.\frac{R_2}{X_1} = \left(\frac{\beta}{\alpha+\beta}\right) = (1-\alpha) \qquad (\alpha+\beta=1) \qquad \text{(CD.24)}$$

$$\frac{\partial X_2}{\partial R_1}.\frac{R_1}{X_2} = \left(\frac{\alpha}{\alpha+\beta}\right) = (1-\beta) \qquad (\alpha+\beta=1) \qquad \text{(CD.25)}$$

Maximisation of a 2 commodity Cobb-Douglas utility function:

$$U = X_1^{\alpha} X_2^{\beta} \qquad \text{(CD.26)}$$

subject to a budget constraint gives first order derivatives (marginal utilities). Dividing the first order conditions for commodities 1 and 2 and rearranging in terms of commodity 2 gives:

$$X_2 = \frac{P_1}{P_2}\frac{\beta}{\alpha} X_1 \qquad \text{(CD.27)}$$

Substituting (CD.27) into the first order condition $\partial L / \partial \Lambda$ and rearranging in terms of X_1 gives:

$$X_1 = \frac{Y}{P_1} \frac{1}{((\beta / \alpha) + 1)} \qquad \text{(CD.28)}$$

Substituting β with $(1-\alpha)$, and simplifying gives the Marshallian Cobb-Douglas household demand function for final commodity 1:[5]

$$X_1 = \frac{Y}{P_1} \alpha \qquad \text{(CD.29)}$$

where 'Y' is consumer (household) income. Using a similar procedure, it is possible to derive the household demand function for commodity 2 as:

$$X_2 = \frac{Y}{P_2} \beta \qquad \text{(CD.30)}$$

From the Marshallian (uncompensated) demands it is a straightforward procedure to demonstrate that own- and cross- price elasticities are -1 and 0 respectively. Moreover, the income elasticity of demand is restricted to one, which is highly restrictive in light of empirical evidence showing food products to have income elasticities considerably less than one. Finally, it is apparent from (CD.29) and (CD.30) that the underlying Marshallian demands are zero homogeneous in prices and income.

2.1.4 Constant Elasticity of Substitution (CES) Function

The CES production function can be expressed as:

$$Q = A\left[\delta_1 X_1^{-\rho} + (1-\delta_1) X_2^{-\rho}\right]^{-\frac{v}{\rho}} \qquad \text{(CES.1)}$$

[5] Where $\alpha + \beta = 1$

where A is an efficiency parameter, δ_1 is a distribution parameter, ρ is an elasticity parameter and v is a scale parameter (see below). Taking first order *partial* derivatives gives short run marginal products (assuming v=1 – the significance of v is discussed below):

$$\frac{\partial Q}{\partial X_1} = MP_1 = A\left[\delta_1 X_1^{-\rho} + (1-\delta_1)X_2^{-\rho}\right]^{-\left(\frac{v+\rho}{\rho}\right)} . \delta_1 X_1^{-(1+\rho)} \qquad \text{(CES.2)}$$

which can be further simplified as:

$$MP_1 = A^{-\rho} Q^{1+\rho} \delta_1 X_1^{-(1+\rho)} \qquad \text{(CES.3)}$$

and similarly for input 2:

$$MP_2 = A^{-\rho} Q^{1+\rho} (1-\delta_1) X_2^{-(1+\rho)} \qquad \text{(CES.4)}$$

Thus, marginal product is unambiguously positive with positive inputs, outputs, scale and distribution parameters. The average product (Q/X_i) can be related to the marginal product via expressions (CES.3) and (CES.4) as:

$$MP_1 = A^{-\rho} Q^{\rho} \delta_1 X_1^{-\rho} AP_1 \qquad \text{(CES.5)}$$

$$MP_2 = A^{-\rho} Q^{\rho} (1-\delta_1) X_2^{-\rho} AP_2 \qquad \text{(CES.6)}$$

As with Cobb-Douglas, strict concavity in CES functions implies stage II of production with respect to each factor (short run) and scale. Similarly, strict quasi-concavity in CES functions implies stages I or II only with respect to each factor and scale (see Beattie and Taylor, 1985, pp68-69).

The CES marginal rate of substitution is given as:

$$MRS_{12} = \left[\frac{\delta_1}{(1-\delta_1)}\right] . \left[\frac{X_2}{X_1}\right]^{1+\rho} \qquad \text{(CES.7)}$$

To derive the elasticity of substitution, differentiate MRS_{12} with respect to the input ratio:

$$\frac{dMRS_{12}}{d(X_2 / X_1)} = (1+\rho)\left[\frac{\delta_1}{(1-\delta_1)}\right] . \left[\frac{X_2}{X_1}\right]^{\rho} \qquad \text{(CES.8)}$$

Moreover, since:

$$\frac{MRS_{12}}{(X_2 / X_1)} = \left[\frac{\delta_1}{(1-\delta_1)}\right] . \left[\frac{X_2}{X_1}\right]^{\rho} \qquad \text{(CES.9)}$$

substitute (CES.9) into (CES.8) to give:

$$\frac{dMRS_{12}}{d(X_2 / X_1)} = (1+\rho)\frac{MRS_{12}}{(X_2 / X_1)} \qquad \text{(CES.10)}$$

Rearranging to give the formula in (CD.6) gives a CES elasticity of substitution value:

$$\sigma = \frac{1}{1+\rho} \qquad \text{(CES.11)}$$

Thus, the elasticity of substitution of the CES is constant and depends on the elasticity parameter, ρ, which is constrained to be greater than –1.

As with CD, it is possible to measure changes in the scale of output (Q) with proportional changes in all inputs. Referring to the two factor CES function (CES.1), assume that $X_2 = \vartheta X_1$ such that the ratio X_2/X_1 is constant with increases in scale. Thus, the CES production function may be rewritten as:

$$Q = X_1^{v} A\left[\delta_1 + (1-\delta_1)\vartheta^{-\rho}\right]^{-\frac{v}{\rho}} \qquad \text{(CES.12)}$$

where the elasticity of output with respect to proportional changes in inputs is given as:

$$\frac{dQ}{dX_1}\frac{X_1}{Q} = v \qquad \text{(CES.13)}$$

The elasticity of scale is a function of the scale parameter 'v'. For example, where v < 1, then the CES function specifies decreasing returns to scale. From the discussion of CD returns to scale above, CES functions are restricted to CRS, so v=1.[6] Given the relationship between homogeneity and returns to scale (see (CD.12)), CES production functions are homogeneous of degree 'v' in inputs. Moreover, it can be proven (this is not done here) that the composite output price function is also homogeneous of degree 'v' in input prices, and compensated demands are homogeneous of degree v-1 in prices.[7]

To derive compensated demands, minimise cost subject to the CES function which gives first order conditions:

$$\frac{\partial Z}{\partial X_1} = R_1 - \left[-\frac{1}{\rho}\Lambda A[\delta_1 X_1^{-\rho} + (1-\delta_1)X_2^{-\rho}]^{-\frac{1}{\rho}-1} - \rho\delta_1 X_1^{-(1+\rho)} \right] = 0 \qquad \text{(CES.14)}$$

$$\frac{\partial Z}{\partial X_2} = R_2 - \left[-\frac{1}{\rho}\Lambda A[\delta_1 X_1^{-\rho} + (1-\delta_2)X_2^{-\rho}]^{-\frac{1}{\rho}-1} - \rho(1-\delta_1)X_2^{-(1+\rho)} \right] = 0 \qquad \text{(CES.15)}$$

$$\frac{\partial Z}{\partial \lambda} = Q - A[\delta_1 X_1^{-\rho} + (1-\delta_2)X_2^{-\rho}]^{-\frac{1}{\rho}} = 0 \qquad \text{(CES.16)}$$

Dividing (CES.14) by (CES.15), cancelling terms and rearranging in terms of X_1 gives:

---

[6] In subsequent chapters, the value of 'v' in CES (and CET) will assume the value of 1.
[7] Marshallian (uncompensated) commodity demands are homogeneous of degree v-1 in prices and income.

$$X_1 = \left[\frac{R_1(1-\delta_1)}{R_2\delta_1}\right]^{-\frac{1}{1+\rho}} X_2 \qquad \text{(CES.17)}$$

Substituting (CES.17) into (CES.16) and simplifying gives:

$$Q = AX_2\left[\delta_1\left[\frac{R_1(1-\delta_1)}{R_2\delta_2}\right]^{\sigma\rho} + (1-\delta_1)\right]^{-\frac{1}{\rho}} \qquad \text{(CES.18)}$$

where σ is defined in equation (CES.11). Rearranging in terms of X_2 gives the Hicksian CES demand function for input (commodity) 2:

$$X_2 = \frac{Q}{A}\left[\delta_1\left[\frac{R_1(1-\delta_1)}{R_2\delta_1}\right]^{\sigma\rho} + (1-\delta_1)\right]^{\frac{1}{\rho}} \qquad \text{(CES.19)}$$

Employing the same techniques, it is possible to derive the CES Hicksian demand equation for X_1:

$$X_1 = \frac{Q}{A}\left[\delta_1 + (1-\delta_1)\left[\frac{R_2\delta_1}{R_1(1-\delta_1)}\right]^{\sigma\rho}\right]^{\frac{1}{\rho}} \qquad \text{(CES.20)}$$

Differentiating (CES.19) with respect to R_2:

$$\frac{\partial X_2}{\partial R_2} = \frac{1}{\rho}\frac{Q}{A}\left[\delta_1\left[\frac{R_1(1-\delta_1)}{R_2\delta_1}\right]^{\sigma\rho} + (1-\delta_1)\right]^{\frac{1}{\rho}-1} . -\sigma\rho\delta_1\left[\frac{R_1(1-\delta_1)}{\delta_1}\right]^{\sigma\rho} R_2^{-\sigma\rho-1}$$

(CES.21)

Multiplying (CES.21) by R_2/X_2 and substituting X_2, Q and A gives the Hicksian (compensated) own-price elasticity of demand for input 2:

$$\frac{\partial X_2}{\partial R_2}.\frac{R_2}{X_2} = -\sigma\left[\frac{X_2 A}{Q}\right]^{-\rho}\delta_1\left[\frac{R_1(1-\delta_1)}{R_2\delta_1}\right]^{\sigma\rho} \qquad \text{(CES.22)}$$

Similarly for input 1:

$$\frac{\partial X_1}{\partial R_1}.\frac{R_1}{X_1} = -\sigma\left[\frac{X_1 A}{Q}\right]^{-\rho}(1-\delta_1)\left[\frac{R_2\delta_1}{R_1(1-\delta_1)}\right]^{\sigma\rho} \qquad \text{(CES.23)}$$

Compensated cross price elasticities of demand are given as:

$$\frac{\partial X_2}{\partial R_1}.\frac{R_1}{X_2} = \sigma\left[\frac{X_2 A}{Q}\right]^{-\rho}\delta_1\left[\frac{R_1(1-\delta_1)}{R_2\delta_1}\right]^{\sigma\rho} \qquad \text{(CES.24)}$$

$$\frac{\partial X_1}{\partial R_2}.\frac{R_2}{X_1} = \sigma\left[\frac{X_1 A}{Q}\right]^{-\rho}(1-\delta_1)\left[\frac{R_2\delta_1}{R_1(1-\delta_1)}\right]^{\sigma\rho} \qquad \text{(CES.25)}$$

2.1.5 Constant Elasticity of Transformation (CET) Function

The CET is the corollary CES function, where the production possibilities of the firm (industry) are a function of different combinations of supply activities. The algebraic representation of the CET function for combinations of supply activities is:

$$Z = B\left[\sum_{i=1}^{n}\gamma_i Q_i^{-\rho}\right]^{-\frac{1}{\rho}} \qquad \text{(CET.1)}$$

where Z is a measure of the firm's overall capacity to produce, and Q_i is a measure of the output level of each supply activity 'i'. As with the CES, B and γ_i are efficiency and share parameters respectively and ρ is a transformation elasticity.[8] Moreover, the function shown is linearly homogeneous, where a doubling of output from each supply activity (Q) doubles the firms overall capacity of output (Z).

The derivation of activity supplies is a revenue maximisation process subject to a production possibilities frontier. The mathematical derivations are parallel exactly to the CES function, where the elasticity of transformation between supply activities is equivalent to the elasticity of substitution in inputs.

2.2 The Theoretical Structure of a Stylised CGE Model

This section discusses the core principles behind the development and structure of computable general equilibrium modelling. At the simplest level, a CGE model consists of a system of equations specifying the behavioural characteristics of producers and consumers, where the aim is to find a vector of prices and quantities which satisfies the market clearing mechanisms.

For purposes of illustration, the model structure chosen here contains a single household and 2 "single-output" industries each employing 2 primary factors. The economy is assumed to be 'closed' (i.e. no external trade) with no government intervention and no savings. Behavioural equations are derived from constrained optimisation techniques based on established principles of neo-classical theory (i.e. utility maximisation, cost minimisation).

2.2.1 Demand for Final Commodities

Household demand is based on the maximisation of a linearly homogeneous Cobb-Douglas utility function for a two commodity (i=1,2) economy:

$$U = X_1^{\alpha} X_2^{\beta} \qquad \text{(CGE.1)}$$

subject to a budget constraint:

$$Y = P_1 X_1 + P_2 X_2 \qquad \text{(CGE.2)}$$

From section 2.1.3, uncompensated demands are given as:

---

[8] The difference between CES and CET is that in CET, ρ is limited to be less than–1 whereas with CES ρ is greater than –1. Thus, CES is convex with respect to the origin and CET is concave with respect to the origin.

$$X_1 = \frac{Y}{P_1}\alpha \qquad \text{(CGE.3)}$$

$$X_2 = \frac{Y}{P_2}\beta \qquad \text{(CGE.4)}$$

2.2.2 Demands for Factor Inputs

On the production side, it is assumed that the production of commodity 1 and 2 (Q_i (i=1,2)) is governed by a CRS CES aggregate of primary factors labour (L_i) and capital (K_i):

$$Q_i = A_i[\delta_i L_i^{-\rho_i} + (1-\delta_i)K_i^{-\rho_i}]^{-\frac{1}{\rho_i}} \qquad \text{(CGE.5)}$$

Denoting 'w' and 'r' as the price of primary factors labour and capital respectively, minimising the cost of the factors, subject to the CES production function gives Hicksian demands:[9]

$$K_i = Q_i \frac{1}{A_i}\left[\delta_i\left[\frac{w(1-\delta_i)}{r\delta_i}\right]^{\frac{\rho_i}{1+\rho_i}} + (1-\delta_i)\right]^{\frac{1}{\rho_i}} \quad (i=1,2) \qquad \text{(CGE.6)}$$

$$L_i = Q_i \frac{1}{A_i}\left[\delta_i + (1-\delta_i)\left[\frac{r\delta_i}{w(1-\delta_i)}\right]^{\frac{\rho_i}{1+\rho_i}}\right]^{\frac{1}{\rho_i}} \quad (i=1,2) \qquad \text{(CGE.7)}$$

2.2.3 The General Equilibrium System of Equations

Having derived the behavioural equations pertaining to each agent (producers and household) in the model, it is now possible to enforce equilibrium conditions by introducing market clearing equations. Assuming perfect competition and perfect mobility across factor markets, the demands for commodities and factors (i.e. full employment) are equal to their respective supplies. Finally, an accounting equation is

[9] It is assumed that factors are perfectly mobile between industry 1 and 2, although it is not uncommon to specify factors as "sluggish" yielding different factor rewards by sector. This approach is employed in the final model and is discussed in chapter 4.

introduced which ensures that the household collects payments from the ownership of the factors of production.

$$Y = w(L_1 + L_2) + r(K_1 + K_2) \qquad \text{(CGE.8)}$$

COMMODITY DEMANDS

$$X_1 = \frac{Y}{P_1}\alpha \qquad X_2 = \frac{Y}{P_2}\beta$$

COMMODITY MARKET CLEARING

$$X_i = Q_i$$
$$i \in 1,2$$

FACTOR DEMANDS

$$K_i = Q_i \frac{1}{A_i}\left[\delta_i \left[\frac{w(1-\delta_i)}{r\delta_i}\right]^{\frac{\rho_i}{1+\rho_i}} + (1-\delta_i)\right]^{\frac{1}{\rho_i}} \qquad i \in 1,2$$

$$L_i = Q_i \frac{1}{A_i}\left[\delta_i + (1-\delta_i)\left[\frac{r\delta_i}{w(1-\delta_i)}\right]^{\frac{\rho_i}{1+\rho_i}}\right]^{\frac{1}{\rho_i}} \qquad i \in 1,2$$

FACTOR MARKET CLEARING

$$L_1 + L_2 = L^*$$
$$K_1 + K_2 = K^*$$

HOUSEHOLD INCOME

$$Y = w(L_1 + L_2) + r(K_1 + K_2)$$

ZERO PROFIT CONDITION

$$P_i Q_i = wL_i + rK_i \qquad i \in 1,2$$

Figure 2.3: A Stylised Closed Economy CGE Model

where factor payments are exhausted on the purchase of commodities 1 and 2 given by the household budget constraint. Finally, zero profits in both industries are assumed:[10]

$$P_i Q_i = wL_i + rK_i \qquad i \in 1,2 \qquad \text{(CGE.9)}$$

In essence the model becomes a closed "circular flow" economy, where production of commodities yields factor income to the household, which in turn is equal to total commodity expenditures. Thus, the value of total output by both industries is equal to the value of household income, which is by definition equal to household expenditure. The solution of the model will be determined by the vector of commodity and factor prices which enables all markets to clear. The model consists of 15 variables given as: X_1, X_2, Q_1, Q_2, L_1, L_2, K_1, K_2, Y, P_1, P_2, r, w, L* and K*. The latter two variables refer to the total endowment of each factor in the economy and are held exogenous to ensure correct model *closure* (i.e., number of equations and variables are equal – see next section). The full stylised 13 equation model is presented in figure 2.3.

Two further issues need to be addressed, the root of which lies within *Walras' Law*. First, due to zero homogeneity in prices in the demand functions, the *absolute* price level has no effect on the level of demand. For example, to show zero degree homogeneity for all prices in the commodity demand functions, substitute (CGE.8) into (CGE.3) and (CGE.4) and impose the factor market clearing equation which yields:

$$X_1 = \alpha\left[\frac{w}{P_1}L^* + \frac{r}{P_1}K^*\right] \qquad \text{(CGE.10)}$$

$$X_2 = \beta\left[\frac{w}{P_2}L^* + \frac{r}{P_2}K^*\right] \qquad \text{(CGE.11)}$$

where commodity demands X_1 and X_2 are clearly zero degree homogeneous in all prices.

---

[10] Where composite output price and quantity variables are linear homogeneous in input prices and input quantities respectively.

This property implies that any level of absolute prices is consistent with a general equilibrium solution. In other words, the absolute price level is *indeterminate* and thus holds no intrinsic meaning. It is often convenient to remove this indeterminacy by setting one of the prices to unity. Thus, if the price of commodity 1 is exogenised and set equal to one, this is in effect a normalisation of the system of equations, where all price movements are now gauged as *relative* to an exogenously fixed *numeraire variable*.

The availability of a numeraire is a direct consequence of *Walrasian* theory which states that a unique vector of prices will ensure the solution to a general system of equations such that all commodity and factor markets clear. Walras demonstrated that if N-1 markets in the system clear, then the N^{th} market will clear. This therefore allows the modeller to omit one equation from the model system, and in having a numeraire, one is left with N-1 endogenous variables and N-1 equations.[11] Another possible alternative (Hertel, 1997) is to specify a walras "slack" variable which can be added to any equation in the model. If all of the markets in the model clear, an endogenous slack variable, which is endogenised and swapped with the numeraire, will assume a value of zero. This serves as a useful check on model implementation.[12]

2.3 Closure

A further issue of model structure is one of closure which was briefly mentioned in sub-section 2.2.3. For a model to be solvable, the number of endogenous variables must be equal to the number of equations. *Closure* is the process by which the model variables are partitioned into exogenous and endogenous categories. Exogenous variables may then be shocked and the resultant effects on the endogenous variables ascertained. Moreover, different partitions of the exogenous and endogenous variables entails making some maintained hypothesis beyond the core mechanisms of the model equations.

For example, single country models may have some form of *external closure* based on the *small country assumption.* This maintained hypothesis states that the country does not have the necessary market power to affect world prices. Thus, world commodity

[11] The numeraire does not have to be in the omitted equation.
[12] This approach is employed in the final model structure.

prices are typically assumed exogenous, and the transmission mechanism between world and domestic prices is via an exchange rate which adjusts to ensure equilibrium in the balance of payments (Shoven and Whalley, 1992, ch.9). In other words, import- and export-demands are determined by a balance of payments market clearing equation. For large country single region models, the import- and export- demand equations may be characterised explicitly using a specific functional form, although simultaneous changes in these demands and the exchange rate must still satisfy the balance of payments constraint (Shoven and Whalley, 1992).

For CGE trade models consisting of two or more regions, external closure is not needed because the interactions of export supply and import demand functions allow an endogenous treatment of trade prices and quantities along bilateral routes. In the case of multi-region models, it is often convenient to think of closure at both the *regional* and *global* level.

At the *regional* level, one can characterise two categories of income flows in CGE trade models. *Expenditure* flows are characterised by; savings (S); government expenditures (G); consumption expenditure (C); and imports (M). Similarly, *revenues* are split up into; investment goods (I); government incomes (G); consumption goods sales (C); and exports (X).[13] In equilibrium, expenditures equate revenues such that:

$$S + G + C + M = I + G + C + X \qquad \text{(CL.1)}$$

Since government and consumption markets clear, this implies:

$$S - I = X - M \qquad \text{(CL.2)}$$

Thus, if deviations occur between regional savings and investment, then this must be matched by changes on the current account balance. Alternatively, fixing the trade balance, X-M, means that movements in the level of savings must be shadowed by changes in investment expenditures.

[13] The designation of consumption and government expenditures and incomes is the same since in equilibrium the two concepts must be equal

There are several closure solutions to the fundamental indeterminacy of investment in comparative static models, although the model application used in this thesis holds the balance of payments at zero such that *external* leakages (savings and imports) are equal to injections (investment and exports) and regional closure is satisfied.

Investment may be specified as being *savings driven*, where 'household' utility accrues through the consumption of a savings good, which is met by production of investment. Thus, the sum of regional savings determines global investment. Since regional incomes, and thus regional and global savings typically change very little, global investment also changes very little, although reallocations of *regional* investment shares may be considerable.[14]

At the global level, if all n-1 markets are in equilibrium, if producers are earning zero profits and if consumers are on their budget constraints then Walras' law will apply such that the n^{th} market or *global* savings will equal *global* investment. In other words, Walras law implies the *global closure identity*:

$$\sum_{r \in regions} S_r = \sum_{r \in regions} I_r \qquad \text{(CL.3)}$$

Thus, regional closure is required such that the n^{th} savings-investment market also clears via Walras law.

2.4 Calibration of CGE Models

This section discusses the advantages/disadvantages of calibration vis-à-vis the econometric approach. The simple calibration example provided is intended to be *general*, since the final CGE model representation used in this study is in linear form, which reduces the difficulty of calibration in the model structure (see section 2.5.3). Nevertheless, this is still regarded as a significant issue of debate in CGE model structure and deserves attention in this chapter.

[14] If one uses a rate of return mechanism to allocate regional investment, this may lead to large discrepancies between regional savings and investment, which must be picked up in the trade balance for regional closure to be satisfied (equation CL.2).

2.4.1 Econometric estimation

Given the dimensions of most CGE model structures, any attempt to estimate simultaneously all model parameters from time series data would require prohibitively long runs of data observations to estimate model parameters, which in turn depends on functional form used, the quality of the data and the size of the system one is attempting to estimate.[15] Given that all but the simplest of general equilibrium models have large numbers of parameters to estimate, this typically leads to complications, whereby the number of parameter estimates exceeds the number of data observations which leads to degrees of freedom problems.

Another problem of econometric estimation is that of non-independent error terms. Consider, for example the factor market clearing equations in figure 2.3. Clearly, these equations link the CES demands for factors to the exogenously specified endowments of capital and labour in the economy. Econometrically, this would imply that successively estimated input demand functions (i.e. through time) would not be independent of one another and gives rise to the problem of non-independently distributed error terms.

Attempts to overcome problems of degrees of freedom and autocorrelation led some researchers (Jorgensen, Lau and Stoker 1982; Jorgensen, 1984) to estimate 'subsystems' which avoid the inclusion of equations with autocorrelated error terms and impose cross equation restrictions to lessen degrees of freedom problems. There is a related problem here in that,

> *'estimates determined from the subsystems (with their implicit exogeneity assumptions) are then put into a model which explicitly recognises the endogeneity of all the variables'* (Roberts, 1992, pp91).

Whilst there are numerous difficulties that arise when attempting to estimate a general equilibrium system of equations, econometricians may argue that the lack of any stochastic element in the calibration procedure is untenable, particularly when one has to accept deterministic parameter findings which in themselves are not *statistically*

[15] This is of course assuming that time series data are available to the level of aggregation required by most CGE models, whereas usually they are not.

justifiable. Within the econometric approach, there are numerous sample goodness-of-fit tests to verify the reliability of the parameter estimates. Conversely, if a calibrated approach is used then no such tests exist. Hence the modeller is merely left with the subjective art of choosing parameters, calibrating, and employing sensitivity analysis to validate model results.[16] Finally, inherent determinism in the calibration procedure implies that the modeller has to assume the choice of functional form, rather than having the opportunity to fit a series of functions to observed data.

2.4.2 Calibration and Functional Form

For the reasons above, the alternative of 'calibration' is favoured by CGE modellers, defined by Greenaway *et al.* (1993) as a:

> ' *deterministic procedure which computes values for unknown parameters of the functional forms used in an applied general equilibrium model from an observed data set. It is assumed that the data set represents an equilibrium for the general equilibrium model under consideration (benchmark equilibrium data set). The model is then solved for its unknown parameters as functions of the observed data. Typically calibration uses only one period (or an average over periods) data'.(pp109)*

In other words, calibration 'maps' parameters from the chosen functions onto the existing static data set, rather than attempting to estimate a system of parameters from scratch using data observations and econometric techniques. The desired end result of model calibration is that the initial data set be perfectly replicated as an initial benchmark solution of the model. Depending on the choice of functional form, a unique solution of parameters as a function of the observed data set may not be obtained. For example, unless a Cobb-Douglas representation is specified, then *parameterised values*, such as elasticity estimates must be obtained, (if possible from the literature), before determination of other model parameters.

[16] Preferably parameters come from the same time period as the benchmark year, or where available by 'borrowing' estimates from other periods or countries.; Sensitivity analysis involves systematically employing different values of key parameters and running multiple simulations to attain central tendency figures. This improves the level of confidence in the expected results.

More complex, flexible functional forms may sometimes be employed in CGE applications, but they significantly enhance the complexity of the model, increase execution times for model solution calculations and require a much larger number of extraneous (pre-specified) substitution parameters. Moreover, since the value of extraneous parameter values affects the magnitude of the model results, this implies greater subjectivity of model results.

Consequently, the main criteria in the choice of functional form for CGE calibrations tend to be 'consistency' and 'tractability'. Thus, there must be consistency with the theoretical assumptions, however, the function must also easily allow the computation of equilibrium solutions to household and producer constrained optimisation problems. Such requirements typically lead to the use of 'convenient functional forms' such as the Cobb-Douglas (CD) and Constant Elasticity of Substitution (CES).

This reduction in the number of parameters has a cost, in that it inhibits the degree of flexibility inherent within producer/consumer behaviour. A common response to this problem is to break the 'convenient' function into *nests*. This allows the modeller to calibrate model parameters with relative ease whilst breaking up a single stage optimisation process into multiple stages. Allowing, for example, an 'appropriate' elasticity of substitution value for each nest, enables the modeller to employ several behavioural parameters within the nest whilst not significantly increasing the degree of complexity in the calibration process. Further discussion of nesting is given in section 2.6.

This type of remedial action does not, however, detract from the fact that many of the family of convenient functions still have restrictions. For example, Cobb-Douglas functions imply unitary uncompensated own-price and income elasticities. The CES relaxes the former restriction, although income elasticities are unitary. This latter assumption is rather more difficult to justify given the large body of evidence suggesting that food expenditure declines with increases in expenditures.

2.4.3 A Simple Numerical Example of Calibration

Before calibrating the model, the first task is to separate the 'value' observations in the benchmark data into price and quantity observations. A commonly used technique, originally adopted by Harberger (1959, 1962), is to adopt the convention that one unit of each factor (or commodity) is worth 1 currency unit.

To illustrate the process of calibration, a simple numerical example is based on the stylised model presented in section 2.2. The derived values of each of the unknown parameters are based on the hypothetical input-output data set presented in table 2.1 above. In the data set, the total value of production of each commodity is equal to the value of sales of each commodity to the household. Similarly, total primary factor returns are equal to household income. In sum, the general equilibrium restrictions apply, where household income and expenditure are equal, which in turn is equal to the total value of production. Further discussion of input-output tables and their larger Social Accounting Matrix (SAM) counterparts is provided in chapter 4.

	Industry		**Households**	**Total Sales**
	1	**2**		
Commodity: 1	-	-	3	**3**
2	-	-	5	**5**
Primary Factors:				
Labour	2	2	-	**4**
Capital	1	3	-	**4**
Production	**3**	**5**	**8**	**16**

Table 2.1: Hypothetical Input-Output Value Data

Starting with the Cobb-Douglas commodity demands in the model, it is possible to rearrange equations (CGE.3) and (CGE.4) to yield:

$$\alpha = \frac{X_1 P_1}{Y} \qquad \text{(CAL.1)}$$

$$\beta = \frac{X_2 P_2}{Y} \qquad \text{(CAL.2)}$$

Given that Y is equal to total expenditure, the parameters α and β in the Cobb-Douglas utility function are expenditure shares for commodity 1 and 2 respectively, which sum to one. Hence, it is a simple procedure to calibrate these parameters from table 2.1 as:

$$\alpha = \frac{3}{8} = 0.375 \qquad \beta = \frac{5}{8} = 0.625 \qquad \text{(CAL.3)}$$

The calibration of the unknown parameters of the CES production function is slightly more complicated. Firstly, it is necessary to impose an extraneous value for the elasticity of substitution (σ_i) between capital and labour within each industry 'i' (i=1,2) in the model. Assume for simplicity that these values are 2 and 0.5 for industry 1 and 2 respectively. Given that:

$$\sigma_i = \left(\frac{1}{1+\rho_i} \right) \qquad \text{(CAL.4)}$$

where ρ_i is assumed to have a value of –0.5 and 1 for industry 1 and 2 respectively. The other unknowns in the CES functions are the distribution parameters (δ_i), and the scale parameters (A_i), which are calibrated below.

Taking the first order conditions from a two input cost minimisation procedure and dividing, yields:

$$\frac{w}{r} = \frac{\delta_i}{(1-\delta_i)} \left[\frac{L_i}{K_i} \right]^{-(1+\rho_i)} \qquad \text{(CAL.5)}$$

Hence, calibration of δ_i (i=1,2) involves substituting in the value flows and the parameterised values of ρ_i into expression (CAL.5) for both industries 1 and 2. Noting that the price of factors are worth one currency unit, and employing the subsequent quantities of labour and capital from table 2.1, for i=1:

$$\frac{1}{1} = \frac{\delta_1}{(1-\delta_1)} \left[\frac{2}{1} \right]^{-0.5} \qquad \text{(CAL.6)}$$

Rearranging in terms of δ_1:

$$\delta_1 = 1/1.7071067 \qquad \text{(CAL.7)}$$

gives a value of 0.586 (3dp). A similar procedure can be employed for δ_2 which gives a value of 0.308 (3dp).

To find scale parameter A_i (for i=1,2) simply substitute the value and parameter values obtained in table 2.1 into the CES production function (CGE.5). Thus, for i=1,

$$3 = A_1[0.5857864 \times (2)^{-(-0.5)} + 0.4142136 \times (1)^{-(-0.5)}]^{-\frac{1}{(-0.5)}} \qquad \text{(CAL.8)}$$

Simplifying and rearranging in terms of A_1 gives a value of 1.943. Conducting the same procedure for A_2 gives the value 1.923.

The numerical example above highlights the importance of extraneous parameter values for the success of the calibration procedure. Moreover, the choice of these values will also have implications for subsequent counterfactual results. However, the difficulty in choosing parameterised values is the uncertainty as to what the value of the parameter should be. For example, there is no consensus on the 'true' elasticity of substitution between factors (capital and labour) within different industries. Caddy (1976) reconciled this debate to an extent with a comprehensive econometric estimation of substitution elasticities from which he constructs 'central tendency' tables. These and many tables like them are often used in the applied literature.

2.5 Model Representation and Solution Methods

An important part of CGE analysis is deeply rooted in computational facility and solution methods and this has often sparked furious debate amongst applied economists on CGE model structure. More specifically, this debate is examined by Hertel *et al.* (1992), who classify model representation into two schools of thought, namely, the ‘North American levels schools’ and the 'Norwegian-Australian school of linearisers'.

The 'levels school', which represents the model equations in the format of the stylised closed economy model in section 2.2, attempts to find a solution through the derivation of a series of excess demand functions of the model system. Much of the work in the literature stems from Scarf (1967a, 1967b), and is based on the proof of an 'existence' of fixed equilibrium points in which his non-linear algorithm guarantees convergence to the approximate fixed point within a few steps. Computationally, however, Scarf's algorithm was expensive and has since been modified in terms of efficiency and applicability by *inter alia* Merril (1972) and Van der Laan and Talman (1979).

The ‘linear school’ approach was pioneered by Johansen (1960), in forecasting growth levels in the Norweigan economy. Using a single country, 22 sector model, Johansen proceeds in the words of Taylor (1975) by,

> *'logarithmically differentiating the equations....with respect to time in order to get a simultaneous system of equations which are linear in all growth rates' (p.100).*

Once the equations are linearised and the endogenous/exogenous split has been established, the model is solved as a linear approximation to the structural equations of the model. Hence, solutions may be found by 'shocking' the exogenous variables and then recalculating the model solution.

According to Hertel *et al.* (1992), there has been considerable confusion in the past due to the tendency to classify models according to the solution method employed. Thus, linear models are not necessarily Johansen models and have only been so designated because the solution method used to solve them has traditionally been a single step Johansen procedure. Indeed, the linear representation of the model serves as a platform from which a plethora of solution methods can be used. In subsequent chapters, a Johansen-based non-linear solution method (Gragg) is employed to solve a linear representation of a model system. Thus, the remainder of this section is given to linear based solution techniques and linearisation procedures.

2.5.1 Solution Methods For Linearised Representations

It is possible to illustrate schematically how a linearised representation can be used to obtain accurate solutions. At the simplest level, assume a model consisting of two variables X and Y, where the former is exogenous and the latter endogenous. Further, assume the model function may be represented by the single function, g(X,Y), which is presented in figure 2.4.

Taking the initial (or benchmark) solution of the model as point (X,Y), an exogenous shock from X to X_1 creates an actual change of Y to Y_1 (or A to B) in the function g(X,Y). The Johansen procedure involves calculating the derivative (dY/dX) at point A, and then passing between X and X_1, one moves along the tangent to the function g(X,Y) at A, bringing us to the point B_1. This represents the *linearised* approximation to the non-linear solution at point B. Intuitively, the bigger the initial shock on X, the poorer the quality of the estimation as the tangent gets further from the 'true' solution (see section 2.5.3).

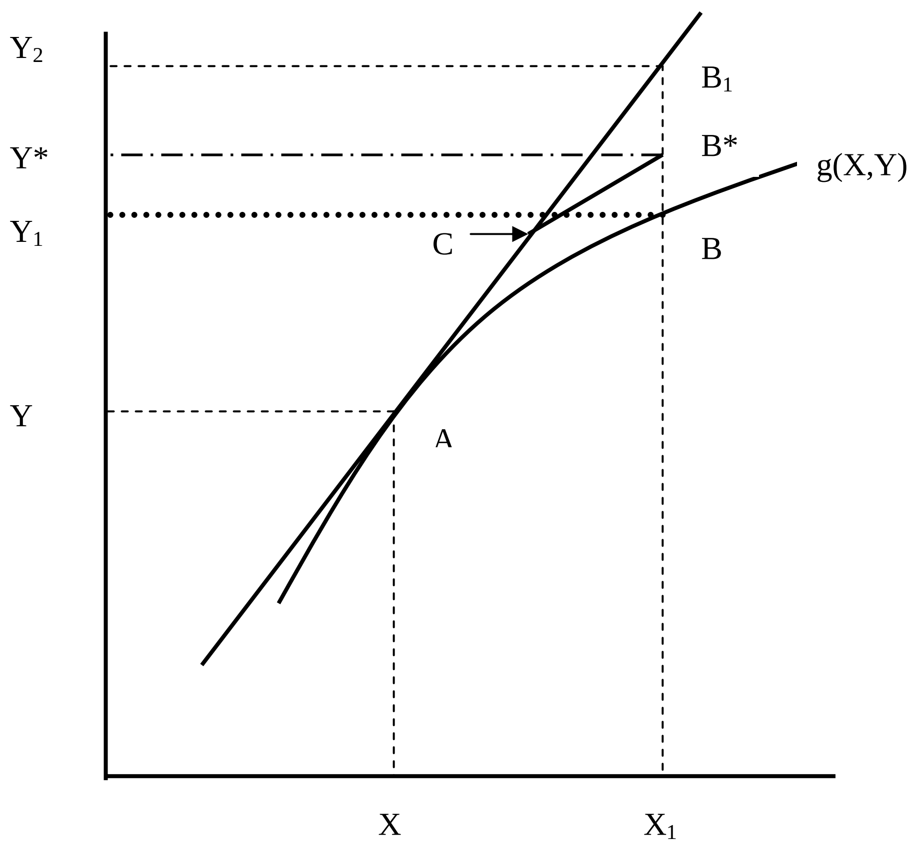


Figure 2.4: Johansen and Euler Solution Procedures
Source: Pearson (1991)

One way of reducing the linearisation error is to follow the function g(X,Y) = 0 more closely by breaking the shock into a number of equi-proportional steps - this is known as an *Euler Solution Method*. Thus, in the *2-step* Euler solution (i.e. the Johansen is equivalent to a single step Euler solution), one proceeds half way along the tangent to point C in the figure. At this point, an *update* procedure of the endogenous variable Y occurs to ascertain the position of the endogenous variable, Y, half way along the tangent. Then from this point, the remaining part of the shock is implemented, where one ends up at point B*, giving a solution Y*.

Following this logic, a higher step solution procedure would yield a much closer approximation to the function, g(X,Y). Hertel *et al* (1992) argue that a solution procedure such as the *Euler* n-step method takes the model into a non-linear dimension because,

> *'like many other non-linear solutions, (Euler's solution) can be used to obtain solutions of any desired accuracy......the way Euler's method relies on calculations of derivatives and partial derivatives has a great deal in common with many other non-linear algorithms' (p.397).*

One potential drawback of Euler's method relates to computational expense in terms of the solution time required to achieve convergence to a true solution for larger classes of models. This problem can be remedied by *extrapolation*, which relies on being able to identify a pattern connecting successive elements in a sequence of steps. To ascertain this pattern, extrapolation uses the mathematical principle of the *limit theorem*, where the point at which the exogenous variable (X) is near to the end of the shock (i.e. approaches zero), the endogenous variable (Y) approaches it's true value (which is Y_1 in the figure). Algebraically, this is expressed as:

$$\lim_{X \to 0} Y(X) = Y_1 \qquad \text{(SM.1)}$$

Thus, taking three Euler simulations (e.g., 5-step, 10-step and 20-step) as points of reference along this domain, the model software estimates using a polynomial function of sufficient degree to estimate, with a high degree of accuracy the final 'true' value of the endogenous variable. The Euler solution method represents just one possible alternative which can be applied once the derivatives are known via a linear representation of the model.[17]

2.5.2 Summary of Solution Methods

The reason why, for many years, modellers have preferred the non-linear algorithm to the Johansen method, has been attributed to the greater accuracy of non-linear algorithmic solutions (see Hertel *et al*., 1992). Moreover, since the linearised method has traditionally been solved by a Johansen approach, the definitions of model solution and model representation (i.e., levels or linear equations) have been inextricably linked over the decades. Consequently, the effect of the *relatively* poor approximation obtained from the Johansen approach has caused much opinion to be biased against the linearised representation as well.

With the development of advanced computer software, there is now a reconciliation between the two schools. In the view of Hertel *et al.* (1992), multi-step procedures give credence to the linear representation, which was much criticised by proponents of the levels school on the grounds that such models were impossible to solve accurately. Equally, supporters of the linearised school are forced to accept the error of margin in the Johansen method and move to a multi-step extrapolation method for better quality results.

One can, therefore, conclude that improvements in computer technology now permits the use of several solution procedures to solve large scale CGE model structures to an equally high degree, rendering the 'importance' and 'classification' of the solution procedure (and thus representation) of trivial interest.

2.5.3 Linearisation

In section 2.2, a stylised closed economy model is represented in levels form. The use of a single step linear approximation by Johansen (1960) and more advanced non-linear derivatives (Euler, Gragg) has given prominence to a linearised representation of the CGE model structure. This section shows how to derive a linear representation of a levels function, which will be employed in the final model structure in later chapters. A

[17] For further discussion see Pearson (1988).

more complex linearisation example can be found in the appendix which provides the derivations of a nested linearised structure.

With multivariate functions, the total differential calculates the change in the dependent variable dz at a point brought about by an *infinitesimal* change in each of the independent variables denoted as dx and dy. Thus, if a multivariate function is given as:

$$z = z(x, y) \qquad \text{(LIN.1)}$$

then the total differential is:

$$dz = \left(\frac{\partial z}{\partial x}\right)dx + \left(\frac{\partial z}{\partial y}\right)dy \qquad \text{(LIN.2)}$$

Equation (LIN.2) measures the change of z with respect to infinitesimal changes in x and y.

More specifically, the total differentiatial of each of the structural (or levels) expressions makes use of three rules of differentials:[18]

The product rule	$R = PQ \Rightarrow r = p + q$	
The power rule	$R = P^{\alpha} \Rightarrow r = \alpha p$	(LIN.3)
The sum rule	$R = P + Q \Rightarrow r = pS_p + qS_q$	

where r, p and q are percentage changes (or they may be interpreted as changes in logarithms) in R, P and Q, α and β are parameters and S_p and S_q are the shares of P and Q in P+Q

Single step Johansen simulations produce linearisation errors when the data are updated by the percentage change variables. For example, using the linearised product rule above, if levels variables P and Q are originally valued at 10 and 5, their product is 50.

[18] For further discussion see Chiang (1984) p.196 and Horridge *et al.* (1993) Appendices A and E.

Changing *both* variables by *+10%*, gives P and Q values of 11 and 5.5 respectively which is a product increase of 21%, compared to the product rule result of 20%. Similarly, larger shocks of *+20%*, give P and Q values of 12 and 6 respectively and a product increase of 44%, compared to the product rule result of 40%. These results occur because the total differential only looks at infinitesimal changes along the curve, so the bigger the change *in a single step*, the poorer is the linear approximation. Conversely, multi-step procedures enable the data flows to be updated after each step, which reduces the linearisation error.

Thus, as an example, the total differential of the Marshallian Cobb-Douglas demand for commodity one (CD.29) in the stylised closed economy model is given as:

$$dX_1 = dY(P_1^{-1}\alpha) - dP(YP_1^{-2}\alpha) \quad \text{(LIN.4)}$$

To convert from differential changes to linearised percentage changes multiply and divide by respective variables and simplify which gives:

$$\frac{dX_1}{X_1}X_1 = \frac{dY}{Y}YP_1^{-1}\alpha - \frac{dP_1}{P_1}YP_1^{-1}\alpha \quad \text{(LIN.5)}$$

Dividing by X_1 and simplifying gives:

$$x_1 = y - p_1 \quad \text{(LIN.6)}$$

$$x_1 = \frac{dX_1}{X_1} \qquad y = \frac{dY}{Y} \qquad p_1 = \frac{dP_1}{P_1} \quad \text{(LIN.7)}$$

Equations (LIN.6) and (LIN.7) are in percentage form, where the lower case letters are the percentage changes in their respective upper case variables. Owing to the use of the Cobb-Douglas functional form, the linearised Marshallian CD function has an income elasticity of one, and own- and cross- price elasticities of minus one and zero respectively.

An important advantage of the linear approach is that the parameters (constants) of the function ‘drop out’ of the expression in the linearisation process, which precludes the need for their calibration. In the words of Hertel *et al.* (1992),

> *‘Linearisation in proportional or percentage changes takes advantage of the invariance to units implicit in rational economic behaviour. Those parameters deduced in the levels calibration process are not required, since their values merely reflect arbitrary price assumptions. Thus, no such calibration step is needed’ (pp394).*

Finally, percentage-change or log-change forms are not appropriate for variables which have initial values of zero. If the levels value at the start of the simulation is zero, the percentage change would be incalculable. To overcome this problem it can be convenient to work with *transformed variables*. A common example of this occurs where the initial value of a tariff is zero and the power of the tariff is represented as one plus the *ad valorem* rate. Thus it is possible to calculate percentage changes or changes in the logarithm of the power of the tariff but not in the *ad valorem* rate.

2.6 Nesting

As mentioned briefly in section 2.4.2, the choice of function under conditions of model calibration favours the use of simpler 'convenient functional forms'. The drawback, however, is that simpler functional forms greatly restrict the number of parameters within the function, which in turn inhibits the degree of flexibility when characterising producer/consumer behaviour.

A common response to this problem is to employ a *separable nested* (or hierarchical) structure, whereby an assumption is made about the partitioning of the elements of the underlying production/utility function into different groups and aggregations. Hence, the assumption of separability implies that constrained optimisation is undertaken in several stages. Nested structures then allow a greater number of elasticity parameters at each stage of the production/utility function. This increases the flexibility of the model, without burdening computational facility.

2.6.1 Separability and Aggregation

In order to undertake a two-stage nested optimisation procedure, two conditions must be met. First, to permit a partitioning of the inputs, Strotz (1957) devised the concept of weak separability. A precise definition of separability is given by Chambers (1988) who notes,

> *'separability hinges on how the marginal rate of technical substitution (MRTS) between two inputs responds to changes in another input'* (pp.42).

To illustrate the relationship between separability and multi-stage optimisation, a theoretical example is employed. Assume a 3 factor (x_i i=1,2,3) production function which is of the form:[19]

$$Y = f(X, x_3) \qquad \text{(N.1)}$$

where input X is represented as an *aggregator function* consisting of inputs x_1 and x_2:

$$X = g(x_1, x_2) \qquad \text{(N.2)}$$

A schematic representation of this two-level nested structure is presented in figure 2.5.

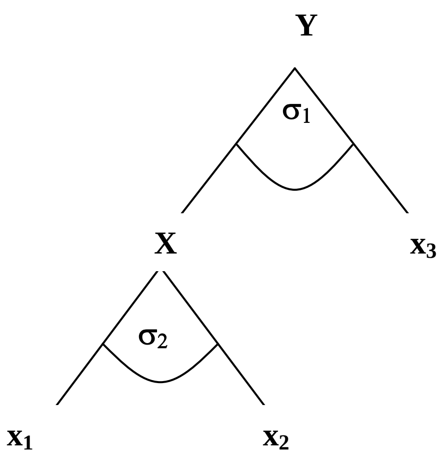


Figure 2.5: A Two-level nested production structure

[19] This theory is equally applicable to the utility function in consumer theory.

It is assumed that the underlying production function (N.1) is weakly separable implying (using Chambers' (1988) notation):

$$\frac{\partial}{\partial x_3}\left(\frac{\partial X / \partial x_1}{\partial X / \partial x_2}\right) = 0 \qquad \text{(N.3)}$$

In words, this expression states that the ratio of marginal products (MRTS) of inputs x_1 and x_2, belonging to the same input nest X, is not affected by changes in the level of input usage of x_3 which is not in that nest. The family of convenient functions such as CD and CES exhibit weak seperability, where in the case of a two-level nested CD production example:

$$Y = AX_1^{\alpha} X_2^{\beta} \qquad \textit{and} \qquad X_1 = Ax_{11}^{\gamma} x_{21}^{\delta} \qquad \text{(N.4)}$$

The $MRTS_{11,21}$ can be shown to be:

$$MRTS_{11,21} = \frac{MP_{11}}{MP_{21}} = \frac{\gamma}{\delta}\frac{x_{21}}{x_{11}} \qquad \text{(N.5)}$$

Clearly, changes in the level of X_2 in the upper CD nest, has no effect on the MRTS between inputs x_{11} and x_{21} in the lower nest. Mathematically:

$$\frac{\partial}{\partial X_2}\left(\frac{\gamma}{\delta}\frac{x_{21}}{x_{11}}\right) = 0 \qquad \text{(N.6)}$$

The second condition is that the aggregator function (N.2) must be linear homogeneous with respect to each of its inputs. In section 2.1.3, it was shown that the output price composite of a linearly homogeneous function is linearly homogeneous in input prices. Thus, the aggregate quantity and price indices are equal to the sum of the prices and quantities of the inputs derived in each nest:

$$RX = \sum_{i=1}^{n} r_i x_i \qquad \text{(N.7)}$$

A basic property of linear homogeneous functions outlined in section 2.1.3 (see equation CD.20), is that first order derivatives (i.e. marginal products/utilities) are homogeneous of degree zero (see pp26). To demonstrate this property, take the case of a linearly homogeneous Cobb-Douglas production function. Hence for a two input production function, MP_1 is given as:

$$MP_1 = \frac{\partial Y}{\partial x_1} = \alpha A x_1^{\alpha-1} x_2^{\beta} \qquad \text{(N.8)}$$

Multiplying each of the inputs by a scalar, λ, yields:

$$\begin{aligned} MP_1 &= \frac{\partial Y}{\partial x_1} = \alpha A(\lambda x_1)^{\alpha-1}(\lambda x_2)^{\beta} \\ MP_1 &= \frac{\partial Y}{\partial x_1} = \lambda^{\alpha-1+\beta} \alpha A x_1{}^{\alpha-1} x_2{}^{\beta} \qquad \text{(N.9)} \\ MP_1 &= \frac{\partial Y}{\partial x_1} = \lambda^{0}[\alpha A x_1{}^{\alpha-1} x_2{}^{\beta}] \end{aligned}$$

Thus, multiplying both inputs by λ, leaves the marginal product of x_1 unchanged. In other words the marginal products are zero degree homogeneous in inputs. The same outcome can be proved for input x_2. Since the MRTS is the ratio of MPs, then proportional increases in both inputs by the scalar value λ (implying higher isoquant levels) have no affect on the MRS. Thus, a ray from the origin must cut all isoquants (indifference) curves at points of equal slope. Green (1971) states that the isoquants (indifference) curves are therefore 'homothetic with respect to the origin' (pp141).

As a result of this property, Allanson (1989) notes that,

> '*optimal factor (commodity) allocations are independent of the level of (aggregate) output (income)' (pp.1).*

Increases in the level of aggregate output (utility) with relative input (commodity) price ratios fixed has no affect on factor intensity since the *expansion path* is a straight line from the origin.[20] Moreover, the assumption of weak separability ensures that the introduction of other inputs (commodities) not in the aggregator function also has no consequence for factor (commodity) usage ratios. Hence, changes in input (commodity) intensities x_i will only be a function of the relative prices of various types of input x_i in that part of the nest.

Allanson (1989) also notes that relative price changes in one nest can have *indirect* effects on input (commodity) allocations elsewhere in the nest. Referring to the nested structure in figure 2.5, if the price of input x_2 increases, this will affect the optimal combination of x_1 and x_2 in the aggregate nest, but due to the separability restriction, it will not directly affect the optimal use of x_3. There will, however, be an *indirect* effect on the use of x_3 due to a rise in the composite price of *aggregate* input X. This implies that the firm will substitute x_3 for aggregate X in the top nest. Moreover, if x_3 was an aggregate input, then as a consequence of linear homogeneity, its increased use would be translated proportionally to all inputs in that nest.

Thus, if expression (N.1) satisfies both weak separability and linear homogeneity, then the underlying production function is said to be *weakly homothetically separable* (or 'homogenously separable' Green 1971, pp.152-156) and ensures *consistent aggregation*.[21] Consistent aggregation makes it possible to index correctly over prices and quantities when forming composites such that multi-stage nested optimisation procedures give equivalent results to single stage optimisation problems (Ozanne, 1992).

2.7 Conclusions

This chapter provides a summary of the key issues in CGE model design and implementation. The first section examines the properties of the family of ‘convenient’ functional forms which are typically employed in CGE model structures. The chapter then proceeds to illustrate the usage of such functions in a simple stylised CGE closed

[20] Increases in aggregate output (utility) are movements onto higher isoquants (indifference) curves; Expansion paths join points of cost minimising equilibria.

[21] It is important to note that weak homothetic separability does not imply that the production function itself is homothetic.

economy model structure. Related issues of closure and calibration are discussed, where in the latter case, a simple numerical example is provided.

The chapter also discusses the concepts of model representation and solution methodology in CGE modelling. According to Hertel *et al.*, (1992), a link between these issues has incorrectly been forged, particularly where traditional linear approximated Johansen type solution procedures have been associated with linear equation CGE model structures. This myth has, at least partially, been dispelled by the advent of non-linear type solution algorithms (Euler, Gragg) based on the Johansen procedure, which can equally be applied to linear model structures (Hertel *et al.*, 1992). Some discussion is also given to the interpretation and implementation of linearised model equations, where the final model used in later chapters is linear in form.

The final section of the chapter discusses the use of nesting structures as a remedial measure against the lack of functional flexibility in CGE model structures. To help the reader interpret the mechanisms of linear model representation and nesting, which play an important role in subsequent chapters, a nested linear production function is presented in appendix A, which subsumes all of the types of convenient functional forms (i.e., CD, CES, Leontief). One popular application of the (two-stage) separable nested production structure in CGE multi-country trade modelling is the Armington assumption, which *differentiates* products by region of origin. A detailed exposition and critique of this mechanism is given in the next chapter, which serves as a platform for introducing other theories of product differentiation.

Appendix A: A Linearised representation of a nested production function

Consider a 2-stage nested production function (this approach can also be applied to a utility function), where final output is a Leontief function of a 'composite' intermediate input and composite primary factor. In the lower portion of the nest, the composite input/primary factor is subdivided into specific types 'i'. The intermediate input nest is characterised using CD substitution possibilities, and the value added nest is specified as CES.

The aim of the exercise is to present a range of possible linearised functional forms typically used in nested CGE model structures. Moreover, it will provide some insight into the interpretation of linearised functions which will be employed freely in the discussion in subsequent chapters.

A.2.1 Notation

$Z_k \Rightarrow$ Output in industry 'k'.

$P_k \Rightarrow$ The output price in industry 'k'.

$Y_{j,k} \Rightarrow$ Demand for the composite intermediate input, 'j' in industry 'k'.

$W_{j,k} \Rightarrow$ The input price of composite intermediate input, 'j' in industry 'k'.

$X_{j,k} \Rightarrow$ Demand for value added composite, 'j' in industry 'k'.

$U_{j,k} \Rightarrow$ The input price of composite primary factor, 'j' in industry 'k'.

$T_{i,j,k} \Rightarrow$ Input demand for intermediate input of type 'i', in composite intermediate input nest 'j' in industry 'k'.

$F_{i,j,k} \Rightarrow$ The price of intermediate input 'i'.

$V_{i,j,k} \Rightarrow$ Input demand for primary factor of type 'i', in composite value added nest 'j', in industry 'k'.

$R_{i,j,k} \Rightarrow$ The price of primary factor 'i'.

Lower case letters are the percentage change equivalent of the upper case 'levels' variable.

A.2.2 Schematic Representation of the Production 'Tree'

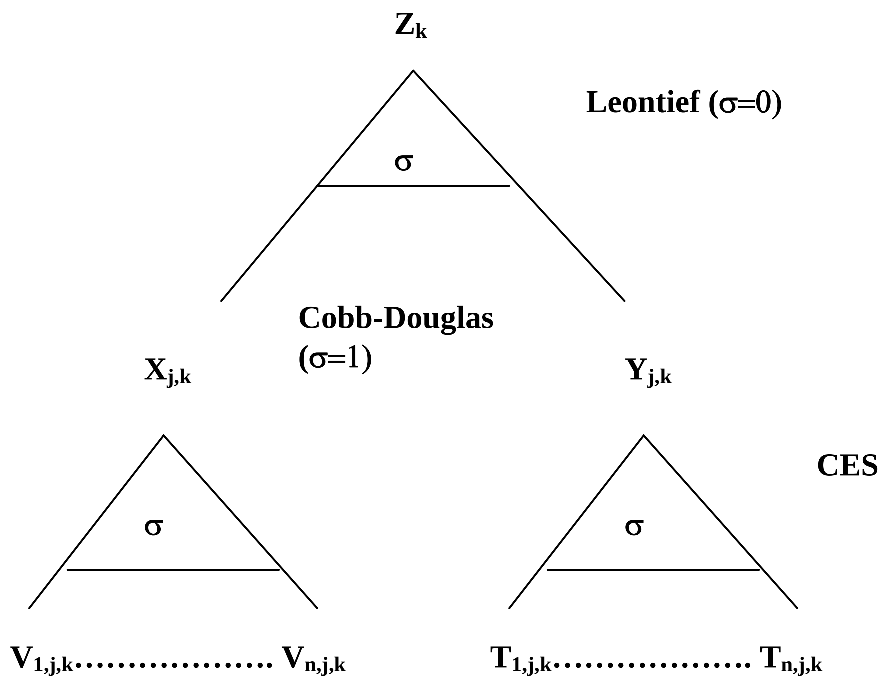


Figure A1: Schematic representation of the production nest.

A.2.3 Mathematical derivations of linearised nested demand functions

A.2.3.1 Composite Input Nest

This appendix is based on the mathematical techniques provided in Dixon *et al.*, (1992). The top nest in the tree is by definition a single production process Leontief structure. Hence, assuming rationality on the part of producers, levels demands for composite inputs are restricted by a fixed share coefficient. Composite intermediate and primary factor demands are given in equation A1:

$$Y_{j,k} = \gamma_{j,k} Z_k \qquad X_{j,k} = \gamma_{j,k} Z_k \tag{A1}$$

where $\gamma_{j,k}$ are the fixed input-output coefficients. Following the approach in section 2.5.3, linearised Leontief demands are given as:

$$y_{j,k} = z_k \qquad x_{j,k} = z_k \tag{A2}$$

Note that the absence of any price effects is due to the zero value of the elasticity of substitution. Hence, increases in output are translated as equiproportional changes in demands for each composite intermediate input which implies CRS.

Assuming zero profit:

$$P_k Z_k = W_{j,k} Y_{j,k} + U_{j,k} X_{j,k} \tag{A3}$$

Substituting demands in (A1) into (A3) and simplifying:

$$P_k = \gamma_{j,k} W_{j,k} + \gamma_{j,k} U_{j,k} \tag{A4}$$

Linearising gives a composite price of:

$$p_k = S_{1,k} w_{j,k} + S_{2,k} u_{2,k} \tag{A5}$$

where $S_{j,k}$ is an output share weighted by price, where for the composite intermediate input:

$$S_{1,k} = \frac{\gamma_{1,k} W_{1,k}}{\gamma_{1,k} W_{1,k} + \gamma_{2,k} U_{2,k}} \tag{A6}$$

A.2.3.2 Primary Factor Nest

In the primary factor nest, production is characterised by a CRS CES function:

$$X_{j,k} = A_{j,k} \left[\sum_{i=1}^{n} \delta_{i,j,k} V_{i,j,k}^{-\rho} \right]^{-\frac{1}{\rho}} \tag{A7}$$

where $A_{j,k}$ is a scale parameter, $\delta_{i,j,k}$ is a distribution share parameter and ρ is an elasticity parameter. Minimising cost subject to (A7) gives first order conditions:

$$R_{i,j,k} = \Lambda A_{j,k}\left[\sum_{i=1}^{n}\delta_{i,j,k}V_{i,j,k}^{-\rho}\right]^{-\frac{1+\rho}{\rho}}\delta_{i,j,k}V_{i,j,k}^{-(1+\rho)} \qquad \text{(A8)}$$

$$X_{j,k} = A_{j,k}\left[\sum_{i=1}^{n}\delta_{i,j,k}V_{i,j,k}^{-\rho}\right]^{-\frac{1}{\rho}} \qquad \text{(A9)}$$

Substituting (A9) into (A8) simplifies the latter:

$$R_{i,j,k} = \Lambda A_{j,k}^{-\rho}X_{j,k}^{(1+\rho)}\delta_{i,j,k}V_{i,j,k}{}^{-(1+\rho)} \qquad \text{(A10)}$$

where (A9) and (A10) are the levels first order conditions. This approach follows the treatment in Dixon *et al.* (1992) (pp124) by linearising the first order conditions and solving and is simpler than the alternative of deriving levels demand functions and linearising.

Thus linearisation of (A9) gives:

$$x_{j,k} = \sum_{i=1}^{n}S_{i,j,k}v_{i,j,k} \qquad \text{(A11)}$$

where

$$S_{l,j,k} = \frac{\delta_{l,j,k}V_{l,j,k}^{-\rho}}{\sum_{i=1}^{n}\delta_{i,j,k}V_{i,j,k}^{-\rho}} \qquad \text{(A12)}$$

Substituting (A10) into the input expenditure share formula (A13) in the intermediate nest:

$$\frac{R_{1,j,k}V_{1,j,k}}{\sum_{i=1}^{n} R_{i,j,k}V_{i,j,k}} \quad \text{(A13)}$$

and cancelling terms shows the equivalence of expressions (A12) and (A13). This alternative form of the share $S_{i,j,k}$ avoids the process of calibration since it eliminates distribution parameter $\delta_{i,j,k}$ where the shares are merely updated by the percentage changes in prices and quantities.

Linearisation of (A10) gives:

$$r_{i,j,k} = \lambda + (1+\rho)x_{j,k} - (1+\rho)v_{i,j,k} \quad \text{(A14)}$$

Thus, equations (A11) and (A14) are linearised first order conditions, where r, x, v and λ are percentage changes in R, X, V and Λ.

Rearrange (A14) in terms of $v_{i,j,k}$ gives:

$$v_{i,j,k} = -\sigma r_{i,j,k} + \sigma\lambda + x_{j,k} \quad \text{(A15)}$$

where σ is the elasticity of substitution between all pairwise types of primary factors (i.e. labour, capital) in the value added nest:

$$\sigma = \frac{1}{1+\rho} \quad \text{(A16)}$$

substituting (A15) into (A11) and rearranging in terms of $\sigma\lambda$ yields:

$$\sigma\lambda = \sigma\sum_{i=1}^{n} S_{i,j,k}r_{i,j,k} \quad \text{(A17)}$$

Substituting (A17) into (A15) eliminates the percentage change Lagrangian variable λ. Factorising the resulting expression gives linearised CES Hicksian primary factor demands:

$$v_{i,j,k} = x_{j,k} - \sigma\left[r_{i,j,k} - \sum_{i=1}^{n} S_{i,j,k} r_{i,j,k} \right] \quad \text{(A18)}$$

For consistent aggregation expression (A19) must hold:

$$U_{j,k} X_{j,k} = \sum_{i=1}^{n} R_{i,j,k} V_{i,j,k} \quad \text{(A19)}$$

By linearising (A19), substituting (A11) and rearranging, it is possible to derive the percentage change in the composite price in the value added nest as:

$$u_{j,k} = \sum_{i=1}^{n} S_{i,j,k} r_{i,j,k} \quad \text{(A20)}$$

Further substitution of (A20) into (A18) gives a simplified version of the linearised Hicksian demand function:

$$v_{i,j,k} = x_{j,k} - \sigma\left\lfloor r_{i,j,k} - u_{j,k} \right\rfloor \quad \text{(A21)}$$

Hence, equation (A21) shows how the demand for primary input 'i' can be broken into an expansion (or output) effect ($x_{j,k}$) and a price effect, the size of which is governed by the extraneous elasticity of substitution parameter, σ. The proportionality of changes in aggregated primary factor usage on each type 'i' is a reflection of constant returns to scale in the aggregator function. Moreover, any increase in the price of factor 'i' ($r_{i,j,k}$), relative to the composite price index ($u_{j,k}$), leads to reduced usage of primary factor 'i' relative to other primary factors in the nest. The size of this price substitution effect is dependent on the magnitude of the elasticity of substitution.

A.2.3.3 Intermediate Input Nest

The choice of functional form for the characterisation of intermediate input demands is a generalised Cobb-Douglas:

$$Y_{j,k} = B_{j,k} \prod_{i=1}^{n} T_{i,j,k}^{\alpha_{i,j,k}} \tag{A22}$$

where minimisation of cost subject to the production function (A22) gives the Lagrangian:

$$Z = \sum_{i=1}^{n} F_{i,j,k} T_{i,j,k} + \Lambda (Y_{j,k} - B_{j,k} \prod_{i=1}^{n} T_{i,j,k}^{\alpha_{i,j,k}}) \tag{A23}$$

Using the same principles as in section A.33.2, gives first order linearised conditions:

$$f_{n,j,k} = \lambda + y_{j,k} - t_{n,j,k} \tag{A24}$$

$$y_{j,k} = \sum_{i=1}^{n} \alpha_{i,j,k} t_{i,j,k} \tag{A25}$$

where the α parameters are cost shares (summing to one), in the same way that the α and β parameters in the 2 commodity stylised model utility function were expenditure shares.

Using the same methodology to solve first order linearised conditions gives Hicksian linearised Cobb-Douglas intermediate input demands:

$$t_{n,j,k} = y_{j,k} - \left[f_{n,j,k} - \sum_{i=1}^{n} \alpha_{i,j,k} f_{i,j,k} \right] \tag{A26}$$

Given consistent aggregation in the nest, the following accounting identity must hold:

$$W_{i,j,k}Y_{i,j,k} = \sum_{i=1}^{n} F_{i,j,k}T_{i,.j,k} \qquad \text{(A27)}$$

Linearising (A27), substituting (A25) and rearranging in terms of $w_{j,k}$ gives the linearised composite intermediate input price in the nest:

$$w_{j,k} = \sum_{i=1}^{n} \alpha_{i,j,k} f_{i,j,k} \qquad \text{(A28)}$$

Substituting (A28) into (A26) gives a simplified version of the Cobb-Douglas Hicksian demands for intermediate input 'i':

$$t_{n,j,k} = y_{j,k} - \lfloor f_{n,j,k} - w_{j,k} \rfloor \qquad \text{(A29)}$$

This linearised demand function has exactly the same interpretation as the CES primary factor demands in section A.33.2. The unitary value of the elasticity of substitution parameter is implicitly recognised within the price effect component of the demand function.

A.2.3.4 Summary of Production Nest Input Demands

Composite Input/Factor Demands (Leontief)

$$y_{j,k} = z_k \qquad \text{(A2)}$$

$$x_{j,k} = z_k \qquad \text{(A2)}$$

Composite price in the nest:

$$p_k = S_{1,k} w_{j,k} + S_{2,k} u_{2,k} \qquad \text{(A5)}$$

Primary Factor Demands (CES):

$$v_{i,j,k} = x_{j,k} - \sigma \lfloor r_{i,j,k} - u_{j,k} \rfloor \qquad \text{(A21)}$$

Composite price in the nest

$$u_{j,k} = \sum_{i=1}^{n} S_{i,j,k} r_{i,j,k} \qquad \text{(A20)}$$

Intermediate Input Demands (Cobb-Douglas):

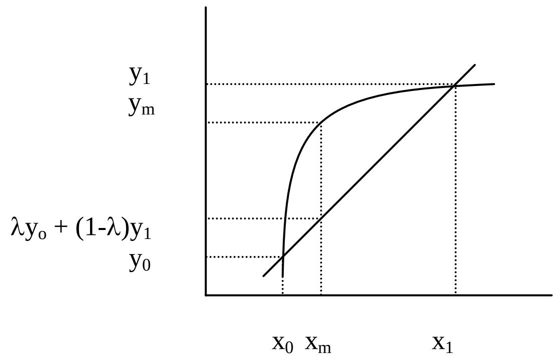
$$t_{n,j,k} = y_{j,k} - \lfloor f_{n,j,k} - w_{j,k} \rfloor \quad \text{(A29)}$$

Composite price in the nest:

$$w_{j,k} = \sum_{i=1}^{n} \alpha_{i,j,k} f_{i,j,k} \quad \text{(A28)}$$

Appendix B: Strict and Quasi Concavity

Following Beattie and Taylor (1985), *strict concavity* can be shown diagrammatically:



Where x_m is a weighted average ($0<\lambda<1$) of x_0 and x_1:

$$x_m = \lambda x_0 + (1-\lambda)x_1$$

Strict concavity implies that y_m must always be *greater* than a weighted value of y from a linear line connecting two points x_0 and x_1 in the domain. Thus, in the figure, the value of y corresponding to an arbitrary value x_m is:

$$\lambda y_0 + (1-\lambda)y_1$$

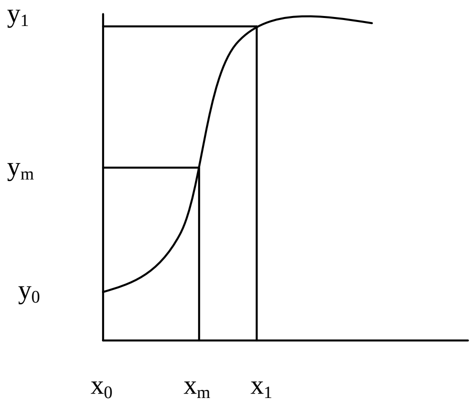
where

$$y_m > \lambda y_0 + (1-\lambda)y_1$$

Strict quasi-concavity states that all values of y_m will always be above the minimum value of the function in the domain. Algebraically:

$$y_m > \min(y_0, y_1)$$

Thus, if the minimum value of the function was y_0, then a strictly quasi-concave function would be represented as:



where the value of y_m will never fall below the minimum value (in this case y_0), although the shape of the curve does not have to be everywhere concave (for example between x_0 and x_1). Strict quasi- concavity is a more general form of concavity which is inclusive of strict concavity (i.e. all strict quasi-concave functions are strictly concave but not the other way round).

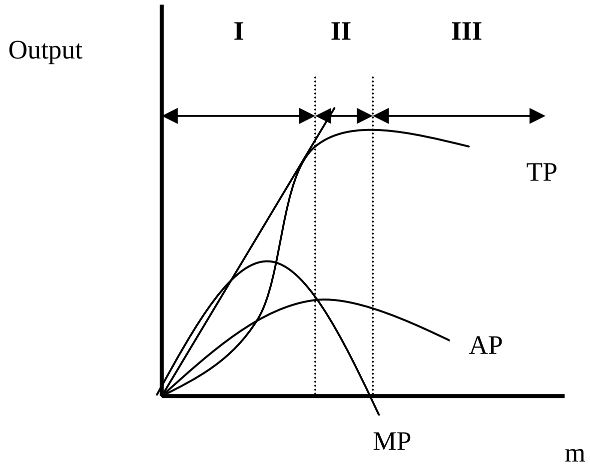
For CD and CES, the restrictions for both forms of concavity are:

	Strict Concavity.	Strict quasi-concavity.
$Y = AX_1^{\alpha} X_2^{\beta}$	$0 < \alpha < 1$	$\alpha > 0$
	$0 < \beta < 1$	$\beta > 0$
	$0 < (\alpha+\beta) < 1$	$A > 0$
	$A > 0$	
$Y = A[\delta_1 X_1^{-\rho} + (1-\delta_1) X_2^{-\rho}]^{-\frac{v}{\rho}}$	$0 < \delta_1 < 1$	$0 < \delta_1 < 1$
	$A > 0$	$A > 0$
	$\rho > -1$	$\rho > -1$
	$0 < v \leq 1$	$v > 0$

Under constant returns to scale, Cobb-Douglas parameters $\alpha+\beta$ must sum to one, which effectively rules out strict concavity.

Appendix C: Stages of Production.

Under neo-classical assumptions of diminishing marginal returns (short run) and returns to scale (long run) a production function (total product (TP) curve) may exhibit an ‘s’ shape which in turn has implications for marginal (MP) and average product (AP) curves. Schematically, the three stages are represented:



Source: Beattie and Taylor (1985)

where in the short-run ‘m’ is a single input and in the long-run, ‘m’ would be a proportional change in all inputs. Thus, stage I is characterised by increases in average productivity up to the point where MP cuts the AP curve at the highest point. Stage II is where MP is positive but everywhere below the AP curve. Stage III characterises negative productivity (i.e., MP is negative). Clearly, it is not sensible for rational producers to be in the third stage of production. Under profit maximising criteria in perfectly competitive input and output markets, equating Marginal Value Product (MVP = MP*P_{output}) with the Marginal Factor Cost (MFC = Average Factor Cost (AFC)) in stage I, will lead to losses where AFC is everywhere above Average Value Product (AVP = AP*P_{output}). Hence, according to the theory, stage II (MP<AP) is the only rational range within which to produce.

Chapter 3

Product Differentiation and Market Structure in CGE Modelling

The CGE trade literature is characterised by the use of multi- and single-country models. Multi-country models have a production and demand specification for each of the countries in question, whereas single-country models treat the 'rest of the world' with a cruder representation, as highlighted in section 2.3. The focus of many *single country* trade models is to simulate with degrees of complexity the effects of reductions/increases in a country's protective structure on the balance of trade, employment levels and the price level, etc. A typical application by Dixon, Parmenter, Sutton & Vincent (1982) examines the effects of a 25% increase in all Australian import tariffs, with results showing falls in employment, a worsening balance of trade deficit and increases in capital goods and consumer prices. These results, and many other single region treatments of trade, (see Feltenstein 1989, Hertel *et al.* 1989, Robinson *et al.* 1989) support the conventional wisdom that unilateral liberalisation leads to welfare gains.

Many early *multi-country* trade models (e.g., Brown & Whalley, 1980; Deardorff & Stern, 1981;Whalley, 1982, 1985), were employed to investigate the welfare and terms of trade effects from possible 'global liberalisation' scenarios related to the GATT Tokyo Round agreement.[1] Numerous studies have also been conducted for the subsequent Uruguay Round (Nguyen, Perroni and Wigle, 1991; Brown *et al.*, 1995; and Harrison *et al.*, 1995a, 1995b), which suggest that global liberalisation leads, with varying degrees of magnitude, to net global benefits (at least in the long run).

Another major policy issue in the multi-country trade policy modelling literature has been that of 'regional integration', for example the enlargement of the EU and the formation of trading blocs such as the North American Free Trade Area (NAFTA). One of the earliest CGE models dealing with EU enlargement is by Miller & Spencer (1977) who look at UK accession to the EU based on the installation of the common external

[1] The terms of trade is defined as the ratio of the export price to the import price.

tariff (CET) in the UK and the subsequent dispersion scenarios of UK tariff revenues to the EU. The results of this study show a net *loss* since the terms of trade effects are outweighed by budgetary contributions by the UK on membership.

Harrison, Rutherford and Wooton (1989) contradict these results when looking at the various possibilities of member states *leaving* the EU with and without the CAP in place. Their results suggest that all eight countries are found to have a small welfare loss on leaving the EU. Hamilton and Whalley (1985) examine free trade areas (FTAs) showing that welfare gains always accrue to developed countries and welfare losses fall on less developed countries.

From this brief resume, it is readily observable that CGE models are suitably tailored to handle hypothetical policy and trade scenarios and provide prescriptive conclusions. Almost all of the studies mentioned follow the traditional assumptions of constant returns to scale and perfect competition in productive sectors.

For multi-region models, there is an extra dimension which pertains to the characterisation of *cross-hauling*, or the simultaneous import and export of similar (differentiated) products. This phenomenon, recognised as intra-industry trade (IIT), is not treated in neo-classical trade theory, although it is supported by trade data. The problem is usually solved using the Armington (1969) assumption, although this treatment has not escaped criticism. These issues are discussed further in section 3.1.

An alternative characterisation of IIT centres around the explicit incorporation of imperfect competition in CGE models. This work has its origins in much of the 'new' trade literature discussed in section 3.2. Section 3.3 gives an overview of the CGE literature pertaining to the use of imperfect competition in trade applications and section 3.4 concludes.

3.1 Product Differentiation in CGE Models

3.1.1 Classical and Neo-Classical Trade Theories

The origins of classical trade theory lie in the Ricardian principle of the law of comparative advantage. This law sought to explain the existence and pattern of international trade based on the relative cost advantages between different countries producing different commodities, although the law says nothing about how or why a comparative advantage exists. Neo-classical trade theory, based on the work of Heckscher (1949) and Ohlin (1933), addresses the latter issue by postulating that comparative advantage arises from the different relative factor endowments of trading countries. A country will export those commodities that are intensive in the factor in which it is relatively most well endowed.[2]

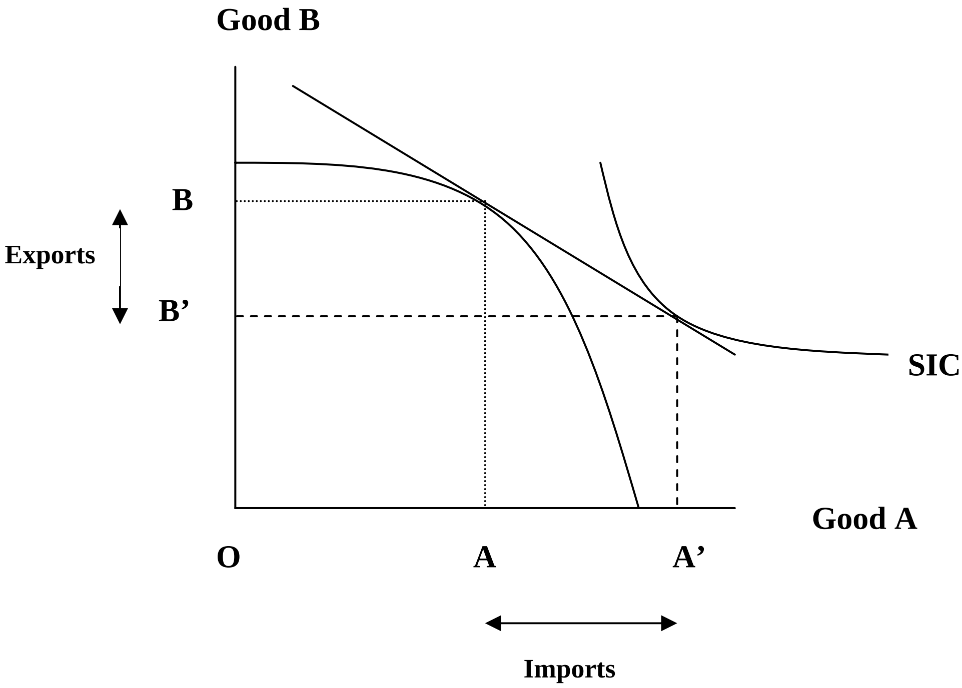


Figure 3.1: Trade in Homogeneous Commodities

Referring to figure 3.1, a two commodity economy is represented by a production possibility frontier, where the equilibrium point of production is the tangency between the slope of the international terms of trade (given by relative commodity prices) and the production possibility frontier. Thus, the economy will produce OA of good A and OB of good B. If consumer preferences are represented by the social indifference curve (SIC), then the net trade effects suggest that the economy will export good B, which according to the terms of trade price ratio, will be traded for imports of good A.

3.1.2 'Exogenous' Product Differentiation in CGE Models

In the forum of CGE modelling (and indeed other empirical trade applications), a large degree of contention surrounds the neo-classical assumption that domestic products and

[2] A full discussion of Heckscher-Ohlin theory is given in Winters (1991) chapter 4.

imports are perfect substitutes, which necessitates that products are either imported OR exported. Such an assumption is not supported by actual trade data which show evidence of *cross-hauling* or *Intra-Industry Trade* (IIT).

The standard CGE treatment to this problem is to employ the Armington (1969) assumption. This approach links product differentiation with *exogenous* considerations which are somehow related to region of origin, without the need to alter the perfectly competitive market structure within the model. For example, in the context of food markets, agricultural produce (e.g., arable crops) may be differentiated due to differences in climate and soil. Another possibility is that the aggregation of types of, say, wheat (soft, hard) into a homogeneous commodity in the database, implies that the composition of the commodity may vary by region.

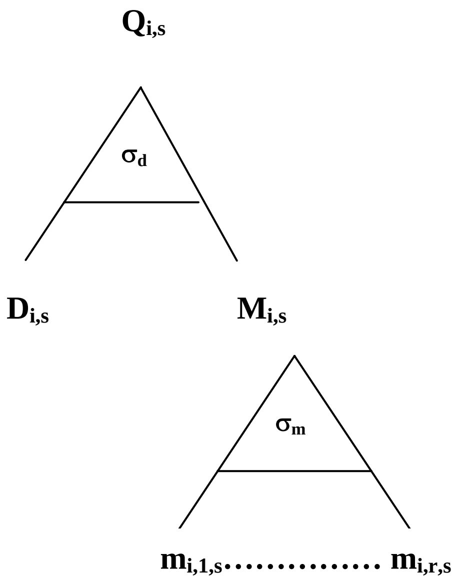


Figure 3.2: The Armington Structure

In modelling terms, the Armington approach is based on a two stage nested function presented in figure 3.2.[3] In the first stage, demands for good 'i' are based on a weakly separable production function which aggregates the import composite ($M_{i,s}$) and the domestic substitute ($D_{i,s}$), in importing region 's' into a composite tradable ($Q_{i,s}$). The second stage function exogenously differentiates imports of (otherwise homogeneous) commodities by region of origin 'r' using an elasticity of substitution parameter, σ_m (=

[3] Some CGE models employ an alternative specification of exogenously differentiating exports by region of destination using a CET function.

$1/(1+\rho_m)$), where the lower is the value of σ_m, the more differentiated are the products in the nest.

Thus, the Armington structure may be characterised by a weak homogeneously separable nested CES function.[4] In levels terms, the upper nest is written as:

$$Q_{i,s} = B_{i,s}\left[\delta_{i,s} D_{i,s}^{-\rho_d} + (1-\delta_{i,s}) M_{i,s}^{-\rho_d}\right]^{-\frac{1}{\rho_d}} \qquad \text{(AR.1)}$$

where:

$Q_{i,s}$ - Composite tradable good; $M_{i,s}$ - Composite imported tradable

$D_{i,s}$ - Domestic tradable; $B_{i,s}$ - Scale parameter

$\delta_{i,s}$ - Share parameter; ρ_d - Elasticity parameter

The variables $M_{i,s}$ and $D_{i,s}$ are treated as 'inputs' producing the 'aggregate tradeable output', $Q_{i,s}$. Composite import and domestic demands in region 's' may be derived through Lagrangian maximisation procedures.[5] The lower level nest is a CES aggregate of imports by region of origin, 'r':

$$M_{i,s} = Z_{i,s}\left[\sum_{r \in reg} \delta_{i,r,s} m_{i,r,s}^{-\rho_m}\right]^{-\frac{1}{\rho_m}} \qquad \text{(AR.2)}$$

where:

$Z_{i,s}$ - Scale parameter; $\delta_{i,r,s}$ - Share parameter

$m_{i,r,s}$ - Imports by region of origin 'r'; ρ_m - Elasticity parameter

CES bilateral import demands are derived in a similar manner.

The magnitude of σ_m determines the 'responsiveness' of domestic demand to a change in the price of imported goods (relative to domestic goods) brought about by trade and

[4] CES is favoured because it is possible to specify any chosen value for the elasticity of substitution parameter (vis-à-vis Cobb-Douglas where σ=1).
[5] Armington import demands may either be utility maximising Marshallian (Q=Q(P,Y)) or cost minimising Hicksian (Q=Q(P,U)).

exchange rate policy or exogenous events. For this reason, σ_m is known as the trade substitution elasticity. If σ_m is high (inifinite), then small (infinitesimal) changes in the price ratio create large (total specialisation) changes in bilateral import demand allocations. If σ_m is very low, then the allocation of import demands will remain fairly static. At the extreme, where σ_m is equal to zero, imports would be treated as perfect complements where relative price movements in imports from certain regions will not affect the demand allocations for imports.

3.1.3 Critique of the Armington Assumption

One advantage of the Armington approach is that it is parsimonious in terms of parameter estimates. The only data required are the elasticities of substitution and trade share data for each import supplier. The drawback is that the modeller is restricted by the assumption that all pair-wise substitution elasticities in the lower nest are identical. However, the Armington structure still offers analytical simplicity and computational ease.

Armington structures usually employ CES functions, which imply that when the budget shares of each of the import demands are small, the compensated own-price elasticity of demand is close or equal to the elasticity of substitution (Shoven and Whalley, 1992). Thus, modellers often try to relate estimates of the elasticity of substitution in the Armington structure to actual estimates of import- and export-demand elasticities. Some authors (e.g., Stern, Francis & Schumacher, 1976) have attempted to provide full lists of econometrically estimated 'trade' elasticities by region and good.

Sensitivity analysis experiments show that changes in the Armington upper and lower nest elasticities have significant impacts on model results. This has led critics to question the employment of the Armington structure which they feel leads to excessive terms of trade effects (Brown, 1987) where changes in import demands have a significant influence on trade prices. Francois and Panagariya (1995), note that, contrary to economic theory, Armington based structures often support gains to all countries participating in regional trading arrangements. Similarly, Boadway and Treddenick (1978) find that tariff reductions in a ‘small country’, like Canada, lead to terms of trade deteriorations leaving the economy worse off. Both studies suggest that this may be an artefact of the Armington parameterisation.

Morkre and Tarr (1993) also note that the Armington assumption may have limitations in certain situations which may bias results. In particular, what may not be apparent is that under the Armington assumption, in response to a change in trade policy (e.g., tariff or quota reductions) in a given sector, absolute resource movement and the welfare impact will be extremely muted in sectors with a small initial import share. Thus, with an elasticity of substitution of 2, a 50% decrease in the import price for sector i, which itself has imports less than 0.5% of overall consumption, would still leave the import share under 1% of overall consumption. If the initial import share of overall consumption were large, then identical reductions in import prices would lead to significantly larger absolute increases in imports as a percentage of total consumption in the sector.

Alston *et al.* (1990) question the validity of the Armington assumption by testing the structural restriction of homogeneous separability in the nest. Using a non-parametric approach the authors reject these pivotal restrictions. An earlier study by Winters (1984) also supports these findings. Moreover, Winters notes that for a linear homogeneous function, import demand intensities are independent of the level of income (see section 2.6.1), which implies that import demand budget share allocations (i.e., with price ratios fixed) are *independent of the level of income*. This assumption hardly seems viable if the modeller is interested in variable import *quality*, since in reality it is likely that increases in income will have an effect on the budget share of those import sources with higher quality. Equally unrealistic is that the usual choice of functional form (CES) restricts the income elasticity of Marshallian import demands to unity.

To conclude, it is widely recognised that the Armington assumption is a useful tool in characterising IIT which lends itself well to simplicity and calibration efficiency. What has also become clear, however, is that certain criticisms of the Armington assumption leave its validity open to question. Problems such as calibration bias, rejection of the structural assumptions of homogeneous separability, and results bias suggest that a better approach may be to model IIT trade flows more explicitly using some form of imperfectly competitive structure. This is reflected by a burgeoning literature of imperfectly competitive CGE trade models and is examined in detail in the next section.

3.2 'New' Trade Theories

International economics/trade theory up until the 1960s was dominated by the assertion that the production of commodities was subject to constant returns to scale in a perfectly competitive framework. Moreover, the 'traditional' CGE trade models tended to emphasise production aspects of the economy such as differences in factor endowments or technology, which was used to determine comparative advantage and the gains from trade. By contrast, the role of consumer preferences played a minor role in such models.

Recognising the existence of IIT (Verdoorn, 1960; Balassa, 1975), the CGE trade literature adopted the use of the Armington assumption, although subsequent criticisms drove many to search for alternative theories. This led to an increased use of 'new' trade theories incorporating forms of imperfect competition and product differentiation. An important deviation from the traditional theories has been the treatment of consumer preferences. In the 'new' trade literature, consumer preferences have more attention by incorporating types of preference structure which have been instrumental in explaining the proliferation in IIT, which traditional theories such as Heckscher-Ohlin have failed to capture.

At the same time, a proliferation in the number of studies in the trade literature showing evidence of scale economies (Chipman, 1965; Caves, 1960) has penetrated the mainstream doctrine behind much of the recent CGE trade literature. What follows is a summary of the more widely accepted imperfectly competitive trade theories which have appeared in the CGE literature.

3.2.1 Oligopolistic Models

This form of imperfect competition is usually characterised by a small number of firms producing a homogeneous product in an industry without entry or exit. One of the most commonly represented forms of oligopoly in CGE modelling comes from the work of Cournot (1838). The Cournot model is a non co-operative oligopoly model, where firms act independently of one another (i.e. no collusion), although the maximisation of profit does take account of rivals' reactions. More specifically, Cournot conjecture postulates that in maximising profits, firm 'k' expects other firms 'j' (k≠j) in the industry to leave their output *unchanged* as firm 'k' changes its output. In a CGE multi-regional context, Cournot producers in each *region* hypothesise about the output responses of firms both at home and abroad.

Following a similar approach to Sodersten and Reed (1994), assume two countries, each with one firm producing an identical commodity, facing identical cost and linear demand curves and exhibiting Cournot behaviour. Moreover, it is implicitly assumed that the number of firms is fixed (i.e., barriers to entry). The inverse demand function in each country 'i' (i=1 domestic; i=2 foreign) is expressed as:

$$P^i = a - b(Q_1^i + Q_2^i) \qquad \text{(OL.1)}$$

where subscripts and superscripts refer to the country of production and consumption respectively. The home producers total revenue function in the home market is thus:

$$TR_1^1 = \left[a - b(Q_1^1 + Q_2^1)\right]Q_1^1 \qquad \text{(OL.2)}$$

and the foreign producer's total revenue function in the home market is:

$$TR_2^1 = \left[a - b(Q_1^1 + Q_2^1)\right]Q_2^1 \qquad \text{(OL.3)}$$

Taking the partial derivative of the total revenue functions with respect to quantity gives the marginal revenue functions for both domestic and foreign producers in the domestic market:

$$MR_1^1 = a - 2bQ_1^1 - bQ_2^1 \qquad \text{(OL.4)}$$

$$MR_2^1 = a - 2bQ_2^1 - bQ_1^1 \qquad \text{(OL.5)}$$

The *reaction function* gives all the profit maximising output levels for a given firm as a function of the other firm's output level. Setting equation (OL.4) equal to marginal cost, given by a constant 'c', yields the profit maximising condition:

$$a - 2bQ_1^1 - bQ_2^1 = c \qquad \text{(OL.6)}$$

which can be re-expressed as:

$$Q_1^1 = \frac{1}{2}\left[\left(\frac{a-c}{b}\right) - Q_2^1\right] = R_1^1 \qquad \text{(OL.7)}$$

In the same way the foreign firm's reaction curve in the domestic market is given as:

$$Q_2^1 = \frac{1}{2}\left[\left(\frac{a-c}{b}\right) - Q_1^1\right] = R_2^1 \qquad \text{(OL.8)}$$

Having derived the reaction functions, it is possible to represent them graphically for each market in figure 3.3. Taking the home market as an example, R_1^1 and R_2^1 are the home and foreign producer's reaction functions respectively. Intersection of R_1^1 and R_2^1 determines equilibrium in the market.

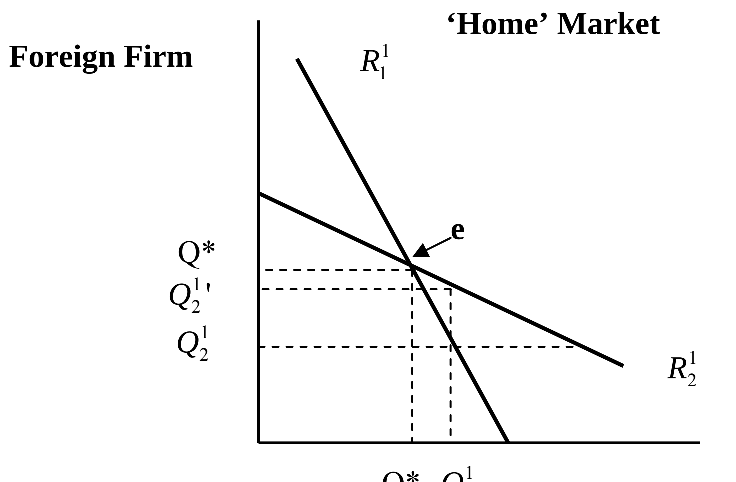


Figure 3.3: Cournot Competition

To show this progression to the equilibrium point 'e', assume the foreign firm produces Q_2^1 in the home market (i=1). The domestic producer believes that if the foreign producer produces Q_2^1 then he is able to maximise profits by producing at point Q_1^1.

Thus, in taking this action, the domestic producer is assuming that the foreign producer is not going to change its output level. In response to this output level of Q_1^1 the foreign firm increases output from Q_2^1 to $Q_2^1{}'$, believing that the domestic firm will remain at Q_1^1. Conceptually, this process continues until equilibrium point 'e' is reached where both firms are maximising profits at output level Q*.

Typically, the concentration level in oligopolistic industries is high. Thus, each firm is capable of influencing other firms' decision variables and this leads to a vast array of complex strategies. The Cournot case can be thought of as the outcome of a game in which countries (firms) choose quantities simultaneously and independently at a single instant. This is very seldom a realistic story insofar as it ignores strategic interdependence, but it is internally consistent and grounded in maximisation.

In applied CGE models, this form of the basic Cournot structure is often modified to account for some form of *conjectural variation* (CV) which is a hypothesis by a given firm of the effect of a change in its strategy on other firms' decision variables. This is a scenario which must involve a sequence of decisions taken over time and implies some form of dynamic component. Thus, it has been argued that attempts to incorporate what is essentially a dynamic concept into a comparative static CGE approach leads to a situation where one does not know what is supposed to be happening, such that the grounding in maximisation is lost (Helpman and Krugman, 1989). Nevertheless, the CV approach is one which has gained momentum in the CGE trade literature.

3.2.2 Monopolistic Models

Another class of imperfectly competitive model structure is that of monopolistic competition. Monopolistically competitive structures assume large numbers of firms. Moreover, each firm sells a *differentiated* product which it monopolises, although it is assumed that these products are close substitutes to one another such that each firm has very little market power. Finally, entry and exit of firms in the long run ensures zero profits.

Two permutations of monopolistic competition which have penetrated much of the mainstream CGE literature are the Neo-Hotelling and Neo-Chamberlinian model structures, although the latter has received far more attention from CGE modellers in recent years.

3.2.2.1 Neo-Hotelling Models

These type of models go back to the work of Hotelling (1929), who was one of the first to recognise the importance of individual consumer preferences between horizontally differentiated products. Hotelling notes:

> '*There is a tendency (for producers) to make only slight deviations in order to have for the new commodity as many buyers of the old as possible, to get, so to speak, between one's competitors and a mass of customers' (pp54, Hotelling, 1929).*

Thus, it is in the sellers' interest to produce goods which are not identical to what is already on the market in order to avoid the type of price wars characteristic in much of the oligopolistic literature.

Subsequent extensions of this early work have been employed in simple stylised CGE trade models by Helpman (1981) and Economides (1981, 1984). However, perhaps the most intuitive and influential approach to modelling neo-Hotelling type preferences has come from the work of Lancaster (1979, 1980) to which the majority of this discussion is now devoted.

Lancaster creates the concept of a *varietal spectrum* where products are differentiated explicitly in terms of the characteristics or attributes that they possess and firms produce varieties with different commodity combinations in response to the broad diversity of consumer preferences for different varietal attributes. At the simplest level, consider a good differentiated in terms of two characteristics A and B, and that the individual variety of each good is based on different ratios of these characteristics. This varietal spectrum is represented in figure 3.4.

Lancaster's approach assumes that for any given consumer, there is an ideal variety (V*) which combines each of the attributes A and B. As there is only a finite number of goods produced, consumers are unable to obtain a good which offers the exact preferred specification and are thus forced to consume an *available* good which comes closest to their ideal.

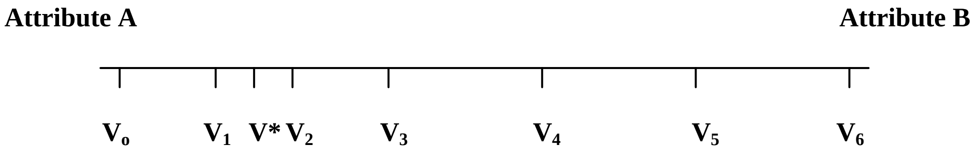


Figure 3.4. A Varietal Spectrum
Source: Vousden (1990)

The available varieties which come closest to the ideal (V*) are V_1 and V_2. Moreover, the degree of substitution has implications on the quantity that is required to maintain a given level of utility when consuming a variety which is not the ideal. In other words, to keep utility unchanged, the price that the consumer pays for a given variety is inversely related to the distance of this variety from the ideal variety. Thus, each consumer's demand for any variety V on the spectrum is a function of its own price (p), the price of other varieties (p') and the distance (d) of the chosen variety V from the consumer's ideal which yields the demand function D(p, p', d). In contrast to the Spence (1976) Dixit and Stiglitz (1977) (SDS – see next section) specification, preferences are said to be *asymmetric*, where two varieties with equal price can still be ranked differently to one another.

The ideal variety V* also represents the cut off point for the two adjacent markets corresponding to the available varieties V_1 and V_2. For example, at given prices any other consumer's ideal which lies to the left of ideal variety V* consumes V_1 and vice versa for V_2. Thus, the distance between V* and the two available goods represents a *half-market* for these available varieties. The *market* demand for each variety is therefore the horizontal summation of consumers demands over both adjacent half-markets for a given available variety.

On the production side, to meet the diverse tastes of consumers, firms differentiate their products through research and development and advertising. In the same specification as the SDS approach, scale economies are realised by reductions in average fixed costs with increases in firm output, (discussed in detail in chapter 6). Combining this assumption with the assumption of uniformity of distribution for consumer's ideal preferences along the varietal spectrum (i.e. for each ideal variety there are an equal number of consumers), Lancaster (1979) shows that in autarky all varieties will sell at the same price implying that D and S for varieties will also be identical.

Vousden shows how opening up the economy to trade can result in varietal and pro-competitive gains for both countries. In figure 3.5, marginal costs are constant and equal to average variable costs, and increasing returns to scale occur with reductions in average fixed costs. Under autarky, the demand for each representative variety along the spectrum is given by D and under profit maximising criteria (MC=MR) equilibrium is at output level Q_O and price P_O. Assuming freedom of entry and exit, this is the long run zero profit point.

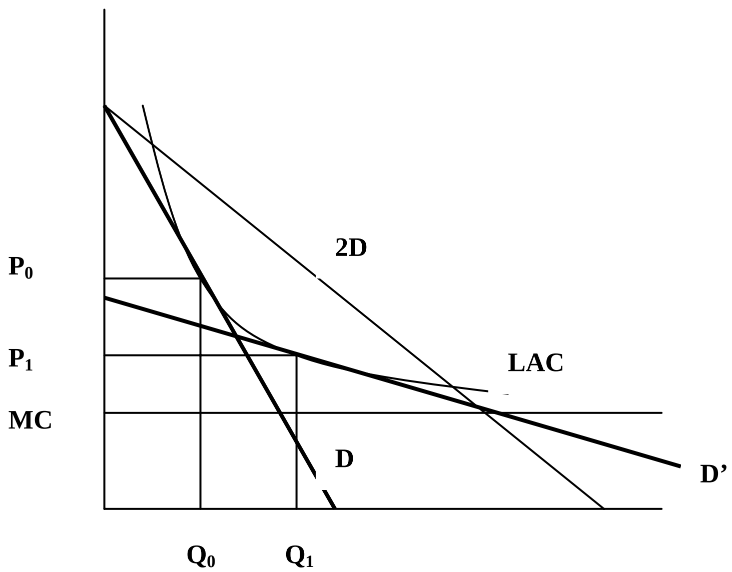


Figure 3.5. Varietal and Pro-competitive Effects
Source: Vousden (1990)

Given the autarkic result that the same varieties are produced in either country A or B, then opening up the domestic economy to free trade does not initially change the range of available products, although *only one firm in either country produces each variety.* This implies that each firm faces its existing domestic market and a new export market which effectively doubles the demand at each and every price. This is given as demand curve 2D in figure 3.5. Firms will now make abnormal profit which in turn will attract other firms (which may be 'old' firms which have now changed the specification of their products) into the industry who will in turn produce their own product variants.

This proliferation has *two* further effects. Firstly, the gaps along the varietal spectrum between consumers' ideal varieties and available varieties narrow, allowing most consumers to attain a closer variant to their ideal. This effectively characterises the Hotelling *variety effect*. This implies that varieties become *closer substitutes* with trade, in contrast to the SDS specification

Secondly, the higher substitution elasticity implies that the producers' perceived price elasticity of demand for varieties will also rise. In figure 3.5, this has the effect of flattening the demand curve to D', such that the long run zero profit equilibrium becomes P_1 and Q_1. This is known as the *pro-competitive* effect whereby the distortion of the output price over the marginal cost is reduced due to increased competition in the industry.

3.2.2.2 Neo-Chamberlinian Models

This form of horizontal product differentiation was first developed by Spence (1976) and Dixit and Stiglitz (1977) *(SDS)*. The underlying assumption of the SDS Chamberlinian model structure is that consumers do not have a preference for any one given variety and seek to consume as many varieties as possible. To illustrate SDS type preferences, the discussion draws on the work of Krugman (1979). Thus, assume the consumption side of the economy is characterised by consumers who have identical sub-utility functions of the form:

$$U = \sum_{i=1}^{n} c_i^{\vartheta} \qquad \text{(CH.1)}$$

where the underlying demands, c_i are the representative consumer's consumption of variety 'i', 'n' is the number of varieties produced and ϑ is a consumption parameter. Typically, these sub-utility functions are aggregated into the utility function at the top of the consumption tree.

Each variety (i=1....n) has the same characterisation in the sub-utility function (c_i^{ϑ}) suggesting that preferences for all varieties are equal. Moreover the sub-utility function imposes concavity, (i.e. diminishing marginal utility for each variety since $0 < \vartheta < 1$) so at the margin the consumer is better off moving to a position of consuming smaller amounts of more varieties. This effectively is Krugman's characterisation of what has come to be widely recognised as the ‘love of variety’ effect.

Two further points should be noted. First, in CGE applications, SDS type preferences are often employed at the aggregate consumer level, where it is assumed that individual (micro) consumers have different tastes which in the aggregate amounts to more varieties. Thus, more varieties demanded by the economy (aggregate consumer) leads to greater levels of consumer satisfaction at the micro level.

Secondly, the elasticity of substitution of the sub-utility function is a constant, ($1/1-\vartheta$), which does not change with the number of varieties. Thus, all pairwise combinations of varieties have identical substitution elasticities and consumer preferences are said to be *symmetric*. In other words, rankings between varieties are based on price alone. This assumption is also used to rationalise the observation that cross price elasticities of demand approach zero (rather than infinity) as ‘n’ increases. This implies that all varieties are equally good substitutes for each other no matter what the level of product variety. Vousden (1990) argues that zero cross price elasticities are possible if the number of varieties on offer is sufficiently large for no variety to represent a significant proportion of the consumer's budget.

> *‘Thus, for example an avid reader who buys a lot of books may regard a large number of books as equally good substitutes for each other, and a sudden doubling of the range of choice may not affect the elasticity of substitution between any available pair. In such a case, it is quite plausible that the cross-price elasticities of demand for different books are low, given that over time the individual buys them all anyway.’ (pp.154, Vousden, 1990)*

As a direct consequence of negligible cross price effects firms follow no form of strategic interaction patterns, so this form of product differentiation given in the utility function *actually favours large group monopolistic structures.*

Turning to the production side of the economy, Krugman (1979) assumes that firms have a single labour factor of production which is fixed in overall supply. The labour requirement to produce x_i units of variety i is given as:

$$l_i = \alpha + \beta x_i \qquad \text{(CH.2)}$$

where α is a fixed requirement of units for producing variety 'i', and β is a constant labour per unit ratio for all output units of x_i. Thus, at a given wage rate, α and β represent fixed and constant marginal costs respectively. This implies that :

(i) MC equals AVC and;
(ii) ATC falls as production increases

Thus, production costs for each variety are equal for each firm and there are internal economies of scale to each firm[6]. This ensures that each variety is produced by a single firm and each firm will profit maximise in its own segment of the market. Moreover, given fixed labour supply and freedom of entry and exit to/from the industry, the number of firms and hence varieties produced is determinate.

Zero long run profits are established by freedom of entry and exit, where each firm *marks up* their price over marginal cost sufficiently to cover fixed costs. In Krugman's model, the industry zero profit condition is:

$$p_i x_i = l_i w \qquad \text{(CH.3)}$$

substituting (CH.2)

[6] By contrast, external economies are *beyond the control of the industry*. For example, external economies of scale in input markets leads all firms in the output market to enjoy lower per unit costs. This is what is popularly characterised as a decreasing cost industry.

$$p_i x_i = (\alpha + \beta x_i) w \qquad \text{(CH.4)}$$

where p_i and w are output and input prices respectively. Using the product rule it is possible to derive the profit maximising MC=MR point of production:

$$MR_i \Rightarrow p_i + \left(\frac{\partial p_i}{\partial x_i}\right) x_i = p_i \left[1 - \left(\frac{1}{\varepsilon}\right)\right] = w\beta \Leftarrow MC \qquad \text{(CH.5)}^{7}$$

where the output price of each variety 'i' is:

$$p_i = w\beta \left[1 - \left(\frac{1}{\varepsilon_i}\right)\right]^{-1} \qquad \text{(CH.6)}$$

where ε_i is the own price elasticity of demand which is a function of the individual's level of consumption of variety 'i'.

Assuming that the labour force is fixed in supply, L, then product market clearing is given as:

---

[7] Since

$$TR = p_i x_i$$

then MR is

$$MR = \frac{d(p_i x_i)}{dx_i} = p_i \frac{dx_i}{dx_i} + x_i \frac{dp_i}{dx_i} = p_i + x_i \frac{dp_i}{dx_i}$$

since the elasticity of demand is defined as:

$$e = -\frac{dx_i}{dp_i} \frac{p_i}{x_i}$$

rearrange to obtain:

$$\frac{dp_i}{dx_i} = -\frac{p_i}{e x_i}$$

substituting into the expression for MR

$$MR = p_i + x_i \frac{dp_i}{dx_i} = p_i - x_i \frac{p_i}{e x_i} = p_i - \frac{p_i}{e}$$

or

$$MR = p_i \left(1 - \frac{1}{e}\right)$$

$$x_i = Lc_i \qquad \text{(CH.7)}$$

where c_i is the level of variety demand. The factor market clearing mechanism specifies that the number of labour units used to produce a given variety of x_i multiplied by the number of varieties (n), is equal to the exogenous supply of labour (L). Using this rule, substitution of (CH.7) into (CH.2) gives:

$$n(\alpha + \beta c_i L) = L \qquad \text{(CH.8)}$$

where the number of firms, n (and hence product varieties) is:

$$n = \frac{L}{(\alpha + \beta c_i L)} \qquad \text{(CH.9)}$$

Vousden (1990) presents a schematic interpretation of the equilibrium determination of varietal demand levels (c_i) and price vectors (P_i, w) when two countries trade. The PP curve shows profit maximising combinations of 'c_i', 'P_i' and 'w'. On the left hand side of figure 3.6, PP slopes upwards since the higher is 'c_i' the lower is the demand elasticity.[8] This increases the firm's monopoly power for variety 'i' and thus enables the firm to charge a higher mark-up (P_i/w). If price elasticity of demand is (assumed) constant, as presented in the right hand side of figure 3.6, then changes in 'c_i' will not affect monopoly power so the PP curve is perfectly horizontal (i.e., the mark-up stays the same).

The curve ZZ shows the zero profit combinations of P_i, w and c_i and is negatively sloped since higher varietal demand (c_i) implies higher supply (x_i), so lower per unit costs occur. Due to internal economies of scale, higher output translates into lower long run zero profit prices as the firm moves down the long run average cost curve.

[8] The greater is the level of demand for a variety, the further one is along the slope of the demand curve and the lower is the own-price elasticity.

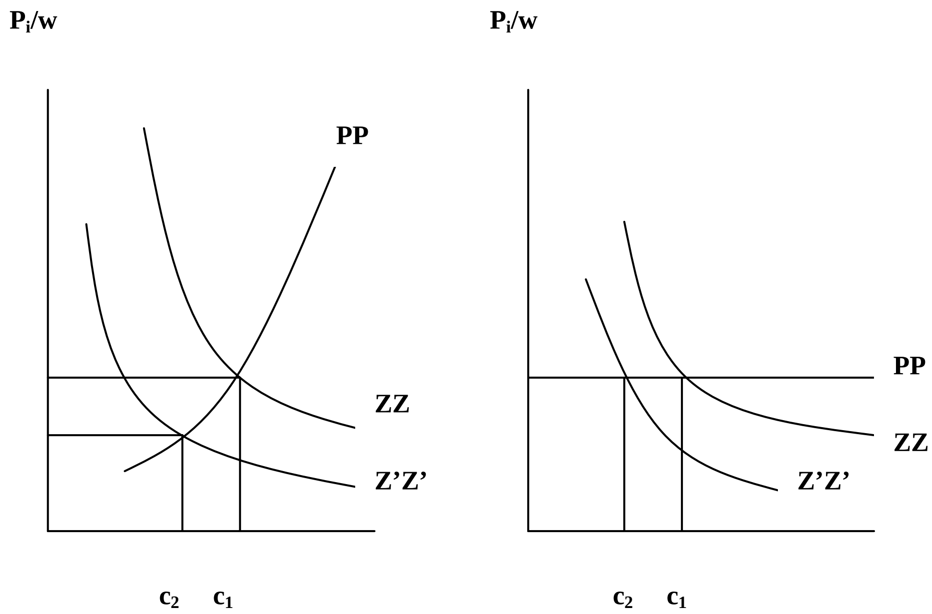


Figure 3.6
Source: Vousden (1990)

Assuming domestic and foreign regions with respective labour populations L and L* where the foreign economy has identical cost and utility functions to the domestic economy, the solutions will be identical to those equilibrium conditions derived above if the domestic economy opens up to trade. Moreover, the size of the market for each variety has increased since the number of consumers, has increased to L + L*.

The curve PP is not a function of L so is unaffected by increases in L. However, ZZ shifts to the left since output ($x_i = c_i.L$) has increased for each value of c which, under economies of scale, implies lower unit costs and prices. Thus, if demand elasticity is a decreasing function of c_i, price and quantity consumed of each variety falls whereas if price elasticity of demand is held fixed then only quantity consumed of each variety falls (see right side of figure 3.6).

The total number of varieties available to consumers in both countries is higher in both cases under free trade since n+n* > n where n+n* is given as:

$$n + n^* = L + L^* / \alpha + \beta c(L + L^*) \qquad \text{(CH.10)}$$

Thus, when free trade occurs, consumers gain access to other varieties. Moreover, welfare gains will also result if increases in output result in scale economies and therefore reductions in unit costs. As already mentioned, welfare gains such as these are quite different from the typical terms of trade and specialisation effects which dominate much of the earlier CGE trade literature. However, although intra-industry trade is explained, the direction of trade is indeterminate because one may not know which varieties are produced in which country.

To conclude this section, both neo-Hotelling and neo-Chamberlinian models both exhibit a *variety effect,* albeit for different reasons. In the former, the proliferation of varieties allows the consumer to chose a variety closer to his/her ideal thereby increasing utility. In the latter, the increased consumption of *all* varieties increases utility due to the 'love of variety' effect. Both approaches also demonstrate how trade increases available product variety to consumers in both countries. Moreover, the demand price is also reduced due to the reduction in monopoly power as firms move down the average cost curve.

3.3 CGE Applications Incorporating Imperfectly Competitive Structures

Perhaps the earliest and most influential work conducted on the incorporation of imperfect competition into a CGE trade model is that of Harris (1984). This is typical of many early studies of imperfect competition (Dixit and Norman, 1980; Venables, 1984; Lawrence and Spiller, 1986; Gros 1987) which seek to extend the monopolistic neo-Chamberlinian framework using SDS preferences, highlighted by Krugman (1979).

Harris (1984) examines the interaction of trade policy and market structure in the case of a single country CGE trade model of Canada. The model uses SDS product differentiation and 20 of the 29 sectors modelled exhibit scale economies internal to the firm. It is assumed that Canada is a price-taker in its import markets (small country assumption) and a price-maker in its export markets (large country assumption).

Harris simulates the effects of a removal of all unilateral and multiple bilateral (or reciprocated i.e. all countries reduce their trade barriers with Canada ONLY) trade restrictions affecting Canada. In the initial case for perfectly competitive industries and constant returns to scale, unilateral and multiple bilateral free trade in Canada results in 0% and 2.4% respective increases in Canadian GNP.

When the same experiment is undertaken incorporating scale economies, welfare gains for the two respective categories are 4.1% and 8.6% of GNP. These results are accompanied by an increase in average output per firm of 37.2% for unilateral free trade and 67.7% for multiple bilateral free trade. Thus, the reduction of protective barriers has opened up trade which in turn has led to a rationalisation of the industry. In other words, previously protected inefficient firms have exited the industry, with remaining firms expanding output and moving down the long run average cost curve due to the decline in fixed costs. This aspect of the result is characterised as the *scale effect*.

A criticism of the this study is the modelling of foreign product differentiation. As the study is a single country framework, Harris uses an *ad hoc* treatment to model the number of foreign product varieties before and after liberalisation where,

> *"importers match in proportional terms any changes in domestic product differentiation" (pp1023, Harris, 1984).*

This assumption is referred to as *competitive foreign product differentiation* which fixes the domestic to foreign variety ratio n/n*.

Although this assumption may keep domestic and foriegn market shares constant at fixed terms of trade, it also prevents the displacement of some domestic varieties by foreign varieties if the domestic country unilaterally reduces trade restrictions. Instead of experiencing an influx of cheaper foreign varieties, unilateral liberalisation leads to a reduction of foreign varieties in ratio to the reduction in domestic varieties which implies a reduction in consumer utility (negative varietal effects).

This restriction is highlighted in the policy experiments incorporating both SDS preferences and scale economies. Under the same scenarios, the model reports welfare gains relative to the perfectly competitive case of 2.7% and 6.2% of GNP for unilateral free trade and multiple bilateral free trade respectively, where smaller gains suggest that falls in consumer utility dampen model results.

Wigle (1988) conducted a follow up study to Harris, questioning the size of the welfare gains as a result of preferential market gains given to Canada under the model structure. Wigle argues that Harris' welfare gains are too large because the multi-bilateral simulation makes the assumption that Canada has preferential market access with all of its partners on a bilateral basis, whereas third countries' trade barriers with each other remain intact. This, Wigle argues, is not a likely scenario, so Canada's welfare gains would be reduced accordingly, which is reflected in his model results.

Other approaches employing monopolistic market behaviour have been structured within the neo-Hotelling framework highlighted in section 3.2.2.1. Lancaster (1984) has examined the welfare effects of the imposition of a tariff in the context of two trading partners in a manner similar to Harris (1984). It is assumed that the country imposing the tariff is 'small' such that imposition of the tariff does not affect the world price and therefore the export earnings of the partner.

The results depend heavily on the type of preference structure employed. For example, the ***split*** arrangement of varieties assumes that the varietal spectrum is partitioned with domestic varieties on one side and imported varieties on the other side of the spectrum. Thus, domestic and imported varieties are poor substitutes (except at the boundary of the partition) implying that price movements will have little effect on substitution possibilities. The ***interleaved*** case assumes that for every domestic variety there is an adjacent foreign variety on the varietal spectrum. This implies that domestic and imported varieties are close substitutes.

In Lancaster's model, the imposition by the home country of an import tariff in the split case unambiguously reduces domestic net welfare. The marginal cost to foreign firms supplying to the domestic economy increases leading to a price increase in foreign varieties. Due to the lack of substitution possibilities between domestic and foreign variants, this leaves those consumers who prefer foreign varieties worse off, with domestic consumers and producers facing no change.

The interleaved case presents a broader range of outcomes since domestic and foreign markets cannot be separated as in the split case. Thus, the increase in the price of foreign variants, due to the imposition of the tariff, leads to a substitution in favour of adjacent domestic varieties which in turn gives domestic firms additional monopoly power (lower price elasticity). In the short run, this pushes up domestic variety prices and the resulting profit signal allows new firms (both domestic AND foreign, to preserve the interleaving structure) to enter the market decreasing the distance between existing varieties, restoring long run zero profits and increasing the elasticity of demand which in turn lowers prices in the domestic industry.

With interleaved preferences, Lancaster (1984) predicts a gain to domestic consumers of new varieties (i.e. proliferation of new varieties gives positive neo-Hotelling variety effect) and gains to domestic consumers favouring the original domestic varieties at lower prices (as varietal proliferation increases price elasticity which forces prices lower). Both of these effects *offset* the losses to domestic consumers favouring foreign varieties (higher prices).

This is a surprising as well as important result, since contrary to the neo-classical trade literature, a small country can **gain** by imposing a unilateral tariff in a world characterised by differentiated products. It must, however, be stressed that the importance of this result relies heavily on Lancaster's assumption that existing *foreign firms remain in the domestic market after the imposition of the tariff to preserve the high substitution possibilities of the interleaved structure*. If foreign firms totally withdraw, product variety actually falls, and the degree of monopoly power of domestic firms increases long run prices above the pre-tariff situation.

Greenaway (1985) reflects that if a tariff leads to greater welfare than the free trade position, as postulated by Lancaster, then the tariff may be correcting a distortion in the form of 'insufficient product variety'. This being the case, Greenaway postulates that **even greater** welfare improvements can prevail if a production subsidy is used since unlike the tariff, this does not push up the price of foreign varieties in the domestic economy. Taking this one step further, Greenaway hypothesises the existence of an optimal degree of product diversity. Increased product variety may only be Pareto improving if the benefit (consumer surplus) at the margin exceeds the cost. This, however, is a question not considered in the Lancaster (1984) study as there is no social cost attached to the introduction of new varieties.

Eaton and Kierzkowski (1984) develop a neo-Hotelling model where firms first decide on entry and variety to produce before taking decisions on prices and output. This sequential process is starkly contrasted to the simultaneous entry, price and output decisions dictated by zero profits alluded to in most models of industrial organisation. The authors derive a similar result to Lancaster (1984) and show that an import-tariff is a Pareto superior position to free trade although this is due to 'profit stealing' from the foreign producer as opposed to sub-optimal varietal choice as proposed by Lancaster.

In comparing the neo-Hotelling and SDS approaches, both applications predict the presence of trade between otherwise identical economies in similar products (i.e IIT) due to consumer access to a broader range of goods. However, Lancaster's findings show that the variance of outcomes on product variety, overall output and welfare can differ significantly depending on the set of assumptions pertaining to the preference structure in the model.

One other development which has occurred in more recent years in the trade literature has been the characterisation of scale effects. Monopolistically competitive studies mostly follow the SDS type preference structure where the mark-up of price above marginal cost is determined by the elasticity of substitution between differentiated varieties. In much of the neo-Hotelling based literature provision is made for the existence of mark-up effects, although these studies place greater emphasis on how trade policy affects variety levels and consumer welfare.

An early attempt to examine the effect of the mark-up distortion of price above marginal cost on welfare was conducted by Harris (1984) for Canada. The mark-up price was a weighted average of the Krugman zero profit price and the Eastman and Skykolt (1967) price. Increased weightings of the latter increased the benchmark mark-up price and led to significantly greater welfare gains in both the unilateral and multiple bilateral cases. Since freer trade provides increased competition, it reduces the discrepancy between domestic price and marginal cost. Thus the higher is the monopoly power, the higher is the domestic price, so the bigger the potential gains from trade liberalisation and thus pro-competitive effects.

More recently, there has been a body of literature which attempts to bridge the gap between monopolistic and oligopolistic market structures. Typically, these studies use standard assumptions of product differentiation and freedom of entry/exit specific to the former structure, and combine them with oligopolistic strategic conjecture.

Studies such as Horn (1984), Flam and Helpman (1987), Brown (1991) and Hertel (1994) all have similar model structures characterised by two countries, two sectors and two factors of production (Horn only uses a single country treatment with a single factor, labour). In each case, one sector is imperfectly competitive and the other perfectly competitive, moreover SDS type preferences are employed and the mark-up varies in response to changes in prices and the number of varieties. In the Hertel (1994) study, a more general representation of the mark-up is employed, enabling the modeller to characterise both Bertrand and Cournot conjectures.

In each case, these models look at the effect of a tariff on imports of the differentiated commodity, although Flam and Helpman also examine the impact of other distortive policies such as export, output and R+D subsidies. The results of the models reflect crucial assumptions about the model structure, particularly with respect to entry and exit behaviour.

In Hertel (1994) the imposition of a tariff on imports of the differentiated commodity, where there is no entry or exit of firms, reduces the degree of foreign competition which in turn increases domestic firm monopoly power in the imperfectly competitive industry. In the absence of increases in the number of firms, output per firm increases which results in an increase in welfare.

In the case where domestic entry and exit is permitted and the number of foreign varieties is fixed, Hertel (1994) finds that the number of domestic firms increases with the tariff on the imported differentiated good due to the profit signal. The effects of this scenario on output per firm and welfare is, however, inconclusive, a result which is echoed in a similar study by Brown (1991). Flam and Helpman (1987) find that welfare actually increases in **both** of the above cases. The authors, however, maintain that the inclusion of more increasing returns to scale imperfectly competitive industries would lead to further sectoral expansion resulting in increased competition for finite resources. Thus, factor price rises may, in this instance, reverse the domestic welfare result.

Hertel (1994) examines a further case where the total number of firms/varieties is fixed although domestic firms may still enter/exit the industry. The result here is that entry of domestic firms results in the displacement of foreign varieties from the domestic market. The tariff on imports of the differentiated product leads to increased monopoly power by domestic firms (increased mark-ups and output prices) although the increase in the number of domestic firms results in a fall in output per firm in the imperfectly competitive sector and thus a reduction in welfare.

Improvements in computational facility have enabled CGE modellers to incorporate product differentiation and complex conjectural variation strategic behaviour into *larger* multi-region CGE applications. One typical example of this is by Harrison, Rutherford and Tarr (1994), who examine full integration of the EU's internal market. This model includes SDS monopolistic product differentiation and freedom of entry and exit, as well as Cournot conjectural variation behaviour. Harrison *et al.* (1994) show that the removal of border costs and supply side standards, results in welfare improving gains of around 0.5% of EU GDP. Inclusion of the additional gains of pro-competitive effects discussed above leads to an overall rise in welfare of around 1.2% of the EU's GDP.

Francois *et al.* (1995b) investigate the implications on model results of incorporating the Armington specification into a monopolistically competitive (MC) model. This study employs two model types: Armington based MC models are referred to as 'nested regional' models and non-Armington MC models are referred to as 'non-nested' global MC models.

In the former specification, firms within a region may be specified as monopolistically competitive but the Armington assumption combines differentiated good imports into a composite. Thus, although the nature of the differentiation in the Armington structure is endogenous (instead of exogenous – see section 3.1.2), it is still a *composite* differentiated good. In the non-nested specification, the lower level of the Armington nest is removed such that foreign and domestic variants/firms *compete directly*.

Francois *et al.* (1995b) show that global MC models yield higher welfare gains since the latter specification allows domestic and foreign firms to compete directly which enlarges the size of the market. Thus, if liberalisation occurs, efficiency and specialisation effects are large and monopolistic competition is referred to as being *global*. The Armington structure *effectively severs the monopolistically competitive tie between regions* leading to smaller welfare effects. In other words, firms only compete through composite goods such that variety and scale effects are limited to the regional level.

To conclude, since 1980, there has been a substantial proliferation in imperfectly competitive CGE applications in the trade literature. In the absence of any uniform theory, this has led to a wide spectrum of CGE trade model variants employing different types of imperfectly competitive structure (oligopolistic vs monopolistic), product preferences (neo-Chamberlinian vs. neo-Hotelling) and structural differences (Armington vs. Non-nested).

Finally, there is a large body of work in the agri-business/marketing literature which examines the relationship between consumer preferences and region of origin. In the context of agricultural trade research, this work is particularly significant given that the exchange of food products is becoming more important in what are now termed global markets. Indeed the volume of trade in food has grown at an annual rate of almost 10% per year, from $27 billion in 1972 to $118 billion in 1990 (Henderson and Handy, 1993). Such an increase in trade is strongly associated with the globalisation of food markets, where consumers are faced with an unprecedented level of variety.

In response to this, food manufacturers and academics have sought to isolate ways in which products can be differentiated from competitors. A number of studies undertaken assessing the influence of country of origin on consumers' perceptions of product quality (Anderson and Cunningham, 1972; Bannister and Saunders, 1978; White, 1979) converge on the opinion that,

> *both empirical observations and experiments indicate that country of origin has a considerable influence on the quality perceptions of a product' (pp.89, Bilkey and Nes, 1982).*

Moreover, market research has been undertaken on the influence of country of origin on *food* product preferences (Kaynak *et al.* 1983, Howard 1989, Morris and Hallaq 1990, Juric *et al.* 1996). Consumers were asked to evaluate both domestic and foreign food and beverage products over a range of attributes (i.e. nutritional safety, quality, taste etc.). In each case respondents favoured the home variety vis-à-vis the foreign substitute.

3.4 Conclusions

This chapter opens with a brief review of the single- and multi-country CGE trade literature. Moreover, attention is given to the role of product differentiation and its characterisation in most standard CGE trade models (i.e., Armington assumption). However, certain criticisms of the Armington assumption leave its validity open to question. Hence, the discussion turns to 'new' trade theories which have emerged and their characterisation of 'endogenous' product differentiation in CGE model structures in the literature.

The focus of this thesis will be to employ the findings pertaining to the influence of region of origin effects on product differentiation in global food markets and incorporate them into a stylised neo-Hotelling CGE application. In other words, 'region of origin' (which is exogenously employed in the Armington specification) is now endogenously incorporated into a stylised model as the central criteria in ascertaining preference for variety with respect to an 'ideal'. Employing these notions of variety, as well as endogenous mark-up and pro-competitive effects in imperfectly competitive sectors, this study adds a new dimension to the notion of CAP costs. A full discussion of the technical aspects of this stylised approach is presented in chapter 6.

Chapter 4

A Multi Region CGE Trade Model and Database

This chapter is in two parts. The first part gives an overview of the mechanisms behind a standard CGE multi-sector global model, which is tailored for use with the Global Trade Analysis Project (GTAP) database (for a fuller discussion of the model structure see Hertel, 1997). In the second part of the chapter, attention is given to the sources, construction and accounting conventions held within a multi-region database.

Thus, the structure of the chapter is as follows: Section 4.1 gives a full description of the behavioural equations inherent within a standard multi-region CGE model implementation. Section 4.2 discusses some of the welfare measures in the model. Section 4.3 gives an introduction to the concept of CGE model data. Section 4.4 examines the structure of a SAM, emphasising the equilibrium constraints that it imposes. Section 4.5 briefly presents the relationship between a SAM and an I-O table. Section 4.6 gives coverage of some of the issues pertaining to data construction and reconciliation which is followed by an outline of both the sets and parameter estimates supplied with the GTAP data in section 4.7. Section 4.8 discusses the accounting conventions within the GTAP data and section 4.9 concludes the chapter To help identify the large number of variables in the standard GTAP model structure which appear throughout this chapter, a glossary of terms has been constructed to aid model interpretation and appears at the end of the thesis.

PART I – The Model Framework

4.1 Behavioural Equations

The sections that follow describe the behavioural patterns of consumers and producers within the economy. Moreover, a description of the global institutions in the model is presented. The equations follow the terminology of the GTAP, where lower case letters are percentage change variables which update the levels database.

4.1.1 Armington Structure

The structure of regional intermediate and final import demands follows the Armington (1969) specification discussed in section 3.1.2. Thus, the quantity of exports of good ‘i’ from region ‘r’ to ‘s’ ($qxs_{i,r,s}$) are derived from changes in relative import prices and composite import demand in the nest at the region of destination, ‘s’. Schematically, the lower Armington nest is presented in figure 4.1.

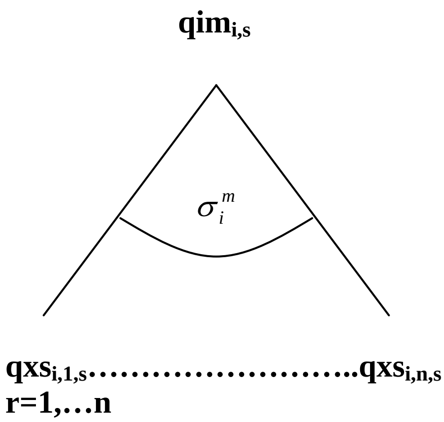


Figure 4.1: The lower Armington Nest in the standard GTAP model.

At the border, linearised CES Hicksian import demands for good ‘i’ (both intermediate and final) from exporting region ‘r’ to importing region ‘s’ are given as:

$$qxs_{i,r,s} = qim_{i,s} - \sigma_i^m \left[pms_{i,r,s} - pim_{i,s} \right] \qquad \text{(B.1)}$$

where

$pms_{i,r,s}$ - The bilateral import price

$pim_{i,s}$ - The composite price in the lower nest

$qim_{i,s}$ - The composite import good in the lower nest

The elasticity of substitution in the lower Armington nest, σ_i^m, allows imperfect substitution possibilities between each of these ‘export demands’ by importing region 's', where all pair-wise combinations of imports have identical substitution possibilities.

The composite price of imports from all foreign (r≠s) regions is given as:

$$pim_{i,s} = \sum_{r \in reg} MSHRS_{i,r,s}\, pms_{i,r,s} \qquad \text{(B.2)}$$

where the share, $MSHRS_{i,r,s}$, shows the market value of imports of tradable commodity 'i' in region 's' from export region 'r' as a proportion of import demands of 'i' from *all* regions 'r'.

The sourcing of regional composite imports ($qim_{i,s}$) in the lower nest to each of the agents within the importing economy 's' is given by the linearised border market clearing expression (B.3). Thus, a general solution is characterised by a vector of prices which leads to market clearing quantity changes:

$$VIM_{i,s}qim_{i,s} = \sum_{j \in prod} VIFM_{i,j,s}qfm_{i,j,s} + VIPM_{i,s}qpm_{i,s} + VIGM_{i,s}qgm_{i,s} \qquad \text{(B.3)}$$

$VIM_{i,s}$ - The value of aggregate imports of tradable commodity 'i' in region 'r' at market prices.

$VIFM_{i,j,r}$ - The value of purchases of composite imported tradable commodity 'i' by firms in sector 'j' of region 'r' evaluated at market prices.

$VIPM_{i,r}$ - The value of expenditure on composite imported tradable commodity 'i' by the private household in region 'r' evaluated at market prices.

$VIGM_{i,r}$ - The value of expenditure on composite imported tradable commodity 'i' by the government household in region 'r' evaluated at market prices.

where the percentage change variables are the respective quantity indices for each of the value terms defined. These composite import quantity indices appear in the upper part of the Armington nest for both intermediate and final demands (see figures 4.2 and 4.7 respectively).

Once the composite import is sourced to each agent, the upper level of the Armington specification separates agents' (final or intermediate) composite import demands for commodity 'i' from the domestic substitute. Once again, a CES specification is employed, where a single elasticity parameter dictates the degree of substitutability of the import composite and the domestic substitute in the upper nest. Moreover, each of the Armington substitution elasticities specified in the GTAP data for each commodity are the same in all regions.

4.1.2 Production nest

The nest for each productive sector 'j' in the model is presented in figure 4.2, where each sectoral production function produces a single output in a perfectly competitive market structure and is assumed to exhibit constant returns to scale. Linear behavioural equations in the upper and lower parts of the production nest are derived from a weakly separable cost minimisation problem which yields conditional **Hicksian** demands and composite prices. These expressions are presented in figure 4.3.

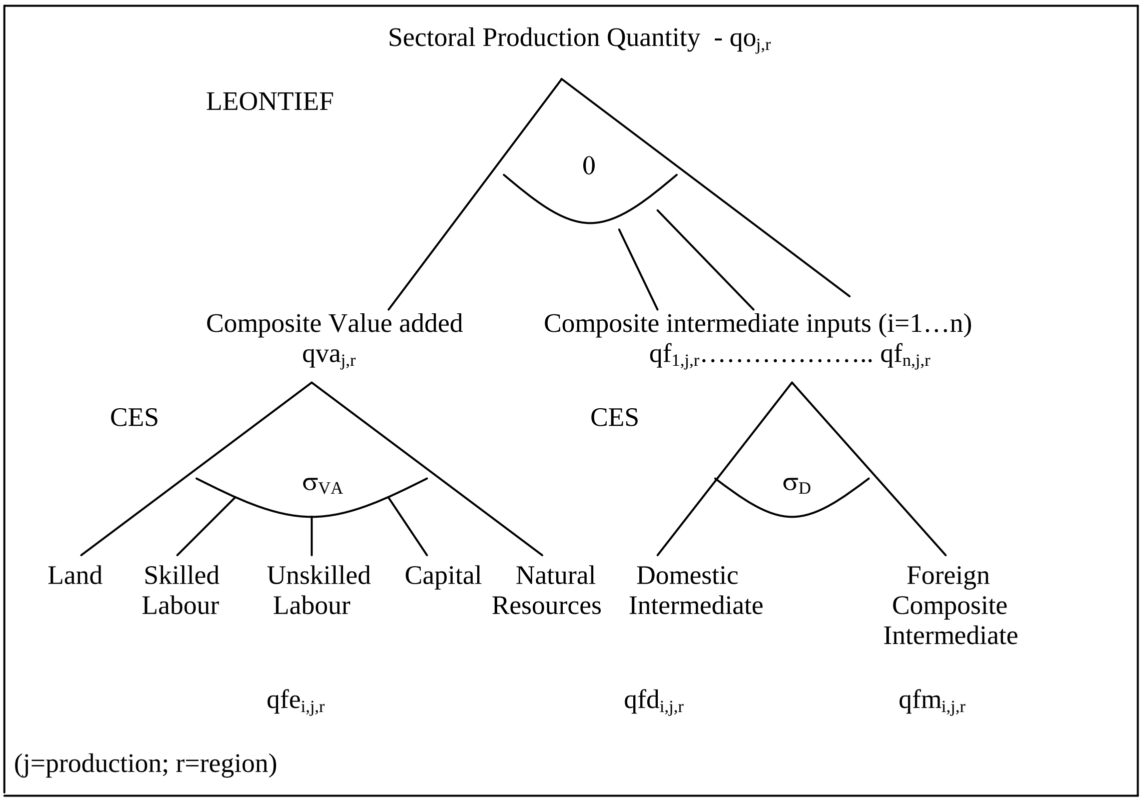


Figure 4.2: The Production Nest

In the lower level of the production nest, CES aggregator functions are used to collect primary inputs and intermediate inputs (domestic and foreign imported 'composites') into aggregate value added and composite intermediates respectively. As specified by the single parameterised value of the elasticity of substitution, the input components of both of these aggregator functions are imperfectly substitutable for one another within each separable group.

Upper Nest – Composite Value added/intermediate input demands

$$qva_{j,r} = qo_{j,r} \qquad \text{(composite value added demand)}$$

$$qf_{i,j,r} = qo_{j,r} \qquad \text{(composite intermediate input demand)}$$

$$VOA_{j,r}.ps_{j,r} = \sum_{i \in endw} VFA_{i,j,r}.pfe_{i,j,r} + \sum_{i \in trad} VFA_{i,j,r}.pf_{i,j,r}$$

(composite price/zero profit)

Lower Nest - Composite Intermediate Inputs:

$$pf_{i,j,r} = FMSHR_{i,j,r}.pfm_{i,j,r} + [1 - FMSHR_{i,j,r}].pfd_{i,j,r} \qquad \text{(composite price)}$$

$$qfm_{i,j,r} = qf_{i,j,r} - \sigma_i^D.[pfm_{i,j,r} - pf_{i,j,r}] \qquad \text{(composite import demand)}$$

$$qfd_{i,j,r} = qf_{i,j,r} - \sigma_i^D.[pfd_{i,j,r} - pf_{i,j,r}] \qquad \text{(domestic tradable demand)}$$

where FMSHR is the share of the import composite or domestic good in the total purchases of ‘i’ by sector ‘j’ in the nest.

Value Added Nest:

$$pva_{j,r} = \sum_{i \in endw} SVA_{i,j,r}.pfe_{i,j,r} \qquad \text{(composite price)}$$

$$qfe_{i,j,r} = qva_{j,r} - \sigma_i^{va}[pfe_{i,j,r} - pva_{j,r}] \qquad \text{(endowment demands)}$$

where SVA is the share of a given endowment ‘i’ in the total endowment purchases by sector ‘j’ in the nest.

Figure 4.3:Linearised Equations of the Production Nest

Moreover, the intermediate input part of the lower nest, is effectively the upper level of the Armington nest discussed in section 4.1.1 above. The top nest demands are Leontief and separable with respect to composite intermediate and value added inputs, where the composite price, in this part of the nest, is also the industry zero profit condition (see A3-A5 in Appendix A).

4.1.3 (Sluggish) Factor Mobility

In each economy, primary factors, 'i', are distinguished by the degree of mobility between the using sectors 'j', where those factors which are restricted from moving freely are deemed as ‘sluggish’. To model imperfect (or sluggish) factor mobility, the model employs a single nested Constant Elasticity of Transformation (CET) function, which is the corollary of the CES function. The CET function is presented in figure 4.4.

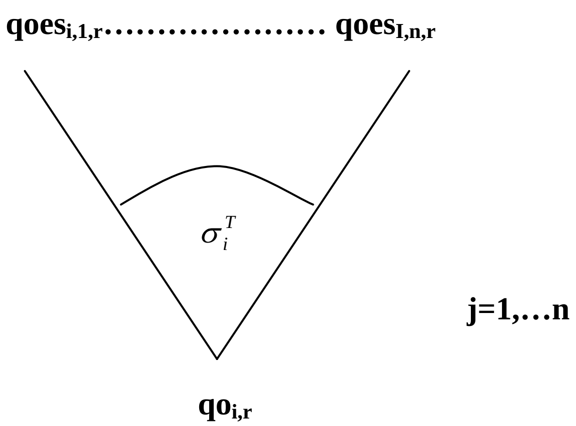


Figure 4.4 CET Factor Supply Function

Maximising factor returns (revenue) subject to the CET function gives the optimal supply allocations ($qoes_{i,j,r}$) of a sluggish factor ‘i’ between using sectors 'j' in response to changes in sluggish factor sectoral prices ($pmes_{i,j,r}$) and the (exogenous) regional quantity ($qo_{i,r}$), with the composite sluggish primary factor price given by $pm_{i,r}$.

$$qoes_{i,j,r} = qo_{i,r} + \sigma_i^T \left[pm_{i,r} - pmes_{i,j,r} \right] \qquad \text{(B.4)}$$

$$pm_{i,r} = \sum_{j \in prod} REVSHR_{i,j,r} . pmes_{i,j,r} \qquad \text{(B.5)}$$

where $REVSHR_{i,j,r}$ is the value of market demands, (i.e., the cost to the using sector inclusive of taxes/subsidies) for sluggish factor 'i' by sector 'j' in region 'r' as a share of the demand for sluggish factor 'i' by *all* using sectors 'j' in region 'r'.

The elasticity parameter, σ_i^T is the elasticity of transformation (the corollary of the elasticity of substitution in CES functions). In the model, the *degree* of factor mobility of the sluggish factor 'i' between using sectors 'j' is controlled by the elasticity of transformation parameter, where the closer the value of σ_i^T is to zero, the more immobile the factor. The direct implication of rigidities in factor markets (vis-à-vis mobile factor markets) is that it allows differences in sectoral factor returns to persist. For example, in sector 1 the demand for the sluggish factor, say land, may be higher than in sector 2, hence returns to land are greater in sector 1. Since land has a high degree of sector specificity, factors can only move sluggishly into sectors with higher returns (i.e., from sector 2 to sector 1) so differentials in sectoral factor returns ($pmes_{i,j,r}$) remain intact.

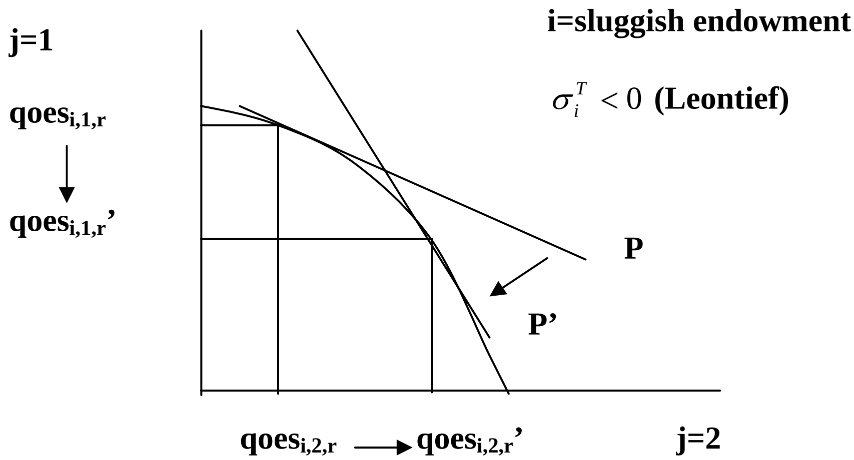


Figure 4.5: CET Transformation Frontier

Thus, an example of factor immobility is presented in figure 4.5, where optimal supply allocations of sluggish endowment 'i' respond sluggishly to changes in factor returns ($pmes_{i,j,r}$) (P - P' in figure 4.5) between using sectors 'j'. At the extreme, one could specify zero factor mobility between using sectors for factor 'i'.

For example, in figure 4.6, the elasticity of transformation between uses of the sluggish factor is zero, so the *transformation* frontier is effectively Leontief in form. This implies that optimal supply allocations of sluggish endowment 'i' no longer respond to changes in factor returns ($pmes_{i,j,r}$) (P - P' in figure 4.6) between using sectors. In this case, sluggish factor ‘i’ is sectorally fixed in supply in each sector, leading to *zero factor mobility*.[1]

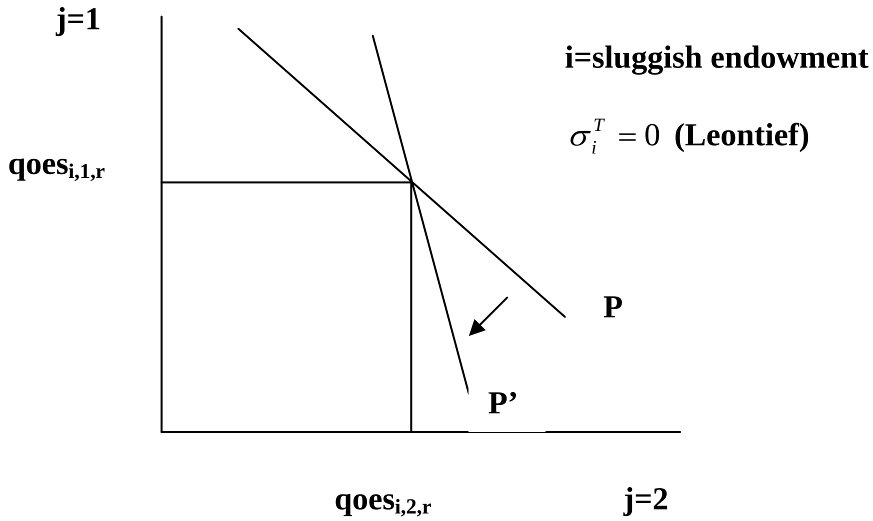


Figure 4.6: Leontief Transformation Frontier for Sluggish Factor ‘i’

Where primary factors are perfectly sectorally mobile, factor returns are equalised across all sectors. Hence, the presence of a common factor price permits the market clearing relationship for mobile factors in the model to be expressed in terms of domestic market values. In the case of the sluggish factor, no one price clears aggregate sluggish markets. Thus, market clearing in each region 'r' is expressed on a *sectoral* basis in terms of quantities (i.e., supply = demand) only. Linearised equations (B.6) and (B.7) show the market clearing conditions for both mobile and sluggish factors respectively:

$$VOM_{i,r}.qo_{i,r} = \sum_{j \in prod} VFM_{i,j,r}.qfe_{i,j,r} \qquad \text{(B.6)}$$

$$qoes_{i,j,r} = qfe_{i,j,r} \qquad \text{(B.7)}$$

$qfe_{i,j,r}$ – Quantity demanded of factor 'i' (sluggish or mobile) by sector 'j' in region 'r'

$VOM_{i,r}$ - Total market value of mobile endowment 'i' in region 'r'.

[1] This technique is often employed to characterise the land constraint in the agriculture sector.

$VFM_{i,j,r}$ - Sectoral market demand value for mobile endowment 'i' by sector 'j' in region 'r'.

Finally, in the GTAP database (for further discussion of the data see part II), the land factor is only purchased by primary agricultural sectors, where for each of the remaining sectors there exists a zero entry in the data set. To avoid the potential problem of forcing the model to calculate percentage changes of zero entries in the data, a dummy variable is used to record zero expenditures by sectors on the land input. Thus, if land expenditure by a sector (non-agricultural) is zero in the data, the dummy variable, D_EVFA(i,j,r), is zero, and the quantity of land purchased is zero. Conversely, non-zero expenditures have a dummy value of one. In a similar manner, dummy variables are also employed for identifying zero expenditures in the data (for all aggregations) for intermediate input demands by firms, zero expenditures on exports of tradables of 'i' from 'r' to 's' and zero supplies of transport services (by non-service sectors) to the global transport sector.

4.1.4 Consumption Nest

Final demands in the model are based on a three stage nested structure. A full schematic representation of the utility tree in the model is presented in figure 4.7. The linearised behavioural equations pertaining to each part of the nest are presented in figure 4.8. Final demands are by the 'regional- household', which collects all incomes in the economy from endowments (mobile and sluggish) and taxes, and pays out subsidies. Thus, in the top level of the nest Cobb-Douglas regional household utility is maximised

$$MaxU_r = CD[UG_r, UP_r, QSAVE_r] \qquad (B.8)$$

subject to the regional budget constraint:

$$INCOME_r = PPRIV_r.UP_r + PGOV_r.UG_r + PSAVE_r.QSAVE_r \qquad (B.9)$$

$$PRIVEXP_r = PPRIV_r.UP_r \qquad GOVEXP_r = PGOV_r.UG_r$$
$$SAVE_r = PSAVE_r.QSAVE_r \qquad (B.10)$$

which yields Cobb-Douglas regional Marshallian demands by each agent (up_r, ug_r, $qsave_r$), with regional savings demands going directly to the global bank (see section 4.1.6).

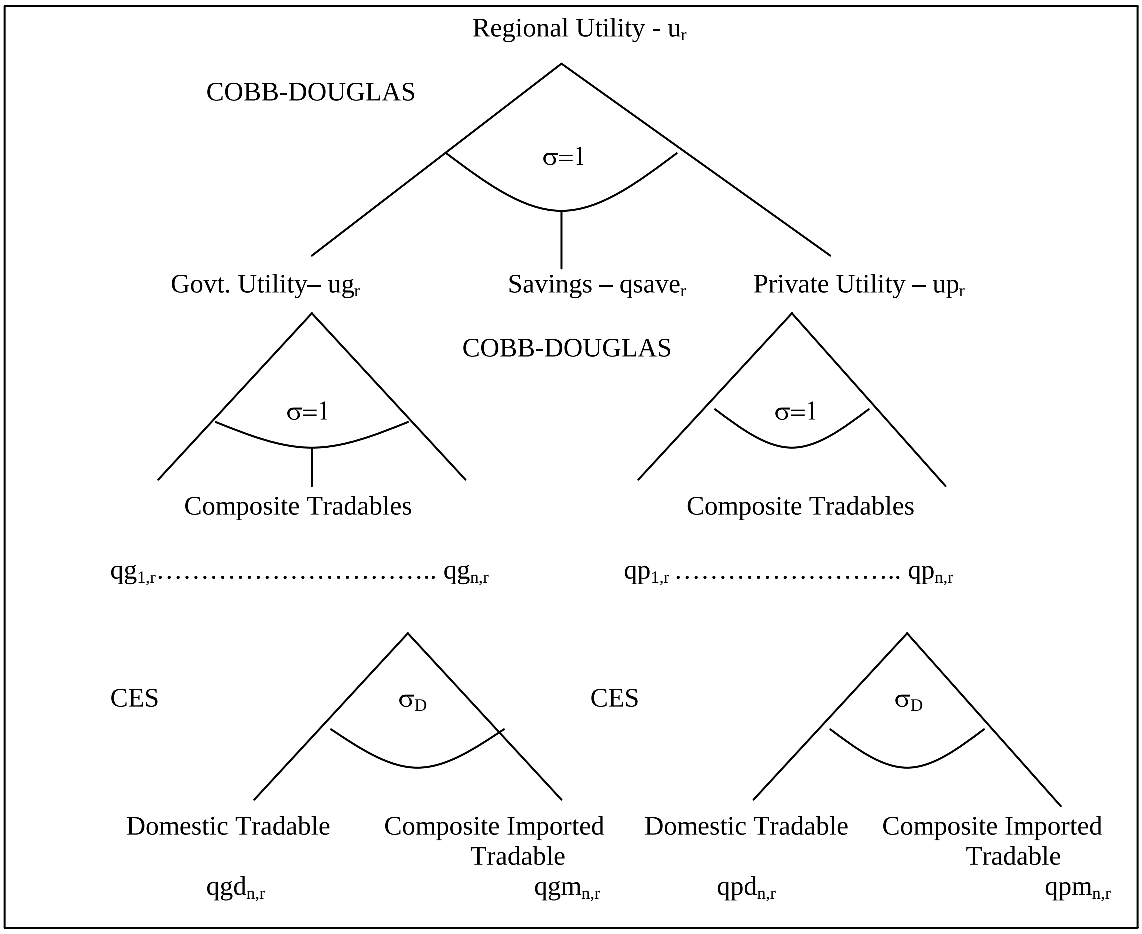


Figure 4.7: The Utility Tree for Final Demands

The equations in the *second* level of the nest are derived using a cost minimisation procedure. For example, minimising government expenditure

$$Min \quad GOVEXP_r = \sum_{i \in Trad} PG_{i,r}.QG_{i,r} \qquad \text{(B.11)}$$

subject to a Cobb-Douglas utility function

Top Nest – Regional Utility

$$INCOME_r.u_r = PRIVEXP_r.up_r + GOVEXP_r.ug_r + SAVE_r.qsave_r$$

(aggregate utility)

$qsave_r = y_r - psave_r$ (regional savings)

$ug_r = y_r - pgov_r$ (government purchases)

$up_r = y_r - ppriv_r$ (private household purchases)

Second level – Agents' demands for composite tradables.

$qg_{i,r} = ug_r - [pg_{i,r} - pgov_r]$ (Govt. demand for 'i')

$pgov_r = \left[\sum_{i \in Trad} VGA_{i,r} / GOVEXP_r\right] . pg_{i,r}$ (composite government price)

$qp_{i,r} = up_r - [pp_{i,r} - ppriv_r]$ (private household demand for 'i')

$ppriv_r = \left[\sum_{i \in Trad} VPA_{i,r} / PRIVEXP_r\right] . pp_{i,r}$ (composite private household price)

where psave is the market clearing price in the global investment/savings market.

Third Level – Demand for import composite/domestic tradables.

$pg_{i,r} = GMSHR_{i,r} . pgm_{i,r} + [1 - GMSHR_{i,r}] . pgd_{i,r}$ (composite price)

$qgm_{i,r} = qg_{i,r} + \sigma_i^D [pg_{i,r} - pgm_{i,r}]$ (composite import demand)

$qgd_{i,r} = qg_{i,r} + \sigma_i^D [pg_{i,r} - pgd_{i,r}]$ (domestic tradable demand)

$pp_{i,r} = PMSHR_{i,r} . ppm_{i,r} + [1 - PMSHR_{i,r}] . ppd_{i,r}$ (composite price)

$qpm_{i,r} = qp_{i,r} + \sigma_i^D [pp_{i,r} - ppm_{i,r}]$ (composite import demand)

$qpd_{i,r} = qp_{i,r} + \sigma_i^D [pp_{i,r} - ppd_{i,r}]$ (domestic tradable demand)

where GMSHR and PMSHR represent the share of domestic/import composite 'i' in total purchases of 'i' in the nest.

Figure 4.8: Linearised Equations in the Utility Tree

$$UG_r = CD\left[\sum_{i \in Trad} QG_{i,r}\right] \qquad \text{(B.12)}$$

gives Hicksian government household demands for composite tradable goods, $qg_{i,r}$. The *third* level of the utility tree in figure 4.7 is the upper level of the Armington structure for both private and government household, where *final* demand quantities for composite import and domestic goods are derived from a CES cost minimisation procedure.

4.1.5 Global Transport Sector

The *supply* quantities of transport services ($qst_{i,r}$) are aggregated as Cobb-Douglas inputs into the composite global shipping commodity output good ‘qt’.[2] Similarly, the corresponding global shipping price, ‘pt’, is a composite of regional service sector prices, ‘$pm_{i,r}$’. These expressions are given as:

$$qst_{i,r} = qt + \left[pt - pm_{i,r}\right] \qquad \text{(B.13)}$$

$$VT.pt = \sum_{i \in trad} \sum_{r \in reg} VST_{i,r}.pm_{i,r} \qquad \text{(B.14)}$$

The latter expression is also a zero profit equation for the global shipping sector which states that the total value of service exports supplied by all regions ($VST_{i,r}$) is equal to the global value of transport services (VT). Note that the aggregation of shipping exports is valued at market prices because sales of shipping transport services are assumed to be free of trade price distortions.

The base value of transportation service demands ($VTWR_{i,r,s}$) to ship good 'i' from region 'r' to 's' is the margin between the free on board (f.o.b.) and cost, insurance freight (c.i.f.) values. Changes in the *quantity demanded* for freight services, $qts_{i,r,s}$, are assumed to be some *fixed proportion* of the quantity of the exported good 'i' being shipped along a given route, $qxs_{i,r,s}$. In percentage terms, the two change at the same rate:

$$qts_{i,r,s} = qxs_{i,r,s} \qquad \text{(B.15)}$$

For market clearing, global shipping supplies should be equal to the sum of all bilateral shipping demands:

[2] Which come from the services sector of each region .

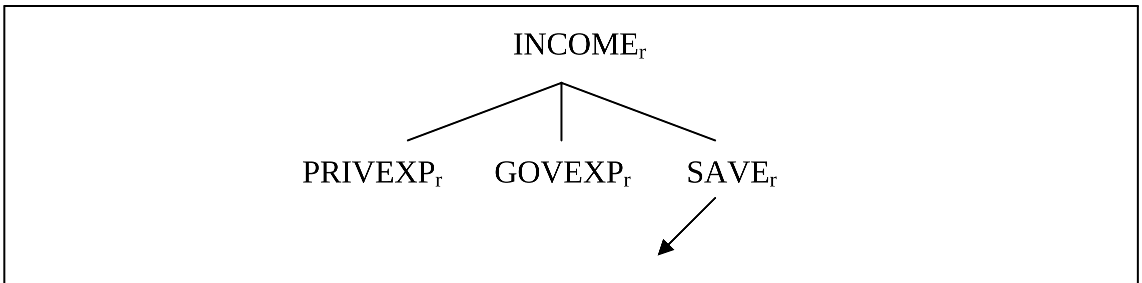
$$VT.qt = \sum_{i \in trad} \sum_{r \in reg} \sum_{s \in reg} VTWR_{i,r,s}.qxs_{i,r,s} \qquad \text{(B.16)}$$

In percentage terms, the change in $qts_{i,r,s}$ and $qxs_{i,r,s}$ will be the same since the quantity of the shipping good required is a fixed proportion of the export quantity. Hence it is possible to substitute $qxs_{i,r,s}$ for $qts_{i,r,s}$.

4.1.6 The Global Bank

The global bank (see figure 6.9) has the role of creating a global investment good summed over all regions minus regional depreciation.[3] The sum of all regional household savings, which is a Cobb-Douglas share of regional income, is interpreted as the global demand for investment or capital goods, where a global investment good (GLOBINV) made up from capital producing sectors in each region is offered by the bank to satisfy this demand (see figure 4.9).[4]

Having established the link between savings and investment via the global bank, the model offers the user a choice of two specifications establishing the allocation of investment (and thus capital production) between regions. The first theory allocates regional investment in capital goods based on changes in rates of return. The second mechanism takes the position of assuming that the composition of net regional investment shares in the global portfolio are constant (see Hertel, 1997). The model structure allows the user to incorporate either investment mechanism into a single set of equations.



[3] Depreciation expenditure is treated as a withdrawal from regional household income. All *expansionary* investment in new capital comes from regional savings.
[4] These are assumed to be additions to the capital stock and are not related in any way to the existing fixed stock of primary factor capital in each region.

$$GLOBINV = \sum_{r \in reg} SAVE_r$$

$[REGINV_r – VDEP_r]$………… $[REGINV_s – VDEP_s]$

Figure 4.9: Global Savings and Investment
Source: Hertel and Tsigas (1993)

Perhaps the key difference between the two investment treatments is with regard to welfare effects. Under the second mechanism, changes in global savings (which typically change very little in response to small changes in regional incomes) create an equal percentage rise in global investment which leads to equal percentage changes in each region's net investment shares. Thus, regional savings and investment are coerced to move together, which under regional closure (see section 2.3) implies, *ceteris paribus*, minimal change in the trade balance.

The alternative mechanism allows regional investment shares and thus capital stocks to respond to variations in expected rates of return. Thus, if regional (and therefore global) savings typically move very little but there are significant reallocations in investment shares between regions in response to differing regional rates of return, then to preserve general equilibrium the trade balance may be forced to react with dramatic consequences on the terms of trade (see section 4.2.1).

In response to regional investment demand for capital goods, each region in the model has a capital goods producing sector which combines domestic and imported intermediate inputs. Moreover, the primary factor input element is zero as it is assumed that value added is already embodied in the production of the intermediate inputs assembled to produce the capital good.

Finally, drawing on Walras' law, the n^{th} market is characterised by savings and investment, where the supply of global capital/investment goods (walras_sup) must be equal to the sum of all savings demands (walras_dem). This identity is checked in the model, where a non-zero value of the endogenous variable, walraslack (which is swapped with the numeraire price 'psave') implies an incorrect implementation of the model (see section 2.2.3, chapter 2):

$$walras\_sup = walras\_dem + walraslack \qquad \text{(B.17)}$$

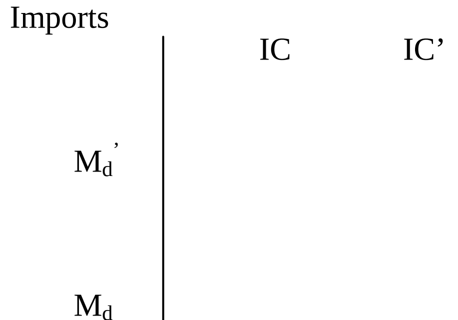
4.2 Welfare (Summary) Indices

All of the equations which fall into this category do *not* affect the solution of the model. Rather, their role is to report various counterfactual equilibrium results in percentage changes which can be calculated from the exogenously and endogenously determined variables in the core model solution. A full list of all the summary indices is presented in Hertel (1997). This section concentrates on the key *welfare measures* contained in this part of the model, namely, the terms of trade, gross domestic product and the equivalent variation in income.

4.2.1 Terms of Trade

Referring to figure 4.10, the terms of trade is defined as the ratio of the price of exports to the price of imports. Assuming the economy is using all its resources efficiently, production will take place at the point of tangency between the international rate of exchange, P_x/P_m, and the transformation function, producing M_1 and X_1 of the import competing and export good respectively. Adding a social welfare function given by the indifference curve, IC, determines exchange of exports (X_1-X_d) for imports (M_1-M_d).

If the terms of trade *improve*, then the price of exports increases relative to the price of imports. This is illustrated in the diagram as a pivot in the international rate of exchange to P_x/P_m', where the higher price of the export good encourages increased specialisation at the new point P'. Thus, export good production increases to X_2 and import competing good production declines to M_2. At the new terms of trade, more imports (M_2-M_d') can be bought per pound of exports (X_2-X_d') sold which, *ceteris paribus*, increases the level of social welfare to the aggregate consumer from IC to IC'. Hence the terms of trade effect also leads to increased specialisation (i.e., a factor allocation effect) in the export good, where domestic resources are redistributed in response to changes in relative price signals.



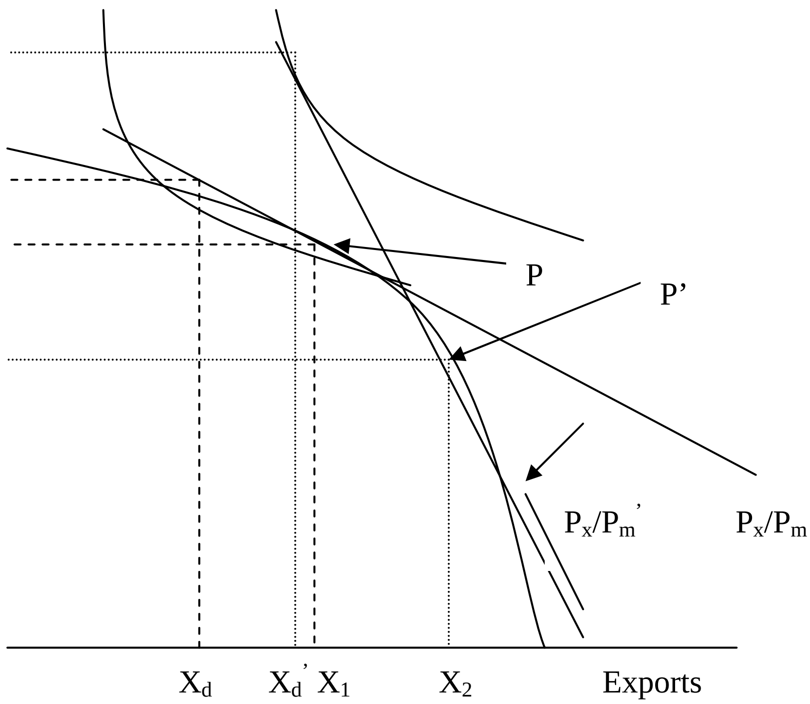


Figure 4.10: An Improvement in the Terms of Trade

In the model, the terms of trade is calculated as the ratio of the price indices PSW_r and PDW_r for tradables. The expression PSW_r is the price index received for *all* tradables produced in region 'r' including ‘sales’ of savings to the global bank. The price index PDW_r reflects prices paid for tradables by region 'r', including investment from the global bank. In linear form, the terms of trade are given as:

$$tot_r = psw_r - pdw_r \qquad \text{(W.1)}$$

4.2.2 Gross Domestic Product

In the model, gross domestic product (GDP) or output in the economy is calculated using the expenditure approach, (i.e., C+I+G+[X-M]). Calculation of GDP is broken down into value ($vgdp_r$), price ($pgdp_r$) and real quantity ($qgdp_r$) indices:

$$vgdp_r = pgdp_r + qgdp_r \qquad \text{(W.2)}$$

If primary factor endowments are *fixed* within an economy, then changes in $vgdp_r$ will typically be dominated by changes in the price index of GDP ($pgdp_r$), which can be thought of as a measure of general prices in each region (inflation). Moreover, with fixed endowments, any change in $qgdp_r$ determines the ability of the economy to reallocate its primary resources efficiently. Thus, increases (which will typically be very small) in $qgdp_r$ are a direct measure of the efficiency gains to a particular region.

4.2.3 Equivalent Variation

The value of equivalent variation (EV) is defined by Varian (1990), who asks the question,

"how much money would have to be (given) taken away (to) from the consumer before the price change to have him as well off as he would be after the price change", (pp.249).

In the model, the EV is calculated as:

$$EV_r = \left[\frac{INC_r}{100}\right] u_r \qquad \text{(W.3)}$$

where INC_r is the level of income (=expenditure) in benchmark period (pre-shock) prices, and regional utility (u_r) is a linearly homogeneous Cobb-Douglas aggregate of private (up_r) and government (ug_r) household utilities and savings demands ($qsave_r$). Thus, the percentage change in regional utility (real income) from the benchmark position is converted into a monetary value from (W.3). The key difference here from Varian's (1990) interpretation of EV is that the welfare gain is *actually realised* in pre-change prices in the model structure vis-à-vis the case where it is merely a compensatory amount to leave the consumer on the same level of welfare. For example, a positive EV figure is the real income gain, in pre-shock (benchmark) prices, which allows an economy to attain a higher level of regional utility. The model calculates world EV (WEV) as the summation of each of the regions' EV values:

$$WEV = \sum_{r \in reg} EV_r \qquad \text{(W.4)}$$

PART II - The Global Trade Analysis Project (GTAP) Database

4.3 Introduction

As shown in part I of the chapter, CGE models use neo-classical behavioural concepts such as utility maximisation and cost minimisation to characterise the workings of the economy. Subsequent questions posed are answered by the interaction of economic agents within each market, whereby an outcome of the model is characterised by a new set of interdependent (counterfactual) equilibria. To ensure that the model obeys the Walrasian laws of general equilibrium, a large system of accounting identities (see Hertel, 1997) are required to guarantee that households and producers remain on their budget and cost constraints respectively and that zero profits prevail in the product, investment and transport sectors in the model. The concept of a Social Accounting Matrix (SAM) enters the discussion since a SAM,

> *"represent(s) in numerical form all of the constraints inherent to a general equilibrium model, including the budget constraints of the actors in the economy and the physical and financial constraints of the system" (pp.78, Roberts, 1992).*

A SAM represents the perfect data set upon which to base a CGE model application, although, in practice, the data requirements for the construction of a detailed SAM for each of many trading countries/regions, as well as the accompanying inter-linking trade data are simply not available. It is for this reason that many multi-region CGE applications favour the use of input-output (I-O) data, where most of the important elements in the economy are present without much loss of accounting detail.

One alternative to building a consistent database is to resort to using an existing database. One such example is the Global Trade Analysis Project (GTAP) which was established in 1992. The GTAP is dedicated to the development and support of a global research network, data base, and modelling framework for the analysis of international trade, environment and resource issues. In its entirety, the GTAP consists of several components: 1) a fully documented, publicly available, global data base; 2) software for manipulating the data; 3) a global network of researchers with a common interest of multi-region trade analysis and related issues and; 4) a consortium of national and international agencies providing leadership and a base level of support for the project (Hertel, 1997).

The GTAP database is a global data-set which combines detailed bilateral trade, transport and protection data characterising economic linkages *between* regions, together with individual country I-O databases which account for intersectoral linkages *within* regions. In their most recent incarnation (version 4), the GTAP data represent the world economy for the year 1995 and cover 45 regions/countries and 50 commodities/sectors.

This application follows the latter approach by adopting an existing global dataset; however, before turning attention to data construction, reconciliation and accounting conventions within the GTAP database, some attention is given to the usage and conventions of SAMs and their relationship with the input-output table which forms an important data source for many multi-region CGE data sets.

4.4 A Social Accounting Matrix (SAM)

The SAM gives a complete, consistent and comprehensive picture of how the various actors in the economy interact at a certain point in time – the base year. King (1981), defines a SAM as,

> *"a series of accounts in each of which incomings and outgoings (or revenue and expenditure) must balance. Furthermore, what is incoming into one account must be outgoing from another account" (p.1).*

The *rows* and *columns* in a SAM designate *revenues* and *expenditures* respectively. For example an entry in row 'i' and column 'j' is an expenditure by account 'j' which is simultaneously a receipt by account 'i', where row and column totals for each corresponding account must balance such that incomes equal expenditures.

Given that the number of rows and columns are identical, a SAM is a *square matrix*. The size of this matrix can theoretically be adjusted by further (dis)aggregation to cover whatever level of economic detail is required although, in practice, highly disaggregate levels require extreme amounts of time, raw data and effort.

An illustrative example of a SAM framework (for Thailand, Drud *et al.*, 1980) is provided below in table 4.1. Typically, it is possible to aggregate the rows and columns into 5 separate account types:

(1) factor accounts;
(2) institution accounts;
(3) production activity accounts;
(4) commodity accounts;
(5) Rest of the World (ROW) accounts.

Thus, in table 4.1, row (i) shows that the aggregate factor receives payments of 176 from agriculture, 153 from manufacturing and 273 from services. From the total of 602, 15 units are factors owned abroad, (the negative sign in row (i) shows outflows from the domestic economy paid to the ROW account) giving net total domestic factor payments of 587.

The domestic factors of production are assumed to be owned by 'institutions'. Institutions are split into one public account for government (iv) and two private sector accounts for households (ii) and companies (iii). Account (v) is a 'combined' capital account which shows the *collective* investments and savings for each of the three institutions.

In column 1, households receive 520 units in wages and 'unincorporated business profits', manufacturing receives 'private-sector corporate profits' of 63 and the remaining 4 units go to government owned 'state enterprises'. All the elements in the intersection of rows and columns 2 to 4 are payments between institutions and are classed as 'transfers' or incomes *not directly* received through production. For example, payments to government may include direct taxes on households and companies as well as social security and pension fund payments and dividend payments by firms.

	Outlays or Expenditures				
		Institutions	Production		

	Factors	Current a/c			Capital	Activities			Commodities			row	
	1	2	3	4	5	6	7	8	9	10	11	12	
Incomes/receipts		HH	C	G		A	M	S	A	M	S		**total**
Factors i						176	153	273				-15	**587**
Current a/c: HH ii	520		4	1								5	**530**
C iii	63	6		10									**79**
G iv	4	9	10						6	48	17	3	**97**
Capital a/c v		72	65	3								49	**189**
Activities: A vi									301				**301**
M vii										521			**521**
S viii											448		**448**
Commod: A ix		132			19	22	47	12				77	**309**
M x		193		8	170	40	232	49				59	**751**
S xi		118		75		63	89	114				32	**491**
row xii									2	182	26		**210**
total	**587**	**530**	**79**	**97**	**189**	**301**	**521**	**448**	**309**	**751**	**491**	**210**	

HH=Household;C=Companies;G=Government;
A=Agriculture; M=Manufacturing; S=Services.

Table 4.1. A SAM for Thailand in 1980 (Units: billions of baht)
Source: Drud *et al.* (1986)

In return, the government may pay out pensions or social security payments, interest service payments on the public debt and a range of subsidies to private firms. Payments are also made from firms to households in the form of capital returns (it is assumed that households own factors) and private corporate pensions. Finally, both households and government may also receive (non-factor) transfer income from abroad (column 12). These incomes are recorded as 5 units and 3 units respectively in rows ii and iv in table 4.1.

Total institutional income is distributed as expenditures in columns 2 to 4. As well as expenditures on transfers between sectors, income also goes on commodity consumption as recorded in rows ix, x and xi. Any income which is not used on transfers or commodity expenditure is saved (row v). Thus, total domestic savings are 140 (72+65+3). Finally, added to domestic savings are foreign savings (which are a deficit to the external balance of payments) of 49.

Thus, total savings are 189 which in column 5 is distributed between manufacturing sector commodities (e.g. buildings, machinery etc.) and, to a lesser extent, agricultural sector commodities (e.g. seeds, trees etc.). These payments are more commonly known as *investment* and by definition must equal the corresponding row total, or *total savings*.

The next set of accounts pertain to the production *activities* of each of the 3 institutional sectors. The activities (rows vi to viii) deliver their output to the commodity accounts (columns 9, 10, 11) in exchange for payments. This is known as the *make matrix* and shows the domestic commodity supplies of 301, 521 and 448 for agriculture, manufacturing and services respectively. To produce these outputs, each sector requires, from each column, inter-industry inputs (commodities) which are shown in the *absorption matrix* (intersection of rows ix to xi and columns 6 to 8) as well as primary factors (intersection in row i and columns 6 to 8) as discussed above.[5]

The commodity accounts columns (9 to 11) record the disaggregation of commodity source values over domestic production, tax revenues to the government, and imports. The corresponding commodity row accounts show the composition of each commodity’s receipts, made up of final and intermediate demands, investment and exports. Clearly, the value of receipts on each commodity must equal the corresponding supply value.

The final account in this matrix is the *external sector* or ROW account. The in-goings to this account are the *imports* in row xii paid by the commodity accounts totalling 210 billion baht. The out-goings, recorded in column 12, are the payments made by the external sector for *exports* of each commodity, (77, 59 and 32), which means that the balance of payments is in deficit by 42 billion baht. This deficit is increased with net factor payments abroad of 15 units and offset slightly by 'net non-factor income receipts' of 8. Thus, the overall deficit is 49 billion baht which is entered into the combined capital account row v as foreign savings.

The level of commodity/activity/institutional detail within a SAM may be increased considerably. For example, institutional accounts could be further disaggregated to

5 It is assumed that when a sector uses its own output as an input in the absorption matrix, it is included in the output figure (i.e. “gross output” vis-à-vis net output) in the accounts. This convention is also followed in the GTAP database.

include separate households and firms, production factors may be disaggregated into land, labour and capital and, if possible, labour may be presented by type (e.g. skilled/unskilled). There is also the possibility of specifying the ROW account into different regions, or even countries, each with 6 account types, as specified here, in an attempt to make more explicit the transactions between the domestic economy and the ROW. Many of these improvements are, however, subject to data availability and resource constraints on the part of the SAM modeller.

4.5 Input-Output Data

The input-output (I-O) matrix shows the source of each industry's inputs (the column elements) and the dispersion of industry output (the row elements). The I-O matrix contained within the SAM in table 4.1 is presented in table 4.2. In practice, the I-O matrix is formed by supplementing the 'absorption' and 'final demands' matrices of the SAM with primary factor payments (row 1), indirect taxes (row 4) and imports (row 12). Thus, an I-O matrix is subsumed within a SAM, whereas a SAM expands on the I-O accounts to include a complete specification of the circular flow of income in the economy.

	Absorption Matrix				**Final Demands Matrix**				
Activities	**A**	**M**	**S**	**Sub-Total**	**C**	**I**	**G**	**X**	**Total**
Commodities									
A	22	47	12	81	132	19	0	77	**309**
M	40	232	49	321	193	170	8	59	**751**
S	63	89	114	266	118	0	75	32	**491**
Sub-Total	**125**	**368**	**175**	**668**	**443**	**189**	**83**	**168**	**1551**
Factors	176	153	273	602					
Indirect Taxes	6	48	17	71					
Imports	2	182	26	210					
Total	**309**	**751**	**491**	**1551**					

Table 4.2. An Input-Output Matrix for Thailand in 1980
Drud *et al.*, (1986)

Multi-country, multi-sector CGE models characterise many regions/countries at the cost of some degree of individual economy detail. Since the data required for the development of SAMs for many trading partners are simply not available, this forces the researcher to work with a lesser degree of detail, which favours the use of I-O tables. For example, the GTAP data has global coverage and therefore relies heavily on the use of I-O accounts as well as statistics on bilateral *gross* trade flows and trade protection data.[6] Thus, it is easy to imagine how the degree of effort required to build a data-set of this size may only be feasible in cases where large teams of modellers are involved, perhaps backed up by consortium support from organisations such as the World Bank.

The next section briefly discusses some of the issues involved in reconciling these data sources within the benchmark GTAP data framework. Section 4.7 examines some of the extra data supplied in the GTAP package pertaining to commodity/region groupings (sets data) as well as the behavioural parameters (elasticities) used in this study.

4.6 Building the GTAP Database

Version 4 of the GTAP database consists of 45 regions/countries and 50 producing sectors. Each region is based on an I-O table and these are connected by a set of bilateral trade data flows (including transport margins) and protection data matrices. The sections that follow briefly discuss each of these data sources in turn. Much of the discussion in this section follows Hertel (1997).

4.6.1 The GTAP I-O Data

The starting point is a set of I-O tables for the various countries (if available), which will be recorded in different currencies and for different years. Each I-O table needs to be based on a consistent structure and sectoral classification, ready to be updated to a given base year (1995). The production structure assumes that all inputs are positive which disallows the existence of negative flows.[7] The sectoral balance restriction on costs and sales implies that the I-O data (and the GTAP database) must have the same sectoral classification for industries and commodities.

The GTAP data base tracks the value usage of each import commodity by each using sector/household for both intermediate and final demands. While there are those I-O tables which supply such information, other source tables provide less than full information, providing perhaps only imports by user or by commodity, but not both.

[6] That is, records of *both* imports and exports along a given bilateral trade route, as opposed to *net* trade flows more commonly employed in partial equilibrium data – This is better suited to intra-industry CGE trade models.

[7] An example of a negative flow is the sale of scrap by households to industry, which in the I-O table may be treated as ‘negative’ sales by industry to households.

Thus, if sufficient information on the breakdown of users of commodity ‘i’ is not provided, it is assumed that the expenditure share of each commodity ‘i’ imported to a given region is shared out in proportion to the size of the sector. If the source I-O table only provides total imports by user (i.e., sector/household), but no decomposition of each user’s imports by commodity, then the GTAP trade data shares are used for each agent. Thus, one would use the by-commodity trade shares for a *region* and map them identically *to each agent* within the region. Finally, to match by-category and by-use import data requires the use of a Row And Sum (RAS) adjustment technique such that the data row and column accounts of the I-O table become mutually consistent.

Another issue is that some I-O tables provide imports at tax inclusive prices, which is compatible to the GTAP import usage data, whereas others do not and have a separate data entry for total import taxes by user. The rule used for dealing with this is to divide the total duty figure for each user in proportion to the size of the expenditures on each commodity by that user to derive a GTAP compatible data entry. Finally, in the case of agriculture, many of the source tables do not identify the land factor explicitly, it usually being aggregated with capital. In these cases, outside sources are used, where possible, to determine the cost shares of capital and land in agriculture. In the absence of such data, an arbitrary 50/50 split is imposed between capital and land in agricultural sectors.

There are a number of regions in the GTAP data where detailed I-O information is not available. Using techniques proposed by Calder *et al.*(1993), it is possible to base a country’s *average* patterns of production, consumption and savings on a country for which I-O data are already available. This comparison is made by observing similarities in per capita GDP and, as a subsidiary criterion, the production structure of the economy. The former criterion has practical application if one refers to Engel’s Law, where countries with lower per capita incomes are expected to spend larger proportions of their budget on food. This implies that countries with similar per capita incomes have similar budget shares, particularly in food related sectors.

Thus, one first identifies all the countries in each the composite regions where no I-O data is available. Then, employing (primarily) per capita data, it is possible to match these countries with individual ‘anchor’ countries already in the GTAP database for which I-O data is available (Gehlhar *et al.* 1996). Thus, within a given composite region, each 'anchor' may have several individual countries attached to it. Weights are then assigned to each anchor based on the GDP share contribution of all the countries associated with the anchor in total GDP for the composite region. Anchor countries which are not fitted to any countries within a region are given a zero weighting

Having calculated these weights for each of the anchors, it is then possible to use the known I-O tables to calculate the I-O parameters for each composite region using 'linear approximation'. For example, to calculate the average propensity to save in a composite region, the assigned weights of each of the anchor countries are multiplied by their respective savings propensities:

$$s = \sum_{r} w_r s_r^{*} \qquad \text{(DAT.1)}$$

w_r - The share weight of the r[th] anchor.

s_r - The savings propensity calculated for the r[th] anchor.

This weighted average becomes the savings propensity for the composite region.

This procedure is repeated to calculate other parameters for the composite regions. Moreover, the nature of the procedure makes newly generated tables consistent with the rest of the GTAP data base, although a valid criticism would be the lack of criteria in linking countries for which little I-O data are known to their respective anchors. Version 4 of the database is a considerable improvement in this respect, insofar that the number of individual countries in the GTAP data has been increased (from 18 to 32 including the UK (Hubbard, 1998) which reduces the size of the composite regions while simultaneously enhancing the portfolio of countries with which to approximate the remaining countries' unknown I-O structures.

4.6.2 The GTAP Trade Data

The GTAP trade data are based on the United Nations D-series trade statistics which form a complete data set with a significant level of commodity and country coverage. Combining the trade estimates of the USDA and the UN data at an aggregation level of

4 SITC (Standard International Trade Classification) digits creates a platform for the GTAP trade data.

Reconciliation of the trade data is on a bilateral basis and involves comparing a county's reported exports (imports) with the partner's reported imports (exports) with a view to identifying differences in value. Thus, if equation (DAT.2) below is true for a bilateral trade flow from region 'r' to region 's':

$$X_{i,r,s} = M_{i,r,s} \qquad \text{(DAT.2)}$$

where $X_{i,r,s}$ - reported exports of commodity 'i' by region 'r'.
$M_{i,r,s}$ - reported imports of commodity 'i' by region 's'.

then there is a consistency in the trade data.

The GTAP reconciliation method (for a detailed discussion see Hertel 1997) involves identifying a subset of the ten most consistent exporters (MCE) and most consistent importers (MCI).[8] The MCE and MCI criteria is based on those reporters with the least percentage of missing values in total transactions. Once these top ten import and export reporters are found, they are placed into 'peer evaluation groups'. A reliability index (RI) is then constructed based on the proportion of accuracy of each country's bilateral trade flows with the peer evaluation group.

Each bilateral trade flow used in the GTAP data is then based on the RI through the use of accuracy weights. Thus, where a reliable reporter trades with an unreliable reporter, unadjusted data from the former is employed. In the case where two unreliable reporters are trading with each other, econometrically derived bias estimates are used to adjust the data.

Once the data flows are finalised, a matrix balancing technique is used to set the trade

[8] However, it has been found that countries tend to report import statistics more accurately than export statistics, due to the fact that many governments keep stricter records of imports for the purpose of levying tariffs, whereas reliable export records may only be apparent in those less frequent cases where an export subsidy/tax is employed.

data to predefined totals. The objective of this approach is to preserve the most reliable reconciled trade data whilst making changes to any unreported trade flows. Moreover, weights based on the RI are used to ensure that those trade flows reported by more reliable reporters are changed less than the poorer reporting partner's exports.

4.6.3 GTAP Protection Data

The data sources for quantifying support policies such as the producer and consumer subsidy equivalent (PSE and CSE) estimates provided by the Organisation of Economic Co-operation and Development (OECD) and the Economic Research Service (ERS) of the US Department of Agriculture, provide most of the data for countries (including composite regions) within version 4 of the GTAP database. Thus, estimates of output subsidies are based on PSE calculations by the OECD for the year 1995. Moreover, declarations on trade protection instruments to the GATT by member countries are also included in the derivation of GTAP export subsidies and import tariffs, where in the case of the latter, all non-tariff barrier protection is approximated through the *ad valorem* tariff equivalent.

4.6.4 Updating the GTAP Data

The final tasks are to update the GTAP data base to a common year and to balance the data with the trade and protection data sources. The update is achieved using a technique developed at the Australian Industry Commission (James and McDougall, 1993) which shocks key economic variables to match the economic conditions in the base year (1995), which are based on a variety of external data sources examining GDP, private and government consumption and investment. These shocked economic variables are as follows:

1) exports by commodity; 2) imports by commodity; 3) aggregate household consumption expenditures; 4) aggregate government spending; 5) aggregate expenditures for gross capital formation; 6) import tariffs; 7) export subsidies and; 8) production subsidies/taxes.

All values of other economic variables in the economy are calculated in response to these shocks under conditions of market clearing and zero profits.

4.7 Sets and Parameter Data

4.7.1 Sets Files

The function of the sets file is to enumerate the GTAP regions, commodities and other sets used in the model framework. Thus, the arrays in the GTAP sets file are as presented in table 4.3.

Header	Dimension	Description
H1	r	Regions (REG)
H2	t	Traded Commodities (TRAD_COMM)
H3	s+m+t+1	Non-saving commodities (NSAV_COMM)
H4	s+m+t	Demanded commodities (DEMD_COMM)
H5	t+1	Produced commodities (PROD_COMM)
H6	s+m	Endowment commodities (ENDW_COMM)
H7	s	Sluggish endowment commodities (ENDWS_COMM)
H8	m	Mobile endowment commodities (ENDWM_COMM)
H9	1	Capital endowment commodity (CGDS_COMM)

m – number of primary factors perfectly mobile across industries
r – number of regions
s - number of primary factors not perfectly mobile across industries
t – number of tradable commodities

Table 4.3 Arrays in the GTAP Sets File

The first array (H1) gives a list of regions in the model. H2 lists those commodities that may be traded across regions (this is in contrast with non-tradable primary factors). There are five endowment commodities in version 4 of the GTAP database (land, unskilled and skilled labour, capital and natural resources) which are listed in H6. In this model, a capital goods produced commodity is indexed in H9 for use in implementing the investment theory in the model.

Header arrays split endowment commodities into two groups, classified by sectoral mobility. In the standard implementation of the model, the long run approach is taken where labour types and capital are classified as mobile (H8), with land and natural resources classified as ‘sluggish’ or immobile between sectors (H7). For short run simulations, users may want to move capital from H8 to H7.

The remaining arrays are provided to aid implementation of the model. The non-savings commodities (H3) comprise all endowments and traded commodities as well as an investment good. Demanded commodities are a subset of H3 and contain only endowments and traded commodities. Finally, produced commodities are placed in header H5, and include all traded commodities and the capital goods producing sector which meets investment demand. An example of the set arrays for a three region (REG), three tradables (TRAD_COMM) aggregation is provided in figure 4.11, which includes five primary factors (ENDW_COMM), of which two are sluggish (ENDWS_COMM) and the remaining three are perfectly mobile (ENDWM_COMM) between using sectors.

REG – European Union, United States of America, Rest of the World
TRAD_COMM – agriculture, manufacturing and services
NSAV_COMM – land, skilled labour, unskilled labour, capital, natural resources, agriculture, manufacturing, services, capital goods.
DEMD_COMM - land, skilled labour, unskilled labour, capital, natural resources, agriculture, manufacturing, services.
PROD_COMM - agriculture, manufacturing, services, capital goods.
ENDW_COMM - land, skilled labour, unskilled labour, capital, natural resources
ENDWS_COMM - land, natural resources
ENDWM_COMM - skilled labour, unskilled labour, capital
CGDS_COMM – capital goods.

Figure 4.11: A 3x3 GTAP Sets Aggregation of Version 4 Data

4.7.2 Behavioural Parameters

The parameter file contains arrays of invariant behavioural parameters, listed in table 4.4.

Header	Dimension	Description
ESUBD - σ_D	t	Elasticity of substitution between domestic product and imports
ESUBM - σ_M	t	Elasticity of substitution between imports from different regions
ESUBVA - σ_{VA}	t	Elasticity of substitution between primary factors
ETRAE - σ_T	s	Elasticity of transformation between industries
RORFLEX	r	Elasticity of expected rate of return with respect to the capital stock
RORDELTA	1	Dummy parameter used to choose between alternative investment theories

r – number of regions
s – number of primary factors not perfectly mobile between primary industries
t – number of tradable commodities (sectors)

Table 4.4: GTAP Parameter Arrays

4.7.3 Trade Substitution Elasticities

The discussion in this sub-section draws on McDougall *et al.* (1998). The GTAP data contain both elasticities of substitution between domestic products and imports, and substitution elasticities between imports from different regions. It is assumed that, for each tradable commodity ‘i’, all agents in all regions display the same substitution elasticity. Since the commodity concordance in the GTAP database is identical to that of the SALTER (Jomini *et al.* 1991), and in the absence of any alternative data, the most obvious approach has been to adopt the same elasticity of substitution values.[9]

The values of these elasticity estimates represent a trade off between econometric evidence and prior belief. Econometric estimates suggest that these values are quite low, although prior belief points to the general notion of weak terms of trade effects from changes in commercial policy. If the latter is true, then changes in demand patterns for imports will not have significant effects on prices.

Thus, a weak terms of trade effect implies that the source substitution elasticities are quite high, where changes in import demands in ‘n’ import space, result in small pivots of the budget line (i.e. small relative price changes between import and export commodities). The final SALTER settings adopted here represent a trade off between econometric estimates and *a priori* belief, where the elasticities are generally higher than the former, but are still low enough to generate significant terms of trade effects.

Another aspect of the SALTER compromise is the divergence between domestic-import and import-import elasticity estimates. Much of the econometric evidence relates to domestic-import values, whereas low terms of trade effects result from the import-import substitution parameters (i.e. if these values are high, than region ‘r’ can displace other regions in its export markets without large reductions in the export price). Thus, by setting the import-import substitution elasticities higher than the domestic-import equivalents, it is possible to reconcile the idea of lower econometric estimates, whilst maintaining weak terms of trade effects. Having reviewed the sparse literature on import-import substitution estimates, the SALTER team concluded that these might plausibly be set at double the levels of the domestic-import estimates.

4.7.4 Factor Substitution Elasticities

The GTAP model’s CES production structure is typical of many CGE multi-region production frameworks. The substitution possibilities between composite value added

[9] The SALTER project is a complete model and database characterisation of the Australian economy funded by the Australian Industry Commission.

and intermediate inputs within each sector is Leontief, while primary factors of production are assumed to substitute for one another according to a CES elasticity parameter - σ_{VA}. The size of this parameter effectively determines the supply response of each sector to changes in commodity prices, particularly in those cases where certain endowments are sluggish (see next section). For example, with land characterised as sluggish in primary agricultural sectors, the ability of agriculture to increase output is dependent on the substitution possibilities between land and labour types, and land and capital. As with the trade elasticities, estimates of primary factor substitution are also taken from the SALTER (Jomini *et al.* 1991) database.

4.7.5 Factor Transformation Elasticities

As discussed in section 4.1.3, these elasticities characterise the degree of primary factor mobility between using sectors. Moreover, the size of the elasticity of transformation, $\sigma_T < 0$, determines the size of the disparity between sectoral returns to the sluggish factor. Thus, if σ_T is close to zero, then the allocation of factors between sectors is nearly fixed and unresponsive to changes in relative returns. The parameter, σ_T may take on larger negative values until at the limit, $\sigma_T = -\infty$, the factor is perfectly mobile and no differential return can be sustained over the simulation period, in which case the factor should be reclassified as perfectly mobile.

4.7.6 Investment Parameters

In the GTAP model, if the user chooses to allow the allocation of global investment to be responsive to regional specific rates of return on capital (RORDELTA =1), then this requires a suitable specification of the parameter RORFLEX. For example, if the user desires a large responsiveness of international investment to a change in the rate of return, then the value of RORFLEX is set closer to zero. Moreover, RORFLEX is indexed over regions which allows the user to characterise some countries' investment as sensitive to changes in the rate of return and vice versa.

4.8 Accounting Conventions in the GTAP database

Having discussed the types of data and reconciliation issues pertaining to construction of the GTAP database, the following sub-sections turn to the accounting flows within each region's data which, *'track(ing) value flows through the data base from production and sales to intermediate and final demands' (Hertel and Tsigas, 1993, pp.2).*

Attention is paid to the relative prices at which each of these flows is evaluated as well as the presence of distortions in the form of taxes and subsidies. Note that in each of figures 4.12 to 4.14, the entries to the right hand side of each of the value flows present the corresponding price and quantity units within the GTAP data. A full list of terms is presented in the glossary at the end of the thesis.

4.8.1 Distribution of Sales

The first accounting relationship is the distribution of receipts to regional markets. At the top of figure 4.12 is the value of output/sales at *agents'* prices of commodity 'i' (produced by industry i) in region 'r', $VOA_{i,r}$. Adding a production tax (or subsidy), $PTAX_{i,r}$, gives the value of the same output at *market* prices, $VOM_{i,r}$. This value is distributed as domestic sales, $VDM_{i,r}$, exports of 'i' *from* region 'r' *to* region 's', $VXMD_{i,r,s}$, and transport services, $VST_{i,r}$, 'supplied' to a global transport sector which is responsible for the delivery of freight between regions. The value of domestic sales of commodity 'i', $VDM_{i,r}$, is split up into the *final* demands of the private household, $VDPM_{i,r}$, and government, $VDGM_{i,r}$, and *intermediate* demands by *each* sector 'j', $VDFM_{i,j,r}$. This relationship is highlighted at the bottom of figure 4.12.

To convert the export component from market price to 'free on board' (fob) values, it is necessary to add a destination generic (specific) export tax, $XTAX_{i,r}$ ($XTAX_{i,r,s}$). Adding the cost of shipping freight, $VTWR_{i,r,s}$, gives the 'cost insurance freight' (cif) value of imports of commodity i, $VIWS_{i,r,s}$. Including the destination generic (specific) import tax in region 's', $MTAX_{i,s}$ ($MTAX_{i,r,s}$), gives the value of imports at market prices, $VIMS_{i,r,s}$. These imports are combined into a composite regional imported value, $VIM_{i,s}$, and are distributed across final ($VIPM_{i,s}$, $VIGM_{i,s}$) and intermediate ($VIFM_{i,j,s}$) uses.

'Domestic' Market 'r'
(i=tradables; r,s=regions) $VOA_{i,r}$ $:PS_{i,r} .QO_{i,r}$
(+ <u>$PTAX_{i,r}$</u>)
$= VOM_{i,r}$ $:PM_{i,r}.QO_{i,r}$

$:PM_{i,r}.QDS_{i,r}$	$VDM_{i,r}$ $VST_{i,r}$	$:PM_{i,r}.QST_{i,r}$
	$VXMD_{i,r,s}$	$:PM_{i,r}.QXS_{i,r,s}$
(+$\underline{XTAX}_{i,r,s}$/$\underline{XTAX}_{i,r,}$)		
	$= VXMD_{i,r,s}$	$:PFOB_{i,r,s}.QXS_{i,r,s}$
World Market	$+ VTWR_{i,r,s}$	
	$= VIWS_{i,r,s}$	$:PCIF_{i,r,s}.QXS_{i,r,s}$
(+ $\underline{MTAX}_{i,r,s}$ /$\underline{MTAX}_{i,s}$)		
	$= VIMS_{i,r,s}$	$:PMS_{i,r,s}.QXS_{i,r,s}$
	$VIM_{i,s}$	$:PIM_{i,s}.QIM_{i,s}$
'Foreign' Market 's'	$= VIPM_{i,s}$	$:PIM_{i,s}.QPM_{i,s}$
	$+ VIGM_{i,s}$	$:PIM_{i,s}.QGM_{i,s}$
	$+ \sum_{j \in Prod} VIFM_{i,j,s}$	$:PIM_{i,s}.QFM_{i,j,s}$
where	$VDM(i,r) = VDPM_{i,r}$	$:PM_{i,r}.QPD_{i,r}$
	$+ VDGM_{i,r}$	$:PM_{i,r}.QGD_{i,r}$
	$+ \sum_{j \in Prod} VDFM_{i,j,r}$	$:PM_{i,r}.QFD_{i,j,r}$

Figure 4.12: Distribution of Sales
Source: Hertel (1997)

4.8.2 Agents in the model

Figures 4.13 and 4.14 show how various agents interact in each of these markets. In figure 4.13, $VPA_{i,r}$, represents purchases of 'i' by the private household in region 'r' at agents' prices. This agents' value is subdivided into domestic purchases, $VDPA_{i,r}$, and imports, $VIPA_{i,r}$, both at agents prices. Subtracting domestic and foreign private household 'commodity taxes' respectively ($IPTAX_{i,r}$ and $DPTAX_{i,r}$) from these values gives the respective market values, $VDPM_{i,r}$ and $VIPM_{i,r}$ which appear in figure 4.13. The same structure is employed for government final demands.

Private Households

	$VPA_{i,r}$	$:PP_{i,r}.QP_{i,r}$	
$VDPA_{i,r}$	$:PPD_{i,r}.QPD_{i,r}$	$VIPA_{i,r}$	$:PPM_{i,r}.QPM_{i,r}$
$\underline{-DPTAX}_{i,r}$		$\underline{-IPTAX}_{i,r}$	
$= VDPM_{i,r}$	$:PM_{i,r}.QPD_{i,r}$	$= VIPM_{i,r}$	$:PIM_{i,r}.QPM_{i,r}$

Government Households

$VGA_{i,r}$ $:PG_{i,r}.QG_{i,r}$

$VDGA_{i,r}$:$PGD_{i,r}.QGD_{i,r}$ $VIGA_{i,r}$:$PGM_{i,r}.QGM_{i,r}$
$\underline{-DGTAX}_{i,r}$ $\underline{-IGTAX}_{i,r}$
$= VDGM_{i,r}$:$PM_{i,r}.QPD_{i,r}$ $= VIGM_{i,r}$:$PIM_{i,r}.QGM_{i,r}$

(i=tradable; r=region)

Figure 4.13: Sources of Private Household and Government Purchases. Source: Hertel (1997)

The value of sectoral purchases, shown in figure 4.14, consists of both tradables (intermediate input demands) and primary endowment factors, which are non-tradable across regions. The value flow, $VFA_{i,j,r}$ represents the value of purchases of tradable good 'i' by sector 'j' in region 'r' at agents prices which is subdivided into domestic and composite imported value flows, $VDFA_{i,j,r}$ and $VIFA_{i,j,r}$ respectively. Including the effects of domestic ($DFTAX_{i,j,r}$) and import ($IFTAX_{i,j,r}$) commodity taxes, gives the market value of domestic and composite imported intermediate tradables to sectors in region ‘r’, $VDFM_{i,j,r}$ and $VIFM_{i,j,r}$ respectively. Purchases of primary factor non-tradables are assumed to be supplied by the private household. The value of purchases of endowment ‘i’ at agents prices is $EVFA_{i,j,r}$. Including the primary factor (household income) tax on factor 'i' used by industry ‘j’, $ETAX_{i,j,r}$, gives the market value, $VFM_{i,j,r}$.

To conclude this subsection, the sales revenues of each sector ‘j’ at agents prices, $VOA_{j,r}$, must be equal to the value of expenditures on all intermediate goods and primary factors, which is a zero profit condition (AC.1).

$$VOA_{j,r} = \sum_{i \in trad} VFA_{i,j,r} + \sum_{i \in endw} EVFA_{i,j,r} \qquad \text{(AC.1)}$$

Intermediate Input Purchases

$VFA_{i,j,r}$:$PF_{i,j,r}.QF_{i,j,r}$

$VDFA_{i,j,r}$:$PPD_{i,j,r}.QFD_{i,j,r}$ $VIFA_{i,j,r}$:$PFM_{i,j,r}.QFM_{i,j,r}$
$\underline{-DFTAX}_{i,j,r}$ $\underline{-IFTAX}_{i,j,r}$
$= VDFM_{i,j,r}$:$PM_{i,r}.QFD_{i,j,r}$ $= VIFM_{i,j,r}$:$PIM_{i,r}.QFM_{i,j,r}$

(i=tradables; j=sector r=region)

Primary Factor Purchases

$EVFA_{i,j,r}$	$:PFE_{i,j,r}.QFE_{i,j,r}$
$-ETAX_{i,j,r}$	
$= VFM_{i,j,r}$	$:PM_{i,r}.QFE_{i,j,r}$

(i=endowments; j=sector r=region)

Figure 4.14: Sources of Producing Sectors' Purchases. Source: Hertel (1997)

4.8.3 Regional Household

The next stage is to define the role of the 'regional household'. The regional household collects incomes in the form of factor endowment returns (net of regional capital depreciation - $VDEP_r$) and taxes between agents and market values as well as paying subsidies, (AC.2):

$$\begin{aligned} INCOME_r &= \sum_{i \in endw} VOA_{i,r} - VDEP_r \\ & PTAX_{i,r} + \sum_{i \in endw} \sum_{j \in prod} ETAX_{i,j,r} \\ & \sum_{i \in trad} IPTAX_{i,r} + \sum_{i \in trad} DPTAX_{i,r} \\ & \sum_{i \in trad} IGTAX_{i,r} + \sum_{i \in trad} DGTAX_{i,r} \\ & \sum_{i \in trad} \sum_{j \in prod} IFTAX_{i,j,r} + \sum_{i \in trad} \sum_{j \in prod} DFTAX_{i,j,r} \\ & \sum_{i \in trad} \sum_{s \in reg} XTAX_{i,s,r} + \sum_{i \in trad} \sum_{s \in reg} MTAX_{i,s,r} \end{aligned} \qquad \text{(AC.2)}$$

Regional income is exhausted over private household ($PRIVEXP_r$) and government ($GOVEXP_r$) expenditures and regional savings ($SAVE_r$). Thus, the regional household is a (Cobb-Douglas) aggregate of all the demand activities of the private and government households as well as savings demands.

$$EXPENDITURE_r = PRIVEXP_r + GOVEXP_r + SAVE_r \qquad \text{(AC.3)}$$

where

$$PRIVEXP_r = \sum_{i=Trad} VPA_{i,r} \qquad GOVEXP_r = \sum_{i=Trad} VGA_{i,r} \qquad \text{(AC.4)}$$

4.8.4 Global Transport Sector

The *supply* values of transport services ($VST_{i,r}$) are assumed to come from the services sector in each region in the database which are sold to the global transport sector (VT):

$$\sum_{i \in serv} \sum_{r \in reg} VST_{i,r} = VT \qquad \text{(AC.5)}$$

The base value of bilateral transportation service demands ($VTWR_{i,r,s}$) is the margin between the free on board (f.o.b.) and cost insurance freight (c.i.f.) values of merchandise trade. Since there is not enough information to link regional transport services to particular commodities and routes, all transport service demand is met from total freight supply (VT):

$$VT = VTWR_{i,r,s} \qquad \text{(AC.6)}$$

4.8.5 Investment and Savings

As in the case of international transport services, the GTAP database does not have information pertaining to bilateral investment levels. Hence the approach adopted is to assume that the sum of each region's savings is equal to total global investment, net of depreciation:

$$\sum_{r \in reg} SAVE = \sum_{r \in reg} \left[REGINV_r - VDEP_r \right] \qquad \text{(AC.7)}$$

Gross regional investment in each region equals the sum total of all inputs ($VOA_{i,r}$ under zero profits) in the capital goods (non-tradable) sector:

$$\begin{aligned} &REGINV_r = VOA_{i,r} \\ &i \in cgds \end{aligned} \qquad \text{(AC.8)}$$

where the index 'i' pertains to the capital goods producing sector.

4.9 Conclusion

This chapter gives a description of a multi region CGE trade model and database. In part I, attention is given to the neo-classical behavioural equations within the production and consumption 'nests', as well as stylised behavioural characterisations of the global bank and global transport sector. Part I concludes with a brief discussion of some of the model's summary indices (e.g., EV, gross domestic product, terms of trade) which are reported later in the thesis.

Part II discusses the types of data sources (SAMs, I-O tables) used in the construction in the Global Trade Analysis Project (GTAP) database, as well as some discussion on GTAP data reconciliation issues and parameter estimates. The final sections of part II give a full explanation of the accounting conventions inherent within the GTAP database.

Chapter 5

Aggregation and Modelling Issues

The first part of this chapter details the chosen aggregation of the Global Trade Analysis Project (GTAP) database used in the final model implementation. The important criterion when choosing a suitable aggregation is to prevent the model from becoming computationally expensive (i.e. execution times for runs, checking and interpreting model results) whilst maintaining as much detail within the aggregation as possible. Moreover, for the purposes of this thesis, an appropriate aggregation choice must subsume the key sectors of the Common Agricultural Policy (cereals, dairy, livestock) as well as the major players in world agricultural markets. Part II discusses the techniques employed to explicitly incorporate CAP support instruments as well as additional modelling issues pertaining to the Uruguay Round constraints and model projections.

Thus, the structure of the chapter is as follows: Sections 5.1 and 5.2 provide the rationale for the choice of GTAP sectoral and regional aggregation. Section 5.3 examines some of the data pertaining to the chosen countrys/regions in the aggregation, with coverage of net trading positions, protection and support structures. Section 5.4 in part II discusses the rationale behind, and implementation of, the model projections. The characterisation of the Uruguay Round is discussed in section 5.5. Section 5.6 details the changes to the model framework to explicitly incorporate CAP support policies, intervention purchases and the community budget. Section 5.7 concludes.

PART I - Aggregation

5.1 Sectoral Aggregation

The study focuses on the effects of varietal preference for food products and imperfect competition under conditions of liberalisation of CAP policies. For this reason, the commodity coverage should have a clear agricultural and food bias. In particular, each of the cornerstone “policy regimes” of the CAP where most support is directed should be included (i.e., cereals, oilseeds, dairy, livestock and sugar), with other agricultural sectors aggregated into ‘other agriculture’. The individual identified agricultural sectors

GTAP commodity	Aggregation	
wht, Wheat	1	**wheat**
gro, Cereal grains nec	2	**ograins**
osd, Oil seeds	3	**oseeds**
c_b, Sugar cane, sugar beet	4	**sugar**
ctl, Bovine cattle, sheep and goats, horses	5	**catshp**
rmk, Raw milk	6	**milk**
pdr, Paddy rice	7	**oagric**
v_f, Vegetables, fruit, nuts	7	**oagric**
pfb, Plant-based fibers	7	**oagric**
ocr, Crops nec	7	**oagric**
oap, Animal products nec	7	**oagric**
wol, Wool silk-worm cocoons	7	**oagric**
for, Forestry	8	**oprim**
fsh, Fishing	8	**oprim**
col, Coal	8	**oprim**
oil, Oil	8	**oprim**
gas, Gas	8	**oprim**
omn, Minerals nec	8	**oprim**
cmt, Bovine cattle, sheep and goat, horse meat prods	9	**meatpro**
omt, Meat products nec	10	**omeatpro**
sgr, Sugar	11	**sugarpro**
mil, Dairy products	12	**milkpro**
vol, Vegetable oils and fats	13	**ofoodpro**
pcr, Processed rice	13	**ofoodpro**
ofd, Food products nec	13	**ofoodpro**
b_t, Beverages and tobacco products	13	**ofoodpro**
tex, Textiles	14	**manu**
wap, Wearing apparel	14	**manu**
lea, Leather products	14	**manu**
lum, Wood products	14	**manu**
ppp, Paper products, publishing	14	**manu**
p_c, Petroleum, coal products	14	**manu**
crp, Chemical, rubber, plastic products	14	**manu**
nmm, Mineral products nec	14	**manu**
i_s, Ferrous metals	14	**manu**
nfm, Metals nec	14	**manu**
fmp, Metal products	14	**manu**
mvh, Motor vehicles and parts	14	**manu**
otn, Transport equipment nec	14	**manu**
ele, Electronic equipment	14	**manu**
ome, Machinery and equipment nec	14	**manu**
omf, Manufactures nec	14	**manu**
ely, Electricity	15	**serv**
gdt, Gas manufacture, distribution	15	**serv**
wtr, Water	15	**serv**
cns, Construction	15	**serv**
t_t, Trade, transport	15	**serv**
osp, Financial, business, recreational services	15	**serv**
osg, Public admin and defence, education, health	15	**serv**
dwe, Dwellings	15	**serv**

Figure 5.1 Sectoral Aggregation Mapping

are used to incorporate explicit modelling of CAP policy mechanisms (e.g. quotas, compensation payments, headage payments).

As well as characterising the key primary agricultural sectors of the CAP, it is equally important to capture detail on agricultural product users, in particular the food processing sectors. Thus, the final aggregation includes coverage of milk and sugar processing sectors, as well as ‘other food processing’ which covers much of cereals usage. Intermediate purchases of meat are split up into two food processing sectors, ‘meat processing’ and ‘other meat processing’, with the former predominantly concentrating on the usage of cattle and sheep meat, and the latter covering all other livestock products.

Aggregate manufacturing and services sectors are included, as well as an ‘other primary’ sector which subsumes all fossil fuel and raw mineral sectors, fishing, and forestry. To accurately characterise variety in food products, each of the food processing sectors are characterised as imperfectly competitive. Finally, aggregate manufacturing and service sectors are also treated as imperfectly competitive. A full sectoral aggregation mapping of the 50 sectors into the chosen 15 is provided in figure 5.1.

5.2 Regional Aggregation (6 chosen regions)

From the point of view of this study, an important change within version 4 of the database, is the inclusion of the United Kingdom as a separate country (Hubbard, 1998). Thus, in modelling CAP policies, the welfare effects of varietal preference and imperfect competition from the point of view of the UK, as well as the Rest of the EU, may now be evaluated. Inclusion of the USA in the aggregation is based on its prominent trade links with the EU. Moreover, both the EU-15 and the USA are large players in world agricultural markets (in terms of agricultural trade volumes, domestic protection and distortionary policies) and thus serve as important inclusions from the point of view of the Uruguay Round.

A further composite region is created for agricultural and food net-exporters, where the primary agricultural sector plays a significant role in GDP. These countries tend to be members of the CAIRNS group, and are thus aggregated into a composite region. For correct implementation of the Uruguay Round reforms, an LDC composite region is created, such that application of the GATT reforms pertaining to LDCs may be correctly applied. Finally, a Rest of the World (ROW) region subsumes all remaining

GTAP Region		Aggregation	
GBR	United Kingdom	1	**UK**
DEU	Germany	2	**RESTEU**
DNK	Denmark	2	**RESTEU**
SWE	Sweden	2	**RESTEU**
FIN	Finland	2	**RESTEU**
REU	Rest of European Union	2	**RESTEU**
USA	United States of America	3	**USA**
AUS	Australia	4	**CAIRNS**
NZL	New Zealand	4	**CAIRNS**
IDN	Indonesia	4	**CAIRNS**
MYS	Malaysia	4	**CAIRNS**
PHL	Philippines	4	**CAIRNS**
THA	Thailand	4	**CAIRNS**
CAN	Canada	4	**CAIRNS**
COL	Colombia	4	**CAIRNS**
ARG	Argentina	4	**CAIRNS**
BRA	Brazil	4	**CAIRNS**
CHL	Chile	4	**CAIRNS**
URY	Uruguay	4	**CAIRNS**
VNM	Viet Nam	5	**LDC**
CHN	China	5	**LDC**
IND	India	5	**LDC**
LKA	Sri Lanka	5	**LDC**
RAS	Rest of South Asia	5	**LDC**
MEX	Mexico	5	**LDC**
CAM	Central America and Caribbean	5	**LDC**
VEN	Venezuela	5	**LDC**
RAP	Rest of Andean Pact	5	**LDC**
RSM	Rest of South America	5	**LDC**
MAR	Morocco	5	**LDC**
RNF	Rest of North Africa	5	**LDC**
SAF	South African Customs Union	5	**LDC**
RSA	Rest of Southern Africa	5	**LDC**
RSS	Rest of Sub Saharan Africa	5	**LDC**
ROW	Rest of World	5	**LDC**
JPN	Japan	6	**ROW**
KOR	Republic of Korea	6	**ROW**
SGP	Singapore	6	**ROW**
HKG	Hong Kong	6	**ROW**
TWN	Taiwan	6	**ROW**
EFT	European Free Trade Area	6	**ROW**
CEA	Central European Associates	6	**ROW**
FSU	Former Soviet Union	6	**ROW**
TUR	Turkey	6	**ROW**
RME	Rest of Middle East	6	**ROW**

Figure 5.2: Regional Aggregation Mapping of 45 regions into 6 regions

countries/regions. Note that the Rest of the World composite region in the fully disaggregated GTAP data does not appear in the Rest of the World mapping in this study. This is because many of the countries subsumed within this composite are low income countries, which favours its placing in the LDC mapping aggregate. A full mapping of the GTAP countries/regions in the final aggregation is provided in figure 5.2.

5.3 Trade Flows and Protection – 15x6 GTAP Aggregation

Prior to discussion of the chosen aggregation of the GTAP database, two caveats are required. Firstly, in constructing version 4 of the GTAP database, it is necessary to aggregate over large numbers of tariff/subsidy lines in order to achieve GTAP sectoral concordance. In this respect, the support and trade protection data presented for individual sectors, (e.g., wheat, sugar, milk) in the GTAP database is still somewhat aggregated implying some loss of detail on specific commodity lines (e.g., durum wheat). Moreover, this situation is exacerbated further when model aggregations involve composite sectors, (e.g., manufacturing, other agriculture).

Secondly, the creation of composite regions, which in some cases contain countries which are fairly consistent with one another in terms of agricultural support and trade protection (e.g. EU-14, CAIRNS), can also lead to groupings of very disparate economic structures (LDCs, ROW). In the latter case, the data reported here contain little meaning, and are reported purely for completeness.

Thus, figures 5.3 and 5.4 show data on regional trade balances and GDP shares for the six region aggregation. In terms of regional trade balances, the USA has the largest trade deficit ($131 billion, 1995 prices), dominated by its large manufacturing sectoral trade deficit. The UK also has a trade deficit ($19 billion), where large net outflows in the manufacturing sectors are offset to some extent by a service sector surplus. Overall, the EU-14 has a net trade surplus ($58 billion), due to surpluses in the manufacturing and service sectors. Finally, the CAIRNS region has a slight deficit ($2 billion), and the ROW has the largest trade surplus ($74 billion).

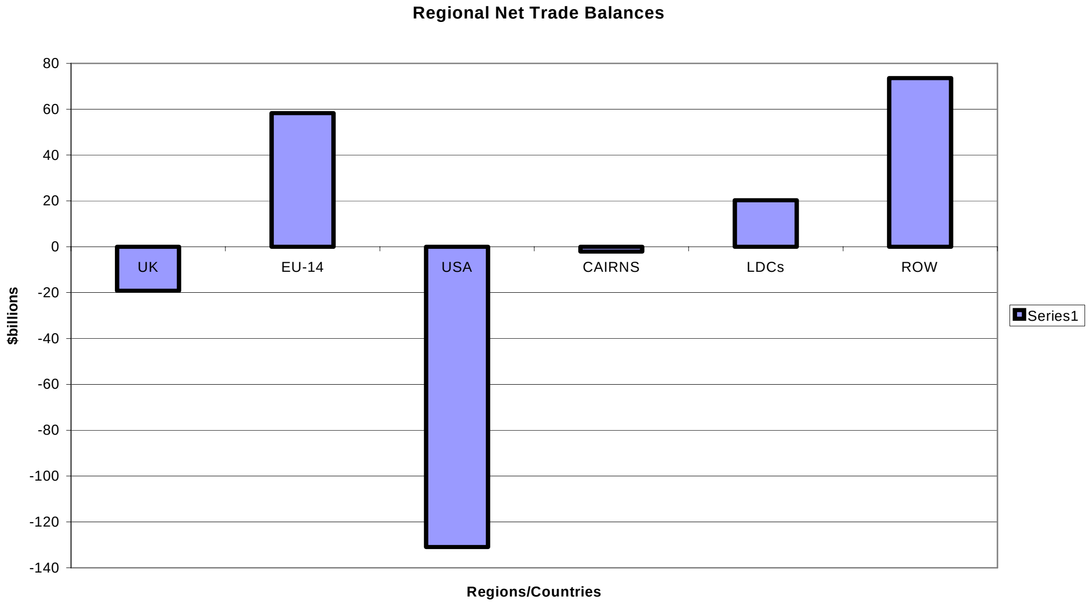


Figure 5.3

In figure 5.4, the smallest share of global GDP belongs to the UK (4%), with the USA accounting for one quarter. The significance of EU (including the UK) and USA regions in the aggregation becomes clear if one adds their respective shares, where they account for over half of global GDP. The largest single share belongs to the ROW composite region (28%) (although the EU-15 remains the largest single market – 29%), with CAIRNS and LDCs on a par (9%).

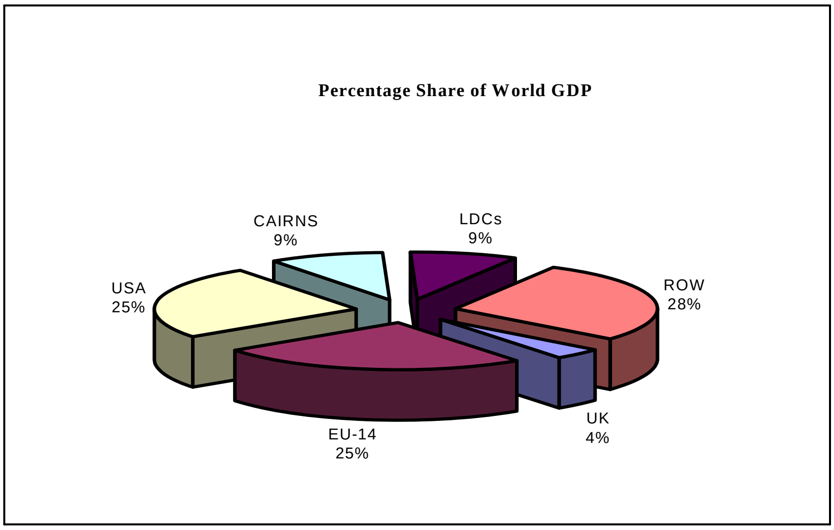


Figure 5.4

5.3.1 United Kingdom (UK) and EU-14

As is evident from figure 5.5, the UK trade balance is dominated by non-food related sectors, where manufacturing (-$32billion) and service (+$21billion) net balances are significant. Moreover, most of the agricultural and food related sectors are fairly close to zero balance, where 54% (GTAP data) of all agricultural and food sector trade transactions come from within the EU.

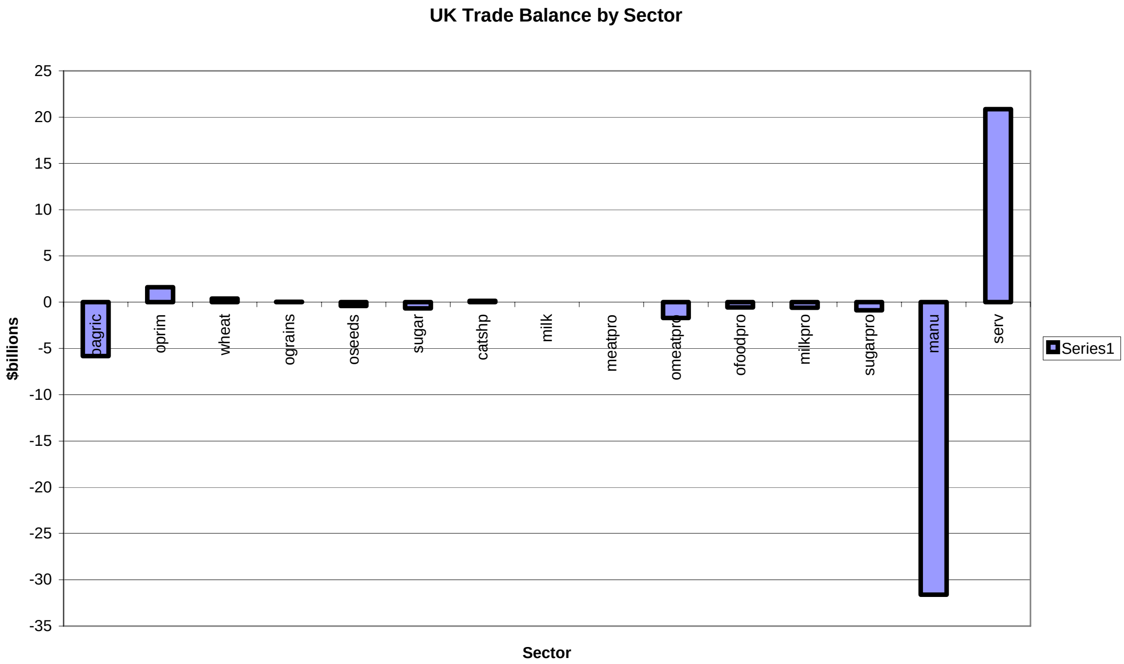


Figure 5.5: (1995 Benchmark).

The EU-14 services and manufacturing trade positions are both in surplus ($88billion and $67billion respectively) table 5.6. Where the UK has small deficits in the food processing sectors, the EU-14 has small surpluses, although both have similar trade patterns in the primary agricultural sectors.

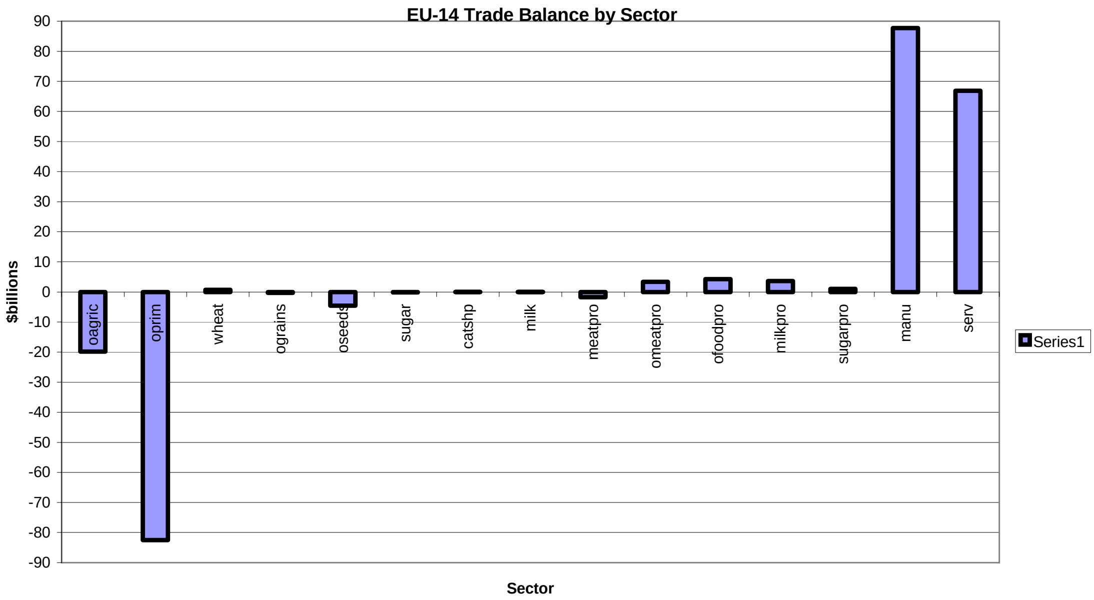


Figure 5.6: (1995 Benchmark).

The range of support instruments used in the EU regions is threefold – import tariffs, export subsidies and output subsidies. Each of these *ad valorem* measures captures a range of trade protection (variable import levies) and support mechanisms (de-coupled payments).

	Output Subsidy		Export Subsidy		Import Tariff	
	US$ million	% of output at mrkt prices	US$ million	% of exports at mrkt prices	US$ million	% of imports at mrkt pri.
OAGRIC	809	4.75	45	2.65	250	3.24
OPRIMARY	-	-	-	-	11	0.08
WHEAT	1526	58.02	16	2.73	5	2.99
OGRAINS	841	53.13	56	11.52	22	5.52
OSEEDS	536	109.51	-	-	-	-
SUGAR	-	-	17	42.33	522	43.14
CATSHP	1812	22.03	161	32.23	100	34.87
MILK*	727	8.91	-	-	-	-
MEATPRO	245	2.95	134	8.54	920	39.17
OMEATPRO	395	3.14	29	3.30	27	1.05
OFOODPRO	-	-	7	0.07	335	2.99
MILKPRO	541	3.78	368	23.31	371	17.04
SUGARPRO	116	3.56	158	31.04	763	38.23
MANUFACTURING	-	-	-	-	3680	1.71
SERVICES	-	-	-	-	-	-

*milk is a non-tradable commodity

Table 5.1: Domestic and Trade Protection in the UK (benchmark 1995)

Tables 5.1 and 5.2 show each of the three support and trade protection mechanisms within the GTAP database for the UK and EU-14 respectively. The *ad valorem* output subsidies expressed as percentages of total values at market prices in both EU regions are considerable, and are predominant in crops sectors and cattle and sheep. A large proportion of this support is accounted for by de-coupled payments.

	Output Subsidy		Export Subsidy		Import Tariff	
	US$ million	% of output at mrkt prices	US$ million	% of exports at mrkt prices	US$ million	% of imports at mrkt pri.
OAGRIC	7881	4.88	353	0.98	1868	3.26
OPRIMARY	743	0.56	-	-	138	0.12
WHEAT	7999	58.02	204	4.25	67	1.70
OGRAINS	8343	53.13	367	8.50	453	9.53
OSEEDS	4640	109.51	-	-	-	-
SUGAR	-	-	94	37.04	236	40.94
CATSHP	6487	22.03	680	18.03	500	14.01
MILK*	4407	8.91	-	-	-	-
MEATPRO	238	0.33	1454	14.58	2295	18.25
OMEATPRO	330	0.34	652	3.90	299	2.30
OFOODPRO	-	-	-	-	1937	2.56
MILKPRO	749	0.65	5963	21.38	750	3.94
SUGARPRO	195	0.53	1442	22.87	625	13.94
MANUFACTURING	-	-	-	-	17397	1.30
SERVICES	-	-	-	-	50	0.01

*milk is a non-tradable commodity

Table 5.2: Domestic and Trade Protection in the EU-14 (benchmark 1995)

Food processing sectors are also supported and protected in both EU regions (in relative terms), particularly the meat, milk and sugar processing sectors. Exports of raw sugar, sugar processing, cattle and sheep, meat processing and milk processing are heavily subsidised within both EU regions. Substantial tariff revenue accrues in the UK sugar and sugar processing sectors, where it is larger in absolute terms than total EU-14 tariff revenue. In the non-agricultural/food sectors, the main form of support is the import tariff, as well as Variable Export Restitutions (VERs) under the Multi-Fibre arrangement which are included as *ad valorem* export tax rates in the GTAP data (this applies to all regions in the chosen aggregation).

5.3.2 United States of America (USA)

The USA is a large net importer of fossil fuel and manufacturing equipment, although has minor sectoral trade surpluses in food related sectors and has a large trade surplus in service goods (figure 5.7).

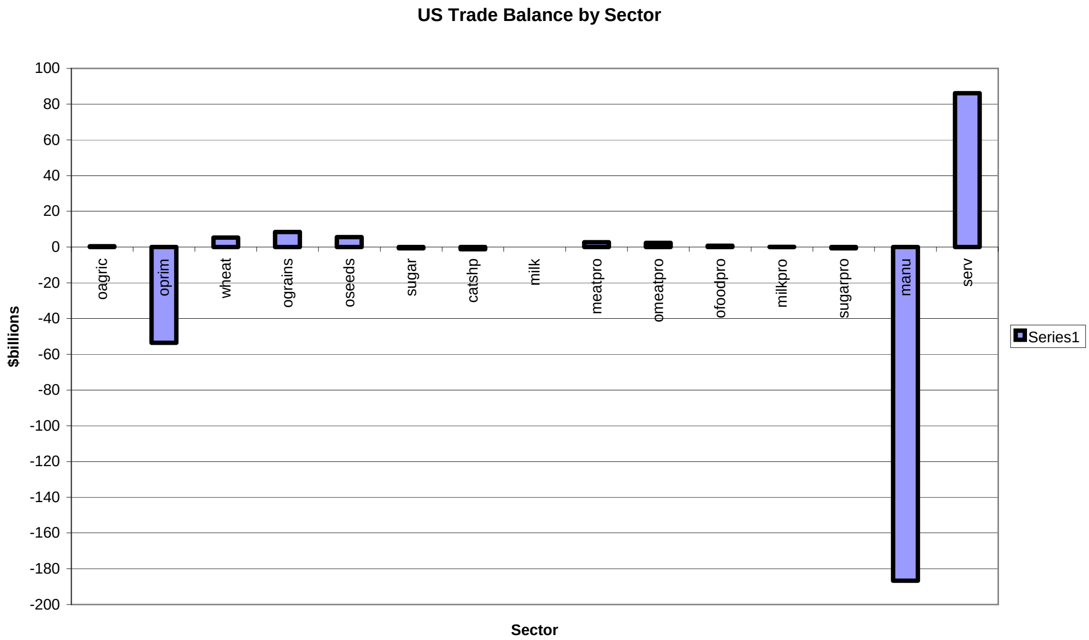


Figure 5.11: (1995 Benchmark)

USA support for agriculture is very dependent on output subsidies which are mostly targeted at primary agricultural sectors, although very little support is given to food processing sectors. Trade protection is clearly biased towards sugar production and sugar and milk processing sectors (figure 5.11). As in the EU regions, there are no subsidies in the non-agricultural/food sectors, where import tariff revenues are prevalent in the primary resource and manufacturing sectors.

	Output Subsidy		Export Subsidy		Import Tariff	
	US$ million	% of output at mrkt prices	US$ million	% of exports at mrkt prices	US$ million	% of imports at mrkt pri.
OAGRIC	1534	1.82	-	-	370	2.60
OPRIMARY	-	-	-	-	117	0.18
WHEAT	2166	17.60	98	1.74	4	1.74
OGRAINS	4247	8.52	-	-	-	-
OSEEDS	1269	7.58	-	-	-	-
SUGAR	213	8.19	8	38.96	413	38.96
CATSHP	3433	4.91	0	0.01	0	0.01
MILK*	931	3.99	-	-	-	-
MEATPRO	-	-	0	0.01	0	0.01
OMEATPRO	-	-	58	1.75	16	1.75
OFOODPRO	-	-	-	-	1196	6.15
MILKPRO	-	-	438	34.11	354	34.11
SUGARPRO	-	-	226	38.96	654	38.96
MANUFACTURING	-	-	-	-	18013	2.70
SERVICES	-	-	-	-	-	-

*milk is a non-tradable commodity

Table 5.3: Domestic and Trade Protection in the USA (benchmark 1995)

5.3.3 CAIRNS

The composite CAIRNS region's net trade balances for food related sectors reflects that all countries within this grouping are agricultural net exporters. There are also large net imports (-US$101 billion) of manufacturing equipment.

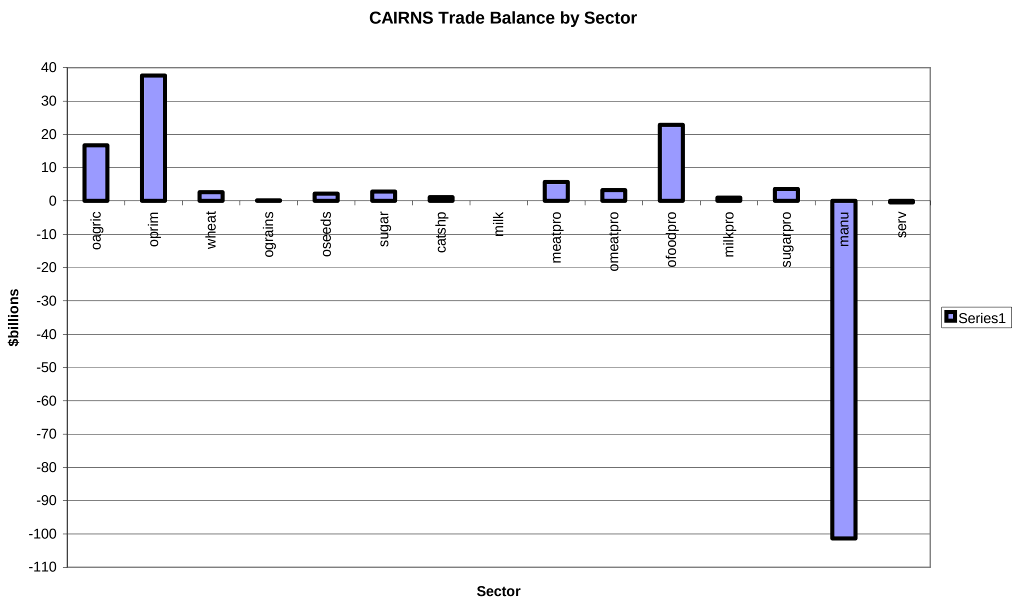


Figure 5.8: (1995 Benchmark).

Agricultural sectors where net exports are particularly significant include ‘other agriculture’ (US$17billion), ‘other food processing’ (US$23 billion), and the ‘meat’ and ‘other meat’ processing sectors (US$6billion and US$3billion respectively).

In the CAIRNS region, levels of output support are typically low, with wheat being the only exception. Much of the trade protection is targeted at the food processing sectors, with import tariffs being the main source of protection for primary agriculture (table 5.4). In the manufacturing and primary resource sectors, import tariff protection is considerable.

	Output Subsidy		**Export Subsidy**		**Import Tariff**	
	US$ million	**% of output at mrkt prices**	**US$ million**	**% of exports at mrkt prices**	**US$ million**	**% of imports at mrkt pri.**
OAGRIC	550	0.31	-	-	679	5.79
OPRIMARY	-	-	-	-	1444	4.91
WHEAT	929	7.23	-	-	493	15.83
OGRAINS	262	1.73	43	2.75	868	38.94
OSEEDS	522	2.85	-	-	65	5.93
SUGAR	173	0.83	-	-	145	15.17
CATSHP	733	2.18	-	-	20	3.74
MILK*	401	2.14	-	-	-	-
MEATPRO	-	-	83	1.16	287	17.14
OMEATPRO	-	-	1258	23.94	159	17.34
OFOODPRO	-	-	867	2.13	2143	11.18
MILKPRO	-	-	563	13.29	1209	32.68
SUGARPRO	-	-	-	-	64	4.24
MANUFACTURING	-	-	-	-	42055	8.24
SERVICES	-	-	-	-	49	0.05

*milk is a non-tradable commodity

Table 5.4: Domestic and Trade Protection CAIRNS (benchmark 1995)

5.3.4 LDCs and ROW

As noted at the beginning of this section, these regions are aggregates of a broad variety of economic structures. Hence, the data reported here are of limited use, although the size of the net trading positions and relative support and the trade protective structure of these composites in the benchmark are useful when examining simulation results.

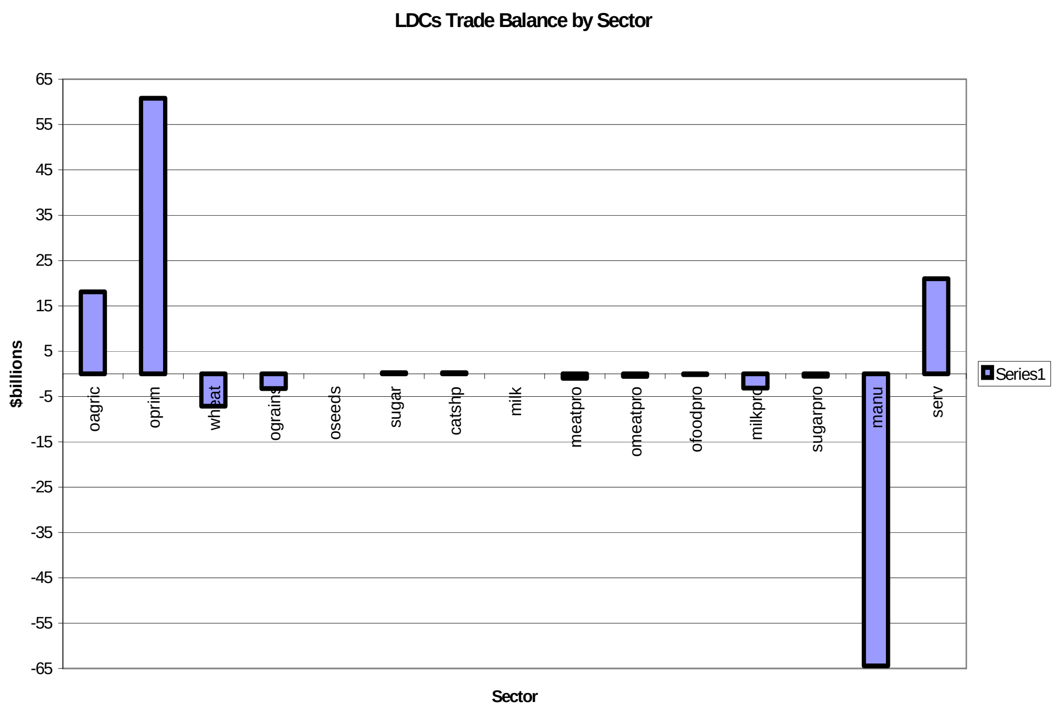


Figure 5.13: (1995 Benchmark).

The largest surplus and deficit sectors in the LDC composite region are ‘other primary’ (+$61billion) and manufacturing’ (-$64billion) respectively. The ROW net trading position is dominated by the manufacturing sector (+$125billion), services (+$34billion) and ‘other food processing’ (-$37billion) (figures 5.9 and 5.10).

ROW Trade Balance by Sector

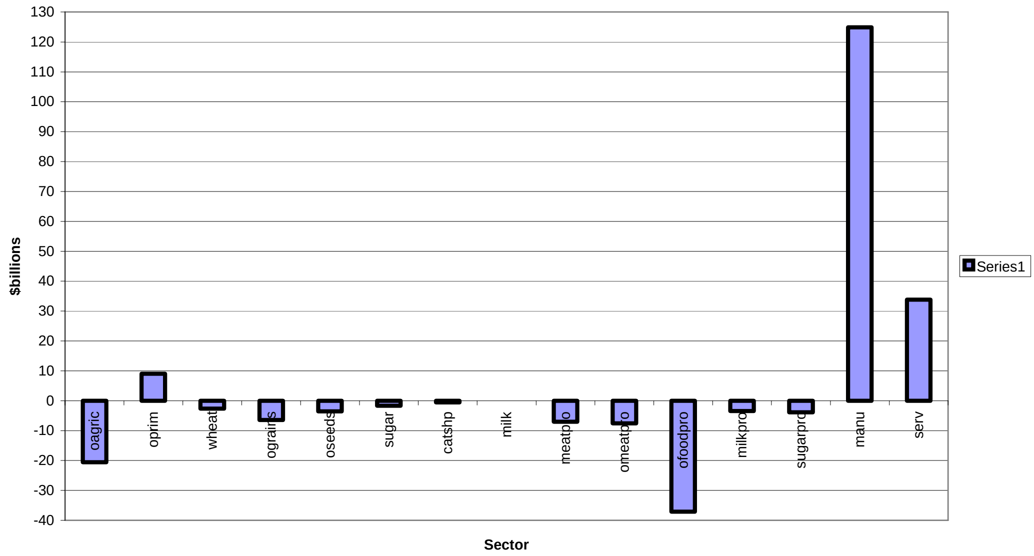


Figure 5.10: (1995 Benchmark).

In the composite LDC region, the main source of protection to the food sectors is through *ad valorem* import tariffs. Agricultural support is a very small proportion of output (in those sectors where support is apparent), and most sectors' exports are not subsidised (table 5.5).

	Output Subsidy		**Export Subsidy**		**Import Tariff**	
	US$ million	**% of output at mrkt prices**	**US$ million**	**% of exports at mrkt prices**	**US$ million**	**% of imports at mrkt pri.**
OAGRIC	-	-	-	-	2734	18.75
OPRIMARY	-	-	-	-	2102	7.04
WHEAT	832	2.42	-	-	-	-
OGRAINS	1176	3.64	-	-	164	4.20
OSEEDS	588	1.75	-	-	70	4.24
SUGAR	508	1.58	360	12.64	264	10.64
CATSHP	105	0.30	-	-	36	7.71
MILK*	-	-	-	-	-	-
MEATPRO	12	0.05	-	-	142	7.51
OMEATPRO	-	-	-	-	159	7.38
OFOODPRO	-	-	-	-	8085	25.41
MILKPRO	-	-	1	0.54	537	14.00
SUGARPRO	-	-	21	0.68	820	18.36
MANUFACTURING	-	-	-	-	99198	19.11
SERVICES	-	-	-	-	527	0.68

*milk is a non-tradable commodity

Table 5.5: Domestic and Trade Protection in the LDCs (benchmark 1995)

Finally, support and protection in the ROW is over all three forms of agricultural support and protection. Import tariff revenue in 'milk processing', 'wheat' and 'other grains' is between 50-70% of the value of total imports, and in the milk processing sector, export subsidies are 54% of the total value of milk processing exports (Table 5.6).

	Output Subsidy		Export Subsidy		Import Tariff	
	US$ million	% of output at mrkt prices	US$ million	% of exports at mrkt prices	US$ million	% of imports at mrkt pri.
OAGRIC	10089	3.01	689	5.46	4000	10.97
OPRIMARY	-	-	-	-	2517	1.86
WHEAT	1118	8.33	-	-	5959	62.29
OGRAINS	847	5.58	36	7.98	18389	72.52
OSEEDS	304	7.24	118	14.92	349	7.70
SUGAR	753	9.62	12	10.85	1109	39.06
CATSHP	1532	5.16	135	13.60	429	23.27
MILK*	4446	11.11	-	-	-	-
MEATPRO	88	0.25	244	38.11	3153	29.80
OMEATPRO	214	0.28	534	13.51	4589	29.56
OFOODPRO	-	-	811	3.52	7720	11.47
MILKPRO	-	-	1696	54.16	4905	50.22
SUGARPRO	-	-	91	17.42	2094	33.06
MANUFACTURING	-	-	-	-	42373	4.42
SERVICES	-	-	-	-	3946	1.33

*milk is a non-tradable commodity

Table 5.6: Domestic and Trade Protection in the ROW (benchmark 1995)

PART II – Modelling Issues

5.4 Model Projections

The agreement reached at the Uruguay Round (UR) of trade talks includes a time horizon for full implementation of each of the agricultural (and non-agricultural) reforms, with Developed Countries (DCs) and Less Developed Countries (LDCs) given periods of 6 years and 10 years, respectively, to complete all of their policy commitments. For this reason, a series of projections on endowment and productivity growth are included in the analysis so as to model the structure of the world economy in 2005, the first year in which the UR agreement will be fully implemented. Thus, the GTAP database is projected 10 years beyond the base year of 1995.

In table 5.7, estimates are presented for forecasted *annual* growth rates in capital, skilled and unskilled labour endowments, real GDP growth and agricultural total factor productivity (TFP) rates.[1] There are no data available on non-agricultural TFP rates at the level of regional and sectoral disaggregation presented in this model framework.

	Factor Endowment Growth			**Real GDP Growth**	**TFP Growth**	
	Unskilled Labour	**Skilled Labour**	**Capital**		**Crops**	Livestock
UK	-0.17	2.60	3.11	2.08	2.00	2.25
REST-EU	-0.17	2.60	3.11	2.08	2.00	2.25
USA	0.97	3.33	2.99	2.73	1.60	1.85
Cairns	1.77	4.10	5.05	5.03	1.98	2.20
LDCs	1.75	4.04	6.01	5.39	1.69	2.16
ROW	0.04	3.46	4.19	3.03	1.80	2.19

Table 5.7: Annual Growth Rates
Source: calculated from Frandsen, Jensen and Vanzetti (1998)[2]

Model projections for factor endowment growth rates are implemented simply by shocking each exogenous endowment 'i' in region 'r', ($qo_{i,r}$). Changes in the level of TFP are characterised by employing an exogenous shift variable, $ao_{j,r}$. In the standard model framework, technological change exhibits Hicks-neutrality where the production function is said to be separable with respect to time. In other words, over time, technical change may occur but this has no effect on the marginal rate of technical substitution between inputs and therefore the slope of the isoquant (Chambers, 1988, pp.207-8). Thus, increases in the exogenous variable $ao_{j,r}$ simulate Hicksian TFP technical change by *uniformly* reducing the value added ($qva_{j,r}$) and intermediate input ($qf_{i,j,r}$) requirements for a given level of output ($qo_{i,r}$). This is shown in the linearised Leontief expressions below:

$$qva_{j,r} = qo_{j,r} - ao_{j,r} \qquad \text{(MP.1)}$$

$$qf_{i,j,r} = qo_{j,r} - ao_{j,r} \qquad \text{(MP.2)}$$

[1] Land and natural resource endowments remain unchanged under the projections.
[2] Crops sectors : wheat; other grains; oilseeds; sugar; other agriculture. Livestock sectors : cattle and sheep; raw milk.

where ‘i’ are intermediate inputs and ‘j’ represents each sector in region ‘r’.

The productivity shocks require minor adjustments to the model structure. This is because a more direct approach of simultaneously applying the agricultural TFP shocks alongside the real GDP shocks results in unrealistically small (endogenous) increases in non-agricultural TFP. The reason is that most of the projected growth in GDP is met by increases in the endowments. To circumvent this problem, a two stage approach is employed.

To allow TFP ($ao_{j,r}$) for the non-agricultural sectors to adjust endogenously requires the creation of a new equation:

$$ao_{j,r} = tfpgrowth_r \quad j \in nonagr \qquad \text{(MP.3)}$$

where the new variable, $tfpgrowth_r$, is the percentage change in composite TFP growth in region 'r'. This variable is endogenised and swapped with the real growth variable ($qgdp_r$) to maintain correct closure. In an initial run, this closure is used where exogenous endowment and real GDP projections are implemented simultaneously, yielding endogenous projected TFP growth rates.

In a second run of the model, equation (MP.3) is eliminated, the assumed shocks for agricultural TFP and the projected shocks for non-agricultural TFP growth rates from the first model run are implemented alongside the assumed endowment shocks, with $qgdp_r$ adjusting *endogenously* to meet these target growth rates.

5.5 The Uruguay Round

The model characterises the most common features of the Uruguay Round (UR) package, namely:

i) - 36% (24% for LDCs) reductions in agricultural and non-agricultural tariffs and converted NTBs

ii) - 36% (24% for LDCs) reductions in agricultural export subsidy expenditures

iii) - 20% (13.3% for LDCs) reduction in agricultural output subsidy expenditures.

Some studies (Jensen *et al.* 1998; Blake 1999) incorporate endogenous behaviour in the modelling of the Uruguay Round reforms. For example, compatibility between the export subsidy expenditure and volume (minimum 21% reduction) constraints is ensured by imposing simultaneous inequality constraints, where it is possible that one, or both constraints may be binding according to changing conditions in each export market. Our approach follows the more standard treatment (Francois *et al.*, 1995a, 1995b; Harrison *et al.*, 1995a, 1995b) of exogenously reducing export and output subsidy expenditures by 36% (24% for LDCs) and 20% (13.3% for LDCs) respectively, as well as reducing all *ad valorem* import tariff rates by 36% (24% for LDCs).

5.6 Explicit Modelling of the Common Agricultural Policy

5.6.1 Sugar and dairy quotas

In CGE data-sets, it is common practice to characterise a quantitative restriction, e.g. an output quota, as a sectoral *ad valorem* tax equivalent. The problem here is that this 'equivalence' only exists in the benchmark, while subsequent endogenous changes in supply or demand will render the tax a poor approximation of the quota. It is for this reason that quotas in the 'raw milk' and 'sugar beet' sectors are modelled explicitly.

Raw milk and sugar beet quotas in the EU are introduced using the price link (in levels terms):

$$PM_{i,r} = (1 + TO_{i,r} + TQ_{i,r}).PS_{i,r} \qquad \text{(CAP.1)}$$

where $PM_{i,r}$ and $PS_{i,r}$ are the post and pre-tax prices of raw milk (sugar), $TO_{i,r}$ is an output tax rate and $TQ_{i,r}$ is a quota tax equivalent rate. Multiplying both sides by a common quantity ($QO_{i,r}$) gives the relationship in value terms:

$$VOM_{i,r} = VOA_{i,r} + VOA_{i,r}.TO_{i,r} + VOA_{i,r}.TQ_{i,r} \qquad \text{(CAP.2)}$$

where $VOA_{i,r}.TO_{i,r}$ is the 1995 benchmark tax/subsidy value, and $VOA_{i,r}.TQ_{i,r}$ is the benchmark value of quota rent.[3] The *net* value total of the two wedges is calculated and inserted into the 1995 benchmark data-set (see section 7.3.13 below). The levels values of the output tax/subsidy ($TO_{i,r}$) and quota rent ($TQ_{i,r}$) rates are calibrated from (CAP.2) above.

Rearranging and linearising expression (CAP.1) gives:

$$ps_{i,r} = pm_{i,r} - \left[\frac{(1 + TO_{i,r} + TQ_{i,r})}{TO_{i,r}}\right].to_{i,r} - \left[\frac{(1 + TO_{i,r} + TQ_{i,r})}{TQ_{i,r}}\right].tq_{i,r} \qquad \text{(CAP.3)}$$

where lower case variables are percentage changes in the corresponding upper case variables. To simulate the effects of the quota, the quantity (qo) of EU 'raw milk' and 'sugar beet' is exogenised and swapped with the quota rent variable (tq). Thus, it is possible to simulate a further tightening (slackening) of the quota by shocking the exogenous variable $qo_{i,r}$ a further -(+)x%, where quota rent adjusts to market conditions.[4]

In the Uruguay Round simulation, the level of quota output is left unchanged at 1995 levels, whereas in the Agenda 2000 scenario, a 1.5% increase in the raw milk quota is modelled. Under the CAP abolition scenario, milk and sugar output is re-endogenised, and quota rents are eliminated.

All EU sectors other than 'sugar beet' and 'raw milk' maintain the standard price link given (in percentage terms) as:

$$ps_{i,r} = to_{i,.r} + pm_{i,r} \qquad \text{(CAP.4)}$$

[3] Following Jensen *et al.* (1998) the initial level of quota rent in the EU is assumed to be 20% of the value of purchases of domestically produced milk (sugar) in each EU region by EU dairy (sugar) processing firms.
[4] A caveat of this approach is that, by definition, one assumes that the quota is *always binding* (i.e. qo is exogenously fixed to the quota level of output), although this is arguably the case in the EU raw milk and sugar markets.

5.6.2 Sugar Policy

In the case of sugar beet, we do not know *a priori* what proportion of sugar output in the GTAP database is under quota ('A' and 'B' sugar) and not under quota ('C' sugar). Following the conventions of the EU sugar policy, it is assumed that the co-responsibility levy on sugar output is enough to offset the cost of surplus disposal of 'C' sugar. Thus, the sugar sector is self-financing in EU budgetary terms and as such *does not* affect the FEOGA budget. To model the self-financing principle, it is assumed that quota rent is sufficient to exactly offset the cost of export subsidies and intervention stocks in the sugar sector. In other words, it is assumed that the quota rent on sugar is equal to the co-responsibility levy which implies that the agricultural household (section 5.6.11) does not receive any rent from sugar quota.

5.6.3 Arable Policy

Perhaps the most important development within the 1992 MacSharry reforms of the CAP has been the de-coupling of support payments to farmers. The term 'de-coupled' is used to describe a support payment to the farm sector which has no effect on output and therefore on the volume of trade. Hence, being a non-distortionary payment from a trade volume point of view, it is not subject to GATT reforms.

The concept of cross-compliance (for example, where land must be set-aside to qualify for the payment), however, leaves compensatory payments as more often recognised as *partially* de-coupled, since to qualify for the payment, the farmer is implicitly taking a set of decisions (which affect output level) which would be different if the cross-compliance were not in place. The modelling approach employed here is closer to the latter concept of partially de-coupled support.

5.6.4 Area and Set-Aside Compensation Payments

External data have been collected for both target area payments and set-aside compensation payments in 1995 (table 5.8). The data on cereals area payments are allocated to 'wheat' and 'other grains' sectors in direct proportion to the share of EU-15 cereal subsidies accounted for by both sectors in the GTAP data.[5] This gives total EU area payments of 5,986 million ecu and 5,774 million ecu to the 'wheat' and 'other grains' sectors, respectively.

	1995 Value (Million Ecu)
EU-15 Cereals Area Payments	11,760
EU-15 Oilseeds Area Payments	2,010
EU-15 Set-Aside Payments	2,370

Table 5.8: EU-15 Area and Set-Aside payments
Source: Blake *et al.* (1999)

Arable (i.e. wheat, other grains and oilseeds) area payments are then disaggregated by each region's (UK, EU-14) share of EU-15 sectoral GTAP output subsidy. Set-aside payments to all three arable sectors are assigned in the same fashion; first by sector for the whole of the EU-15, then allocated to each region. The resulting calculated values are presented in table 5.9. Moreover, using the July 1995 ($/Ecu) exchange rate of 1.3311, dollar values of each of the cereals payments are calculated for the 1995 benchmark database (see section 5.6.13).

Million Ecu (1995)						
	Area Payments			Set-Aside Data		
	Wheat	Other grains	Oilseeds	Wheat	Other Grains	Oilseeds
UK	958	531	209	151	84	54
EU-14	5,028	5,243	1,801	794	826	461
Sub-Total	5,986	5,774		945	910	515
Total	11,760		2,010	2,370		

Table 5.9: Area and Set-Aside payments by sector and region
Source: Author's own calculations

To characterise the nature of de-coupled support, set-aside and area compensation payments are stripped out of the output subsidy wedge in the cereals and oilseeds sectors in the GTAP database. Area-compensation is re-calibrated as an input subsidy to the *land* factor in each of these EU arable sectors, and the land subsidy drives a wedge (i.e., rents) between the market price of land, $pm_{i,r}$, and the price the farmers pay for land ($pfe_{i,j,r}$). Hence support is no longer direct, but is partially removed from production in the form of the land subsidy.

[5] 'Wheat' and 'other grains' sectors account for 50.9% and 49.1% of total cereals output subsidies to the EU in the GTAP database.

Set-aside compensation payments (i.e., support for reductions in cereals land area) are re-introduced as a totally de-coupled lump-sum payment from the FEOGA budget to the agricultural household (see sections 5.6.10 and 5.6.11) in each EU region. Under this characterisation, it is argued that set-aside compensation payments are given to the land-owners rather than to the productive sector.

In each case, the total value of the 1995 set-aside and area payments stripped out from the output subsidy does not exceed the benchmark GTAP output subsidy values. The *residual* output subsidy now provides a *more accurate measure of direct support* and accounts for disposal and storage costs, food aid and other forms of CAP cereals expenditure. Finally, changes to the level of compensation under Agenda 2000 are based on percentage changes between 1995 levels and proposed Agenda 2000 compensation levels (table 5.10).

Crop	1995 base	Agenda 2000	Percentage change
Cereals	262 Ecu/ha	321 Ecu/ha	22.52
Oilseeds	438 Ecu/ha	321 Ecu/ha	-26.71
Set-aside	334 Ecu/ha	321 Ecu/ha	-3.89

Table 5.10: 1995 and Proposed Area and Set-Aside Compensation Payments
Source: Blake *et al.* (1999)

5.6.5 Characterising Cereals and Non-Cereals Land

To qualify for arable area payments, a base acreage must have been registered. Thus, movements of previously unregistered land into arable sectors do not qualify for area and set-aside compensation. This effectively deters large movements of 'new' land from non-arable to arable uses. Moreover, immobility of the non-cereals/cereals land factor is further supported by the fact that much of the livestock land area is unsuitable for use in cropping.

To model this immobility the land endowment in both EU regions is disaggregated into cereals land (Aland) and non-cereals land (Land) factors. Both types of land factor are held within Constant Elasticity of Transformation (CET) functions, where the degree of mobility within each is controlled by the elasticity of transformation (set at unity in the simulations that follow).

5.6.6 Modelling Land Set-Aside

Changes to the level of set-aside are modelled by the addition of land in the cereals sectors. This is characterised by shocking the endowment of 'cereals land'. In table 5.11, data on compulsory set-aside, five year set-aside and total base acreage are recorded for 1995. From these data, it is possible to calculate the actual usage of land area in 1995, which is assumed equal to the benchmark area (in value terms) in the 1995 database.

'000 ha	UK	EU-14	EU-15
1995 Land Area	3,827	42,475	46,302
(+) compulsory set-aside	597	5,814	6,411
(+) voluntary five year set-aside	37	811	848
(=) total base area	4,461	49,100	53,561
Agenda 2000 voluntary set-aside	131	2,869	3,000

Table 5.11: Set-Aside Levels
Source: Agricultural Situation in the European Union

To model the Agenda 2000 reforms to land set-aside, our approach follows an EU projection that total voluntary set-aside will be 3 million hectares (Blake *et al.*, 1999), where all compulsory set-aside is abolished.[6] The uptake of voluntary set-aside in the Agenda 2000 scenario is assigned using the share of voluntary set-aside uptake in 1995. Thus, under the proposed Agenda 2000 reforms, set-aside is now only 5.6% of the total EU-15 base acreage in 1995 (compared to the actual 1995 set-aside level which is 13.6% of total EU-15 base acreage).

To implement the Agenda 2000 proposals, the 1995 benchmark cereals land area is increased by 13.14% (8.84%) for the UK (EU-14) to characterise the elimination of compulsory set-aside. Under the CAP abolition scenario, all set-aside is abolished and the 1995 cereals land endowment in both EU regions is increased up to 1995 base area levels.

5.6.7 Headage Payments

In the GTAP database, all of the de-coupled support to the livestock sector is captured within the output subsidy wedge. As with area payments, headage premia are re-

[6] A full description of the Agenda 2000 reforms are provided in the appendix to this chapter.

assigned as input subsidies to *capital* in the livestock sector, where suckler cows are considered as part of the productive capital necessary to produce slaughter animals. Moreover, for the same reasons as above, modelling headage payments as input subsidies more accurately characterises the partially de-coupled nature of livestock support. Finally, capital is mobile in the livestock sector, where the projected ten year time horizon in the model is assumed sufficient for cattle farmers to change herd size (i.e., capital) in response to changes in the level of compensation (i.e. input subsidy).

The data in tables 5.12 and 5.13 show the headage payment rates and aggregate payment ceilings in 1995, as well as proposed changes under the Agenda 2000 reforms. EU-15 livestock expenditures recorded in column 4 of table 5.13, are disaggregated using regional output subsidy share data. Thus, the share of EU livestock subsidy expenditure going to the UK (EU-14) is 21.8% (78.2%), such that the UK (EU-14) receives $581m ($2,086m) (calculated by 1.3311/1 $/Ecu) of EU headage subsidy in the benchmark year (1995). These subsidies are withdrawn from the output subsidy wedge and inserted as capital input subsidies on livestock.

(Ecu/head)	1995	Agenda 2000	% change
Suckler Cow	145	215	48
Male Bovine - bull	135	368	173
- steer	109	232	113
Dairy Cow	0	70	--

Table 5.12: Headage Payment Rates
Source: Blake *et al.* (1999)

	1995 (livestock millions)	Ag. 2000 (livestock millions)	% Change	1995 (m Ecu)	1995 ceiling (m Ecu)	Ag.2000 Ceiling (m Ecu)
Suckler Cow	9.976	10.285	3.1	1,046.7	1,446.5	2,211.3
Male Bovine	9.038	9.095	0.6	957.1	1,102.6	2,728.5
Dairy Cow	0.000	20.250	--	0.0	0.0	1,417.5
Totals	19.014	39.630	--	2,003.8	2,549.1	6,357.3

Table 5.13: Headage Payment Ceilings
Source: Blake *et al.* (1999) and author's own calculations[7]

Under the Agenda 2000 proposals, there is an addition of dairy cow premia payments which increases the 1995 base ceiling expenditure level across the whole of the EU. Thus, for the Agenda 2000 proposals, the level of input subsidy capital expenditure in

[7] Ceiling limits on headage expenditure are calculated by multiplying headage payments in table 7.6 by animal head limits in table 7.7.

the livestock sector is increased in proportion to the ceiling expenditure increase. In the CAP abolition scenario, all headage payments are eliminated.

5.6.8 Stocks and Floor Prices

Intervention stocks are designed to maintain the commodity support price between pre-designated limits and promote price stability. Thus, if there is over-supply, stocks are purchased to prevent the price from falling below the floor price. In periods of under-supply, surplus stocks are used to prevent the commodity price rising too high. Recent history of the CAP suggests that the latter has never been an issue. Moreover, purchases of stocks have created further problems in terms of storage costs. In the absence of any dynamic treatment in the model and in relation to the reason given above, it is solely the *accumulation* of stocks which is included in the model specification. In other words, stocks may be purchased, but are not re-sold.

In 1995, market prices were high compared to intervention prices, and stock buying only occurred for a few products.[8] Since those products affected by stock purchases form only small components of the aggregated commodity groupings in the model, it is assumed that stock purchases initially start at zero in the benchmark. Stock buying occurs in 'wheat', 'other grains', 'meat', 'other meat' and 'milk' processing sectors.

	1995		**Agenda 2000**	
	UK	**EU-14**	**UK**	**EU-14**
Wheat	78.37	79.13	62.70	63.30
Other grains	89.93	85.70	71.68	68.31
Meat processing	95.00	95.00	66.64	66.64
Other Meat processing	95.00	95.00	66.64	66.64
Milk Processing	95.00	95.00	85.50	85.50

Table 5.14: Intervention Price / Support Price Ratios
Source: Blake *et al.* (1999)

Data presented in table 5.14 shows how far support prices may fall before reaching the intervention price. For example, in the case of the wheat sector in the UK in 1995, the price may fall 21.63% before triggering stock buying. In the processing sectors, the highly aggregate nature of the commodity categories precludes the availability of price

[8] In 1995, stock buying occurred in fruit and vegetables, wine and fishery products. Other storage and disposal costs were incurred due to the build up of stocks in previous years.

ratio data, where instead a 5% difference between the market and intervention price levels is assumed. Following Blake *et al.* (1999), the Agenda 2000 intervention price is also calculated as a percentage of the 1995 market price, given the 1995 ratio and the proposed Agenda 2000 changes in intervention prices.

5.6.9 Modelling Stock Purchases

The demand for stocks is based on falls in the support price ($pm_{i,r}$). If the support price falls to intervention price levels, stocks accumulate. In the model, the demand for stocks is given as:

$$stocks_{i,r} = STCK_i * pm_{i,r} \qquad \text{(CAP.5)}$$

where $STCK_i$ is the responsiveness of stock buying to falls in the support price. The *change* in the value of stock buying is introduced into the market clearing equation for only those tradable commodities, 'i', where stocks may accumulate.

Thus, to implement these mechanisms into the model solution, two stages are required. An initial run is made where the value of $STCK_i$ is zero (no stock buying) and endogenous percentage changes in the support price ($pm_{i,r}$) are checked to see if they fall below the intervention price. If the support price falls to the intervention price-trigger, the elasticity parameter $STCK_i$ becomes non-zero in the second stage and is iteratively increased until the level of stock buying in the market clearing equation is such that the support price falls only to intervention price levels.

5.6.10 The Brussels Household

Calculating the net budgetary contributions of each EU member state to the FEOGA budget requires the inclusion of a "Brussels household" within the model. The Brussels household collects revenues from each member state by way of resource (i.e., GDP and VAT) contributions and EU agricultural import tax contributions. From these revenues, the FEOGA budget meets expenditures on export and output subsidies, area, set-aside and headage payments and intervention purchases.[9]

Reference to table 5.15 shows that in 1995, the biggest net loser to FEOGA was Germany (-12bn ecu), with the UK (after rebate) and France as the second and third biggest net losers, respectively. The biggest net gainer from the FEOGA budget was Spain, which received 7.5bn ecu more than it paid into the budget. Other significant gainers were Greece, Portugal, Belgium and Ireland.

Country	Ecu (mill)	% GNP	Country	Ecu (mill)	%GNP
AUS	-883.5	-0.50	ITA	-317.6	-0.04
BEL	2,455.2	1.16	LUX	690.5	4.86
DEN	471.1	0.37	NL	-684.5	-0.23
FIN	-116.0	-0.12	POR	2,542.2	3.21
FRA	-1,444.3	-0.12	SPA	7,516.4	1.76
GER	-12,090.9	-0.66	SWE	-754.1	-0.44
GRE	3,548.2	4.02	UK	-3,005.1	-0.36
IRE	2,072.3	4.85	Net Total	0.0	-

Table 5.15: 1995 Budgetary Balance after UK Rebate
Source: European Commission (1998)

The Brussels household equation is calibrated to external data on the net CAP contribution ($NETCONT_r$) by the UK (-3,005m. ecu) in 1995.[10] Moreover, since the budget balances, the EU-14 net contributory position is assumed to be the exact opposite to that of the UK (i.e. +3,005m. ecu). Thus, the net contributory position of each EU region 'r' in the benchmark is given as:

$$
\begin{aligned}
NETCONT_r . = & \sum_{i \in agr} \sum_{s \in noneu} EXPORTSUB_{i,r,s} + \sum_{i \in agr} OUTPUTSUB_{i,r} \\
& + \sum_{i \in capital} \sum_{j \in livestock} HEADAGE_{i,j,r} + \sum_{i \in land} \sum_{j \in arable} AREAPAY_{i,j,r} \\
& + \sum_{j \in arable} SETASIDE_{j,r} + \sum_{i \in stock} STOCKS_{i,r} \\
& - \sum_{i \in agr} \sum_{s \in noneu} IMPORTTAX_{i,s,r} - RESOURCE_r
\end{aligned}
\tag{CAP.6}
$$

[9] Sugar does not enter the FEOGA budget since the GTAP data shows that the production of sugar is taxed. Moreover, all export subsidies are paid by the producer co-responsibility levy, not the EU budget.
[10] At the July 1995 exchange rate of $1.3311/Ecu, this is –$4,000m.

In order to reconcile the external data on net contributions to the CAP with GTAP data on CAP expenditures and import revenues, the regional resource cost is calculated by rearranging (CAP.6) in terms of $RESOURCE_r$. Further, to maintain zero FEOGA profits in the counterfactual data, each region has a fixed share of the *total* EU resource contribution, such that percentage changes in total resource costs and each EU region's resource costs are equal.

Where there is a regional net contributory deficit (surplus) in the benchmark, regional income will be less (greater) than domestic expenditure in the benchmark by the size of the net CAP contribution, $NETCONT_r$. The easiest way to accommodate this change is to alter the value of regional savings, which is calculated as the residual of regional income minus private and government household expenditures. Since the CAP budget is in balance, the overall level of *EU-15* savings will not change, such that further data modifications are not required.

5.6.11 Agricultural Producers and Asset Holders

To ascertain the welfare effects on agricultural producers and asset holders (i.e., owners of quota) in each EU region, it is necessary to include an agricultural producers' welfare function.[11] This should include all factor payments going to the agriculture sector net of depreciation on capital assets, plus all forms of EU compensation and quota rents.

It is not possible to determine from the base data what proportion of regional factors are owned by the agricultural sector, or indeed what proportion of depreciation expenditure is incurred by agricultural sectors. For this reason, the disaggregation of endowment ownership into agricultural and non-agricultural sectors is based on GTAP expenditure data on each primary factor. Thus, the share parameter '$\eta_{i,r}$' in (CAP.7), is the proportion of total (i.e., all sectors) demands for *each* primary factor accounted for by primary agricultural sectors, where the shares for each factor are multiplied by the corresponding total value of each endowment. Depreciation expenditure appears in the GTAP data by region. Hence, to approximate depreciation expenditure by primary agricultural sectors,

[11] This is included only as a summary statistic and as such does not affect the model solution.

we use the share of *regional* expenditure on all factors by all primary agricultural sectors, multiplied by the regional depreciation value.

It is assumed that quota rent from the sugar sector exactly covers the cost of surplus disposal of sugar on export refunds and stock buying (see section 5.6.2). Hence, netting these flows out from the agricultural household function leaves quota revenue accruing from the milk sector only. In levels terms, the agricultural household welfare function is defined as:

$$AGINCOME_r . = \sum_{i \in endw} FACTORINC_{i,r} \times \eta_{i,r} - VDEP_r \times \eta_{i,r}$$

$$+ \sum_{i \in capital} \sum_{j \in livestock} HEADAGE_{i,j,r} + \sum_{i \in land} \sum_{j \in arable} AREAPAY_{i,j,r}$$

$$+ \sum_{j \in arable} SETASIDE_{j,r} + \sum_{j \in rawmilk} RENT_{j,r} \qquad r \in eureg \qquad \text{(CAP.7)}$$

5.6.12 Agricultural household welfare

To calculate the equivalent variation (EV) for the agricultural household, it is necessary to determine *real* changes in agricultural household income. Thus, in percentage change form, it is possible to determine the change in agricultural income ($yagric_r$) under each of the policy scenarios. Using percentage changes in each EU region's GDP price index ($pgdp_r$) to deflate nominal agricultural income changes gives real changes in agricultural household income ($yragric_r$). In percentage change form this is represented as:

$$yragric_r = yagric_r - pgdp_r \qquad \text{(CAP.8)}$$
$$r \in eureg$$

Thus, changes in EV for agricultural households and asset holders ($AGEV_r$) are given by:

$$AGEV_r - [AGPR_r / 100].yragric_r = 0 \qquad \text{(CAP.9)}$$
$$r \in eureg$$

where $AGPR_r$ is the initial value of agricultural income in benchmark (pre-shock) prices.

5.6.13 Data Manipulations

In version 4 of the standard GTAP database, there are no input subsidies or taxes in the primary arable and livestock sectors. Moreover, it is not possible to simply introduce a new input subsidy wedge and leave the rest of the data unchanged as this destroys internal consistency. Hence, this study follows that of Malcolm (1998). Thus, input subsidy wedges calculated in sections 5.6.4 and 5.6.7 are calibrated into the benchmark data by shocking the exogenous input subsidy/tax variables $tf_{i,j,r}$. A simultaneous shock is also applied to the output subsidy/tax variable $to_{j,r}$ to remove that part of the original output subsidy wedge now pertaining to the new input subsidy.[12]

To correctly calculate the wedge one must calculate the desired shocks. Thus, using the output subsidy case as an example, the GTAP data *ad valorem* subsidy (S) is calculated as the ratio of agents' value (A) to market value (M):

$$S = \frac{A}{M} \qquad \text{(CAP.10)}$$

where if S is greater than unity we have a subsidy and if S is less than unity we have a negative subsidy (i.e., tax). If A is 25 and M is 15, then the *ad valorem* subsidy is 1.667. Assume that we wanted to reduce the wedge between A and M from 10 down to 5 such that A is now 20, this would imply that S would now assume a new value of 1.333 (S'). To calculate the percentage reduction in S to achieve this new wedge, employ the formula:

$$\left[\frac{S' - S}{S}\right] * 100 \qquad \text{(CAP.11)}$$

[12] In the arable sector, the output subsidy is calculated after price compensation has been stripped out of the wedge. In the sugar and raw milk sectors, output subsidies/taxes are adjusted to include quota rents.

which gives a percentage shock of -20%. This procedure is repeated for each of the output and input subsidy shocks simultaneously and forms the 1995 benchmark data set.

As with any simulation, the model calculates how these shocks affect other flows in the model (i.e., the resultant effects on the endogenous variables in the model). However, the difference between a normal experiment and the data manipulation procedure is that in the former case, model structure, closure and parameter values are chosen to represent economic reality as accurately as possible, whereas in the latter case, they are chosen to minimise disturbances in the database resulting from exogenous shocks, such that the adjusted benchmark data are as close as possible to the original data.

Malcolm (1998) addresses this question by conducting a series experiments using an array of model variants. Malcolm finds that allowing all factors to be perfectly mobile, keeping the trade balance exogenous and characterising all substitution possibilities as Cobb-Douglas, minimises the disturbances in the database. Some changes, such as the setting of elasticity parameters equal to one, will maintain the value shares (i.e. any price change will be offset by a change in quantity) in each nest thus minimising disturbances. Other changes, (exogenous trade balance, perfect mobility of all factors) are introduced simply on an empirical basis, where sensitivity testing reveals that such additions are beneficial to minimising data changes from the original positions.

5.7 Conclusion

This chapter gives an overview of the chosen model aggregation which is tailored towards our investigation of CAP costs. The choice of sectoral aggregation is biased toward inclusion of each of the key cornerstone CAP commodity regimes (i.e., dairy, cereals, livestock). Regional aggregation includes correct implementation of the Uruguay Round (UR) reforms (i.e., DC/LDC split) and accommodates the large players in world agricultural markets (USA, CAIRNS) which have significant trade links with the EU regions. An important factor in the choice of both sectoral and regional aggregation is the need to constrain model size such that computational expense does not become prohibitive. The second part of the chapter builds on the choice of sectoral and regional aggregation by detailing the range of modelling techniques employed in our stylised characterisation of the CAP, the Uruguay Round constraints and model projections.

Appendix A: A full list of reforms pertaining to the Agenda 2000 proposals

The following lists the changes implemented in the model under the Agenda 2000 proposals:

- **Quota –** Raw milk quota to be increased; Sugar quota remains unchanged
- **Set-Aside –** All set aside is reduced to voluntary set-aside only.
- **Area Compensation –** Cereals sectors undergo increases in area compensation, with concurrent reductions in the oilseed area payment.
- **Set-Aside Compensation –** All set-aside payments are reduced under the proposals.
- **Headage Payments –** The addition of dairy cow premium leads to increases in headage premia to the cattle and sheep sectors of the EU-15.
- **Intervention Purchases –** Intervention prices are reduced further under the scheme
- **Import Tariffs and Export Subsidies –** This remains unchanged from the Uruguay Round scenario.

Chapter 6

Incorporating Imperfect Competition and Hierarchical Preferences

This chapter gives a detailed discussion of the stylised modifications required to incorporate neo-Hotelling hierarchical preferences (section 6.1) , imperfect competition and scale economies (section 6.2) into the standard GTAP model framework. Attention is also given to changes in the model structure/terminology employed (section 6.3), as well as alterations made to the standard GTAP data files (section 6.4). Section 6.5 gives a numerical example and section 6.6 concludes.

6.1 Incorporating Neo-Hotelling Preferences into the Model Structure

6.1.1 Hierarchical Preferences in a CGE Trade Model

In the context of a multi-region CGE model which emphasises international trade, we assume that a single 'representative variety' of a given differentiated commodity is produced by each region, where the representative variety is made up of product variants within a region. For example, within the United Kingdom (UK), there are many different cheeses available, which in this model are combined into a composite UK cheese. Preferences are treated heterogeneously by assuming a 'varietal spectrum' of characteristics, where agents' preferences are based on how such characteristics are combined in the representative varieties.[1]

Figure 6.1 presents a varietal spectrum, where the 'ideal' represents the perfect combination of attributes for a particular consumer. Employing the result from the SDS model specification in chapter 3, that only a finite number of varieties are produced, Vousden (1990) argues that,

> "consumers are unable to obtain a good which offers their exact preferred specification, and they are forced to consume an available good which comes closest to their ideal" (pp160).

Thus, each of say 3 regions, the European Union (EU), the United States of America (US) and the Rest of the World (ROW), produces a representative variety characterised by a combination of attributes (e.g., after sale service, quality, taste, packaging) which determines its position on the *varietal spectrum*. It is assumed that these attributes are dominated by the *region of origin* of the product. As there are only a finite number of varieties produced, most agents are unable to obtain a variety which offers their ideal specification, but consume an available variety which comes closest to their ideal.

Thus, the variable, $QDF_{i,r,s}$, represents the consumer's demand in region of destination 's', for the representative variety 'i' produced by exporting region 'r'.[2] Suppose that the varietal spectrum pertains to the aggregate consumer in the EU (i.e. s=EU). The distance 'V' of each representative variety from zero determines the preference ranking; those representative varieties with values of V closer to the ideal are more preferred. Thus, in Figure 6.1, $V_{i,EU,EU}$ is larger than $V_{i,US,EU}$, implying that the EU consumer prefers the domestic representative variety to the US representative variety. As the discussion in chapter 3 indicates, such patriotic purchasing behaviour for food products is readily observable (i.e., "Buy British" campaigns).

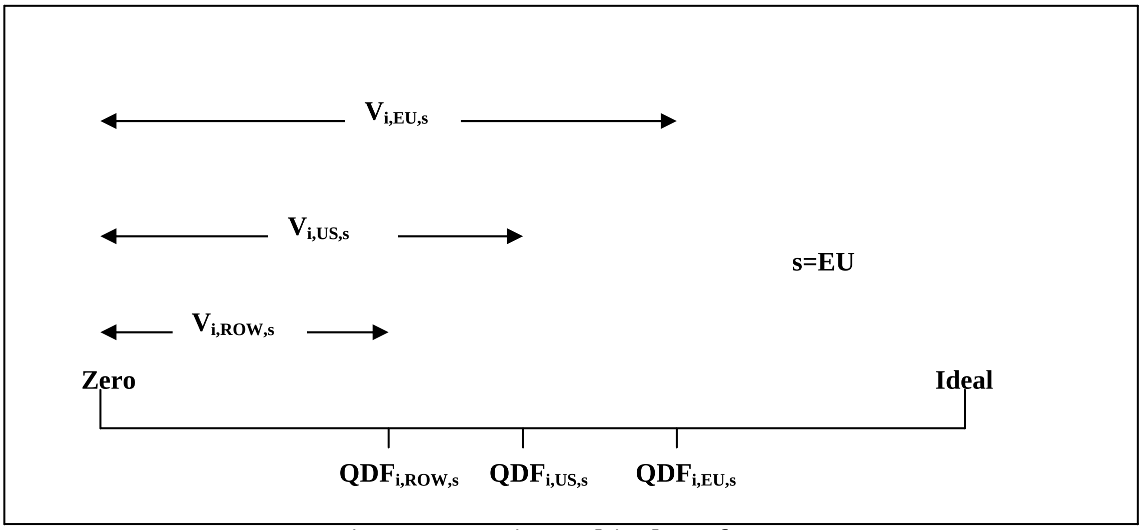


Figure 6.1: Hierarchical Preferences

---

[1] Varietal preferences apply to intermediate demands as well as private household and government final demands.

[2] This variable does not appear the final model structure, it is just a *general* aggregate agent differentiated demand variable. Each agent's demands for differentiated commodities are presented in the modified final and intermediate demand nesting structures.

Thus, our approach is a variant of the 'interleaved' type of preference structure (Lancaster, 1984; see chapter 3), where the domestic representative variety (i,EU,EU) is substitutable with imported varieties (i,US,EU) and (i,ROW,EU) through the nesting structure.[3] Our approach also assumes that each firm in those sectors which are classified as imperfectly competitive produces a 'product variant' of the representative variety, i.e., there is a one-to-one mapping between firms and product variants. There are two reasons for this approach. First, from an economic point of view, a new firm is more likely to succeed in the industry by producing a new product variant instead of duplicating an existing one (i.e., firms are trying to capture a niche in the product space). Secondly, a firm producing more than one product variant would imply a different mark-up pricing rule for each of its products, which would significantly enhance model complexity.

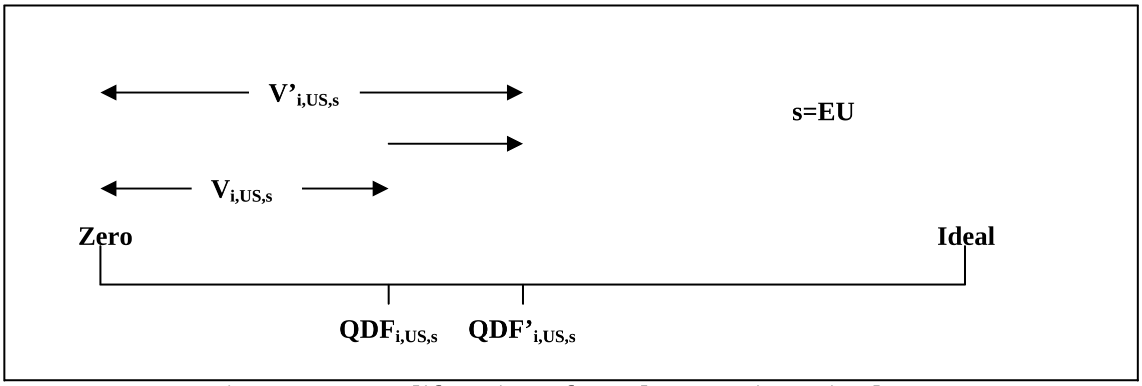


Figure 6.2: Proliferation of Product Variants in the US

The neo-Hotelling approach predicts that proliferation in the number of available varieties narrows the gaps between the closest available variety and the consumer's ideal (Vousden, 1990, pp162). In the same way, we assume that product variant/firm proliferations within each region improve the position (and possibly the ranking) of the representative variety in the hierarchical preference structure since that region now offers more variety (within a composite) to the consumer. Thus, in Figure 6.2, a proliferation of the US domestic product variants of the US representative variety

[3] In this model, the term variety refers to the *representative* variety, not the product variants manufactured within a region as is the case in Lancaster. Thus, in this application, the demand specification by consumers (i.e., by household and sector) is for the representative variety only.

implies that the preference value of $V_{i,US,EU}$ on the EU consumer's varietal spectrum increases to $V'_{i,US,EU.}$ It is this process that characterises the 'variety effect'.

In a general equilibrium context, each representative variety of commodity 'i' produced by each exporting region 'r' (r=EU, US, ROW) is demanded by aggregate agents in importing region 's' (s=EU, US, ROW), albeit with a different preference value across each market (i.e. $V_{i,US,EU} \neq V_{i,US,US} \neq V_{i,US,ROW}$). An equal percentage increase (decrease) in US varieties/firms will therefore improve (reduce), although in different degrees, the standing of this representative variety on each of the varietal spectrums of the aggregate consumers in the EU, US and ROW.

6.1.2 Aggregate Preferences

Consumers of final/intermediate goods may only be disaggregated to a certain level, (one for each sector 'j', private and government household agents), where further disaggregation would involve large numbers of micro-consumers within each market (as in the Lancaster (1979, 1980, 1984) approach), and would significantly enhance model size and computational expense. For this reason, it is assumed that the preference rankings and behaviour exhibited by the final/intermediate consumers reflect the preference hierarchies of micro consumers within each market/sector.

6.1.3 Modelling Hierarchical Preferences

To model such a preference structure, we take our motivation from the Lancaster (1984) approach. In general form, utility from the consumption of a representative (regional) variety, $Z_{i,r,s}$, is given as:

$$Z_{i,r,s} = Z_{i,r,s}[V_{i,r,s}] \qquad \text{(H.1)}$$

where:

$Z_{i,r,s}$ - Hierarchical cardinal utility function,

$V_{i,r,s}$ – Preference ranking of a representative variety 'i' produced by region 'r' along the varietal spectrum of each agent in region 's'.

Our specification employs a *levels* specific form for the utility function:

$$Z_{i,r,s} = \left[1 + V_{i,r,s}\right]^{\gamma_{i,s}} \qquad \text{(H.2)}$$

where:

$\gamma_{i,s}$ - Preference heterogeneity parameter for differentiated representative variety 'i' in region 's'.

Note that hierarchical preferences for intermediate demands are indexed by each sector 'j'. Correspondingly, *levels* hierarchical cardinal utilities for the three agents are given as $ZPS_{i,r,s}$, $ZGS_{i,r,s}$ and $ZFS_{i,j,r,s}$. In the model structure, each of the regional agents in 's' have *levels* preference rankings for each representative variety 'r', given as $VP_{i,r,s}$, $VG_{i,r,s}$ and $VF_{i,j,r,s}$ for private household, government and sectoral differentiated intermediate good preferences respectively.

Following a similar structure to Lancaster (1991) function (H.2) exhibits two characteristics. Firstly, it is strictly increasing in $V_{i,r,s}$ and secondly, to quote Lancaster,

> *'the effect of distance increases as products differ more and more from the ideal' (pp3)*

where, in this framework, preferred varieties with higher values of benchmark preference ($V_{i,r,s}$) give higher amounts of hierarchical utility ($Z_{i,r,s}$) compared to less favoured varieties, although at a decreasing rate.

For agents in each region, the specific levels form of the cardinal hierarchical utility function *linearises* to:

$$z_{i,r,s} = \left[\frac{\gamma_{i,s} V_{i,r,s}}{\left[1 + V_{i,r,s}\right]}\right] n_{i,r} \qquad \text{(H.3)}$$

$$i \in mcomp \qquad r, s \in reg$$

where lowercase letters are percentage changes in the corresponding uppercase variables. Following Vousden (1990), increases (decreases) in the number of regional firms/product variants ($n_{i,r}$) proxy for improvements (deteriorations) in each region's preference ranking ($V_{i,r,s}$) representative variety on the varietal spectrum.

The parameter $\gamma_{i,s}$ characterises the degree of preference heterogeneity of each agent. In other words, how sensitive are final/intermediate consumers to proliferations/reductions in the number of product variants and their effect on the position of the representative variety on the varietal spectrum. This implies two characteristics inherent within the hierarchical utility function.

Firstly, larger values of $\gamma_{i,s}$ result in bigger differences in benchmark preference utilities between higher and lower ranked representative varieties. This implies that consumers have a more strongly defined ranking structure. On the other hand, where $\gamma_{i,s} = 0$, all representative varieties have the same hierarchical utility value ($Z_{i,r,s} = 1$) which implies preference homogeneity.

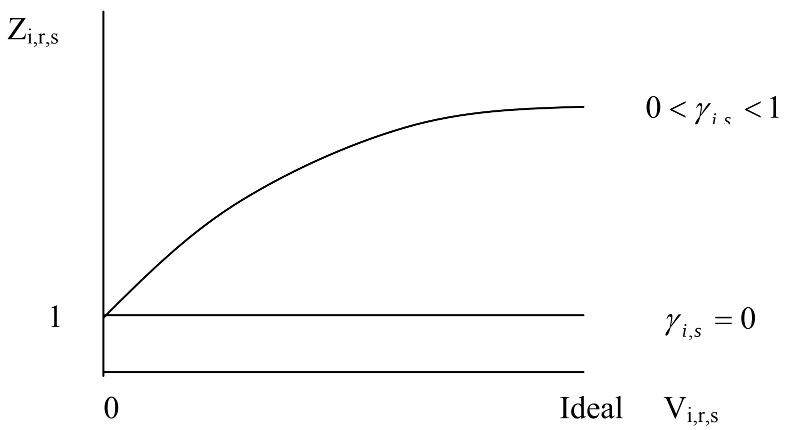


Figure 6.3: Concavity of the Hierarchical Utility Function

In this study, we assume that the level of marginal hierarchical utility from the consumption of a representative variety diminishes as we move closer to the ideal (i.e., incremental proliferations in product variants within representative varieties yield smaller improvements in utility). Thus, the preference heterogeneity parameter assumes a value between zero and one, which implies that the shape of the levels cardinal hierarchical utility function is concave. In other words, the change in the level of hierarchical utility ($Z_{i,r,s}$) associated with increases in the preference value ($V_{i,r,s}$) of a representative variety falls. This function is presented in figure 6.3 alongside the case where $\gamma_{i,s}$ is zero (i.e., preference homogeneity), where the derivative $\partial Z_{i,r,s} / \partial V_{i,r,s}$ is zero.

The second feature is that for values of $\gamma_{i,s}$ closer to one, proliferations (reductions) in the number of regional variants ($n_{i,r}$) will lead to significant incremental increases (falls) in hierarchical utility to agents, vis-à-vis the case of low values of $\gamma_{i,s}$ (i.e., closer to zero), where consumers exhibit 'sticky' reactions to changes in varietal diversity of a given representative variety. Thus, when, $\gamma_{i,s} = 0$, percentage changes in hierarchical utility ($z_{i,r,s}$) are zero, so Hicksian demands are standardised as functions of prices and sub-utility only, (i.e., preference homogeneity). In those cases where $\gamma_{i,s}$ assumes a value closer to one, the consumer strongly identifies with varietal improvements (deteriorations), where, for example, proliferations (reductions) in regional variants of a given representative cheese, have big impacts on their choice set (i.e., larger changes in $z_{i,r,s}$) leading to more marked increases (reductions) in purchasing behaviour. Where $\gamma_{i,s}$ assumes a value close to zero, consumers exhibit more indifference between representative varieties, where new variants yield small improvements (deteriorations) on the benchmark varietal choice set.

6.1.4 Nesting Structure

In chapter 3, criticism was levelled at the Armington structure. Our approach follows the work of Swaminathan and Hertel (1996) and Francois *et al.* (1995) in implementing a non-nested Armington structure, where the lower import composite nest of the Armington framework is eliminated to allow domestic and foreign firm product variants to compete *directly* with one another.

The modified nested structure for final demands is presented in figure 6.4. Examining the second level of the nest, composite commodity 1 (i=1….n) is differentiated, and commodity n is homogeneous. In the third level of the nest, $qdfgs_{1,r,s}$ and $qdfps_{1,r,s}$ are percentage changes in government and private household differentiated demands for commodity 1 respectively. Moreover, in these same nests, each of the foreign (r≠s) and domestic (s=s) representative varieties compete directly with each other.

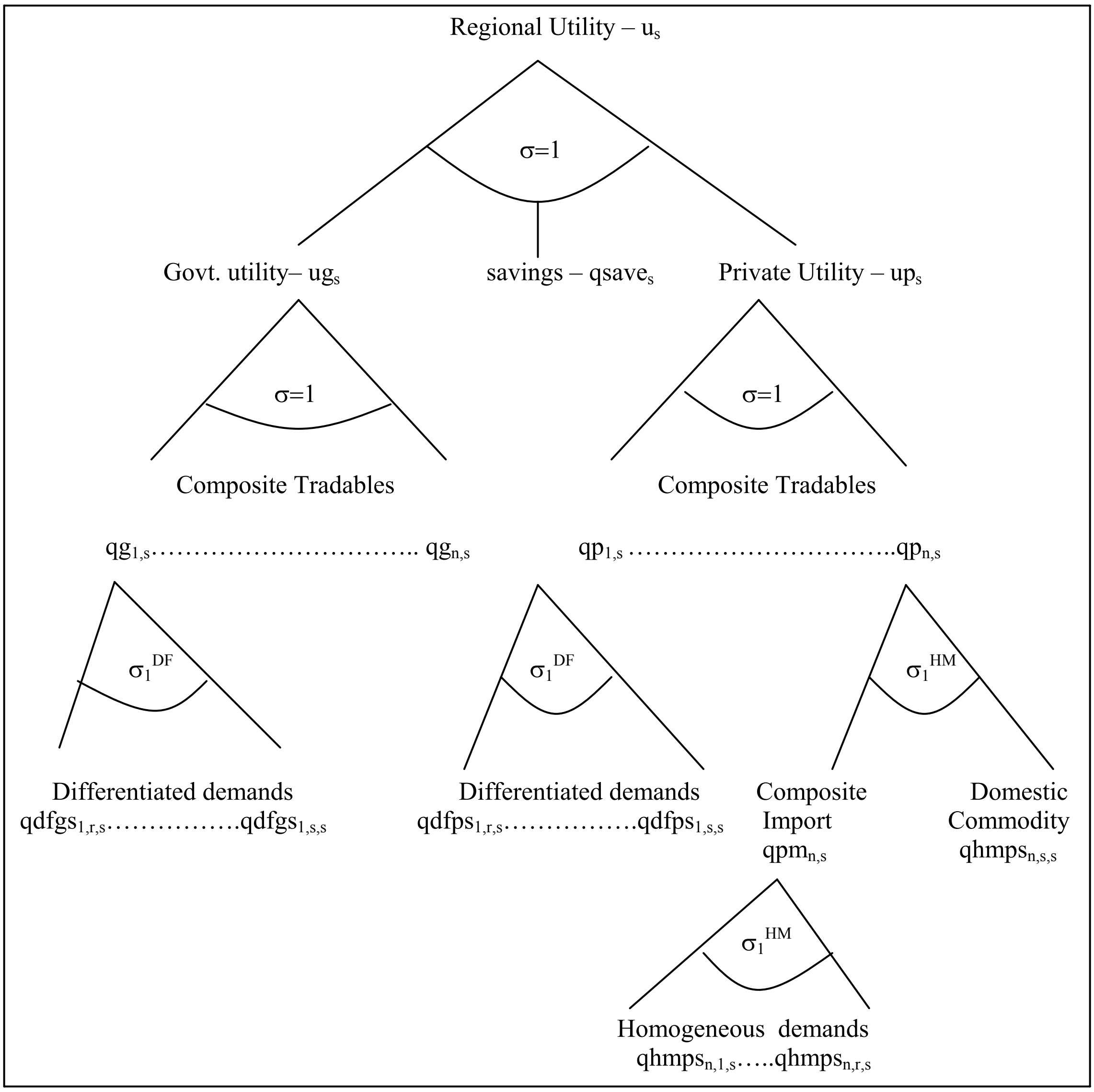


Figure 6.4: The Utility Tree for Final Demands

The structure of intermediate demands is identical (see figure 6.5), where representative varieties of differentiated commodity 'i' from region 'r' are demanded by each sector 'j' in region 's' ($qdffs_{i,r,j,s}$). Similarly, domestic (r=s) and foreign (r≠s) representative variety intermediate input demands compete directly with one another in the second level of the nest (see figure 6.5).

Finally, for homogeneous demands of commodity ‘n’ ($qhmps_{n,r,s}$), the standard Armington structure is maintained. Thus, homogeneous goods demands ($qhmps_{n,1,s}$ to $qhmps_{n,r,s}$) are aggregated into a composite homogeneous good ($qpm_{n,s}$) which competes with the domestic (s=s) substitute $qhmps_{n,s,s}$. In figure 6.4, the schematic presentation of homogeneous goods demands is shown for private households.

6.1.5 Hierarchical Preferences and CES Hicksian Demands

In this thesis, aggregate agents’ hierarchical preferences are approximated using a *CES* cost minimisation procedure (Lancaster, 1984). Thus, in levels form, and taking the private household as an example, minimising expenditure (cost) on all representative varieties:

$$\sum_{r \in reg} \left[PPS_{i,r,s} QDFPS_{i,r,s} \right] \qquad \text{(H.4)}$$

subject to a modified levels neo-Hotelling CES sub-utility function for composite differentiated tradable 'i' in region 's':

$$QP_{i,s} = A_{i,s} \left[\sum_{r \in reg} \delta_{i,r,s} QDFPS_{i,r,s}^{-\rho_i} ZPS_{i,r,s} \right]^{-\frac{1}{\rho_i}} \qquad \text{(H.5)}$$

$$i \in mcomp$$

where:

$A_{i,s}$ - Scale parameter.

$QP_{i,s}$ - The level of sub-utility from the consumption of differentiated commodity 'i' in region 's' to the aggregate private household consumer.

$QDFPS_{i,r,s}$ - Demands by the aggregate private household agent for differentiated commodity 'i' from region ‘r’ to region ‘s’.

$ZPS_{i,r,s}$ - (Private household) hierarchical utility preference variable

$\delta_{i,r,s}$ - Differentiated commodity 'i' share parameters.

ρ_i – Elasticity parameter.

gives first order conditions:

$$PPS_{i,r,s} = \Lambda A_{i,s}\left[\sum_{r\in reg}\delta_{i,j,k} QDFPS_{i,r,s}^{-\rho_i} ZPS_{i,r,s}\right]^{-\frac{(1+\rho_i)}{\rho_i}} \delta_{i,r,s} QDFPS_{i,r,s}^{-(1+\rho_i)} ZPS_{i,r,s}$$

(H.6)

$$QP_{i,s} = A_{i,s}\left[\sum_{r\in reg}\delta_{i,r,s} QDFPS_{i,r,s}^{-\rho_i} .ZPS_{i,r,s}\right]^{-\frac{1}{\rho_i}} \quad \text{(H.7)}$$

Substitution of (H.7) into (H.6) simplifies the latter:

$$PPS_{i,r,s} = \Lambda A_{i,s}^{-\rho_i} QP_{i,s}^{(1+\rho_i)} \delta_{i,r,s} QDFPS_{i,r,s}^{-(1+\rho_i)} ZPS_{i,r,s} \quad \text{(H.8)}$$

where (H.7) and (H.8) are the levels first order conditions. Following the approach of appendix A.2.3, linearisation of (H.7) gives:

$$qp_{i,s} = \sum_{r\in reg} S_{i,r,s}\left[qdfps_{i,r,s} - \frac{1}{\rho_i}.zp_{i,s}\right] \quad \text{(H.9)}$$

where $zp_{i,s}$ is a linearised expenditure share weighted average of bilateral hierarchical utilities:

$$zp_{i,s} = \sum_{r\in reg} S_{i,r,s} zps_{i,r,s} \quad \text{(H.10)}$$

where the expenditure shares are given as:[4]

$$S_{i,r,s} = \frac{PPS_{i,r,s}.QDFPS_{i,r,s}}{\sum_{r\in reg}\left[PPS_{i,r,s}.QDFPS_{i,r,s}\right]} \quad \text{(H.11)}$$

[4] See expressions (A12) and (A13) in appendix section A.2.3.2 for the derivation of this result.

Hence changes in hierarchical utility ($zps_{i,r,s}$) for more preferred representative varieties in region 's' have larger effects on the composite ($zp_{i,s}$).

Linearisation of (H.8) gives:

$$pps_{i,r,s} = \lambda + (1+\rho_i).qp_{i,s} - (1+\rho_i).qdfps_{i,r,s} + zps_{i,r,s} \qquad \text{(H.12)}$$

Thus, equations (H.9) and (H.12) are linearised first order conditions, where lower case letters are percentage changes in the corresponding upper case variables. Rearranging (H.12) in terms of $qdfps_{i,r,s}$ gives:

$$qdfps_{i,r,s} = -\sigma_i.pps_{i,r,s} + \sigma_i.\lambda + qp_{i,s} + \sigma_i.zps_{i,r,s} \qquad \text{(H.13)}$$

where σ_i is the elasticity of substitution between all pair-wise types of representative varieties in the nest:

$$\sigma_i = \frac{1}{1+\rho_i} \qquad \text{(H.14)}$$

substituting (H.13) into (H.9) and rearranging in terms of $\sigma_i\lambda$ yields:

$$\sigma_i.\lambda = \sigma_i.\sum_{r\in reg} S_{i,r,s}.pps_{i,r,s} - \sigma_i.\sum_{r\in reg} S_{i,r,s}.zps_{i,r,s} + \left[\frac{1}{\rho_i}\right].\sum_{r\in reg} S_{i,r,s}.zps_{i,r,s} \qquad \text{(H.15)}$$

Substituting (H.15) into (H.13) eliminates the percentage change lagrangian variable λ. Factorising the resulting expression gives linearised CES Hicksian differentiated hierarchical demands:

$$\begin{aligned} qdfps_{i,r,s} = qp_{i,s} - \sigma_i\left[pps_{i,r,s} - \left[\sum_{r\in reg} S_{i,r,s}.pps_{i,r,s}\right]\right] \\ + \sigma_i\left[zps_{i,r,s} - zp_{i,s}\right] + \frac{1}{\rho_i}zp_{i,s} \end{aligned} \qquad \text{(H.16)}$$

For consistent aggregation, expression (H.17) must hold:

$$PP_{i,s}.QP_{i,s} = \sum_{r\in reg} PPS_{i,r,s}.QDFPS_{i,r,s} \tag{H.17}$$

By linearising (H.17), substituting (H.9) and rearranging, it is possible to derive the percentage change in the composite price ($pp_{i,s}$) in the value added nest as:

$$pp_{i,s} = \sum_{r\in reg} S_{i,r,s}.\left[pps_{i,r,s} + \left[\frac{1}{\rho_i}\right].zps_{i,r,s}\right] \tag{H.18}$$

Substituting the weighted composite hierarchical utility variable expression (H.10) gives:

$$pp_{i,s} = \sum_{r\in reg} S_{i,r,s}\, pps_{i,r,s} + \left[\frac{1}{\rho_i}\right].zp_{i,s} \tag{H.19}$$

Rearranging (H.19)

$$\sum_r S_{i,r,s}\, pps_{i,r,s} = pp_{i,s} - \left[\frac{1}{\rho_i}\right].zp_{i,s} \tag{H.20}$$

Substitution of (H.20) into (H.16), expanding the brackets and collecting terms gives:

$$\begin{aligned} qdfps_{i,r,s} &= qp_{i,s} - \sigma_i\left[pps_{i,r,s} - pp_{i,s}\right] + \\ &\sigma_i\left[zps_{i,r,s} - zp_{i,s}\right] - \sigma_i\left[\frac{1}{\rho_i} zp_{i,s} - \frac{\sigma_i}{\rho_i} zp_{i,s}\right] \end{aligned} \tag{H.21}$$

Rearranging (H.14) in terms of ρ_i and substituting the result into (H.21), it is then possible to manipulate, factorise and cancel the result such that linearised CES Hicksian differentiated hierarchical demands ($qdfps_{i,r,s}$) are simplified to:

$$qdfps_{i,r,s} = qp_{i,s} - \sigma_i \left[pps_{i,r,s} - pp_{i,s}\right] + \sigma_i zps_{i,r,s} \qquad \text{(H.22)}$$

The private household linearised differentiated Hicksian demands ($qdfps_{i,r,s}$) in equation (H.22) are a function of subutility ($qp_{i,s}$), representative variety prices ($pps_{i,r,s}$) and hierarchical utility ($zps_{i,r,s}$). In a similar manner, the modified composite price ($pp_{i,s}$) of representative variety 'i' is given as a weighted average of all representative variety prices and composite hierarchical utility ($zp_{i,s}$) (equation (H.19)). Identical demand specifications are derived for government final and sectoral intermediate demands.

Varietal effects can be discussed in the context of this framework. With s=EU, the effect of an increase in hierarchical utility ($zps_{i,r,s}$) due to increases in domestic variants/firms, will always have a positive effect (*ceteris paribus)* on the demand for the domestic representative variety, $qdfps_{i,r,s}$. Varietal effects may also occur at constant prices with increases in composite hierarchical utility. The parameter σ_i must be greater than one, implying that ρ_i is negative.[5] Thus, reference to the composite price ($pp_{i,s}$) equation (H.19) shows that increases in composite varietal diversity, $zp_{i,s}$, which is dominated by increases in the favoured variety, has the effect of reducing the per unit expenditure necessary to acquire an extra unit of sub-utility $qp_{i,s}$ in the nest (Swaminathan and Hertel, 1996). This is because *increases* in the level of *aggregate* varietal diversity (dominated by improvements in the favoured variety) enable consumers to purchase higher utility yielding varieties with the same per unit cost, which is equivalent to accruing equal amounts of utility at lower cost.

The *price* effects in the demand structure are characterised in a similar manner, with relative movements in the representative variety ($pps_{i,r,s}$) and composite ($pp_{i,s}$) prices determining movements in demand ($qdfps_{i,r,s}$). Thus, in this structure there are hierarchical representative utility and price effects contained within the Hicksian demands. Moreover, following Lancaster (1984, pp139), it is possible to have the same

[5] Referring to equation (H.9) in the main text, if σ_i were equal to or less than one, then ρ_i would be zero or positive. In the former case, $1/\rho_i$ in composite price equation would equal infinity which prevents a model solution. In the latter case, ρ_i would be positive which would be counter intuitive with respect to changes in composite hierarchical utility in the composite price equation. Moreover, values of σ_i less than 2 yield much larger foreign mark-ups than the domestic mark-up which implies that firms always have a better 'foothold' abroad than in the domestic market, which does not appear intuitively appealing.

level of demand for two representative varieties, where one variety has a lower preference ranking value, ($V_{i,r,s}$), but also a lower price, ($pps_{i,r,s}$).

Following the agri-business and marketing literature discussed in chapter 3, it is our intention to characterise the *domestic* representative variety as most favoured on each agent's varietal spectrum. Thus, the benchmark preference parameter values, $V_{i,r,s}$, are calibrated from sourced GTAP data expenditure shares by aggregate consumers in each market on domestic and competing imports of the differentiated commodity. The choice of expenditure share as a criteria for initial preference is based on the fact the domestic expenditure share is typically the largest.

Thus, the base preferences of the private household in region 's' are derived as:

$$VP_{i,r,s} = \frac{PPS_{i,r,s}.QDFPS_{i,r,s}}{\sum_{r}\left[PPS_{i,r,s}.QDFPS_{i,r,s}\right]} \qquad \text{(H.23)}$$

The level of expenditure on a given representative variety from 'r' is a proxy for each agent's degree of preference, where the domestic variety typically has the highest (trade share) preference ranking.

6.2 Incorporating Pro-Competitive Effects and Internal Scale Economies

In the following sections, a full description is given of the modified production structure for imperfectly competitive industries. This application draws on similar CGE studies (Hertel 1994, Harrison *et al.* 1995) combining strategic (Cournot) conjecture, with product differentiation and freedom of entry/exit of firms.[6] Mark-ups are therefore allowed to adjust endogenously, and vary according to the seller's market (i.e., domestic vs export).

6.2.1 Modelling Pro-Competitive Mark-up Effects

Due to a lack of data, it is assumed that all firms in the imperfectly competitive industry are symmetric (i.e. they have the same cost and technology structure and face the same demand curve). This assumption allows the modeller to treat each firm as a micro-scaled version of the industry which in turn allows the use of industry data. Secondly, there is a one to one relationship between firms and domestic product variants where the *representative variety* ‘j’ represents the *composite* (regional) industry variety ‘j’. The *composite* representative variety price will be equal to each firm’s product variant price, because each firm has the same cost and demand structure (identical prices) and an identical output share.

Unlike profit maximising behaviour in perfect competition, which yields marginal cost pricing (P=MC), imperfectly competitive industries have enough market power to mark-up output price over marginal cost, thus leading to short run profits. The freedom of entry/exit ensures zero profits in the long run and determines output per firm. Thus, assuming each of the N symmetric firms in the industry face the same profit function:

$$\Pi_i = PQ_i - TC_i \quad i \in mcomp \qquad \text{(M.1)}$$

where for each symmetric firm ‘i’:

Π_i – Firm profit.

P – Industry output price

Q_i – Output level

TC_i – Total costs

Under Cournot conjecture, each firm maximises profit through changes in output. Moreover, each symmetric firm anticipates, or conjectures, the output responses of rivals to changes in its output. Taking the derivative $(\partial \pi_i / \partial Q_i)$, and manipulating the resulting first order conditions gives the mark-up for each symmetric firm’s price over marginal cost.[7]

---

[6] Arguably, food processing sectors, typically regarded as oligopolistic, are more aware of quantity changes in perishables across bilateral routes vis-à-vis the alternative of price as a strategic variable.

[7] A full mathematical derivation of this result is given in appendix A.6.1.

$$MARK-UP_i = \frac{P - MC_i}{P} = \frac{\Omega_i}{N} \cdot \left|\frac{1}{\varepsilon}\right| \qquad \text{(M.2)}$$

where

$\Omega_i = \frac{\partial Z}{\partial Q_i}$ - changes in industry output (Z) with respect to changes in firm output (Q_i).

N - The number of firms in the industry.

$\left|\frac{1}{\varepsilon}\right|$ - The *absolute* value of the inverse elasticity of demand for the composite industry tradable.

Under the assumption of long run zero profits in each imperfectly competitive sector (P=ATC), and constant returns to scale in variable costs (see sections 6.2.3 to 6.2.5) a mark-up ($P-MC_i/P$) of 0.3, implies that the marginal cost (equal to average variable cost) and average fixed costs are 70% and 30% of the output price respectively.

Employing this equation, it is possible to characterise a range of oligopoly cases.[8] For example, the standard Cournot-Nash conjecture corresponds to $\Omega/N = 1/N$ (Francois, 1998) where each firm believes that other firms will not change output, and that industry output changes correspond with its own. Thus, in the case of a *symmetric* duopoly, if only one firm increases output 10%, then in percentage terms, industry output will only increase by half the amount of that firm's output change, i.e., 5%.

By contrast, a perfectly collusive oligopoly, where all symmetric firms in the industry react to changes by the i^{th} firm, implies that $\Omega/N = 1$. In this case, a 10% increase by a single firm 'i', will be matched equally by all other firms in the industry, such that industry output increases 10%. At the other extreme, a conjectural variation (Ω) value of zero, where an output change by one firm has no effect on the industry, corresponds to perfectly competitive, average cost pricing. Hence, a range of market structures can be classified by $0 \leq (\Omega/N) \leq 1$.

It is assumed that each of the 'n' symmetric domestic firms in region 'r' produces for both the domestic **and** export bilateral market routes. Thus, the inverse elasticity of demand for the representative variety of the domestic region ‘r’ is indexed over domestic (r=s) and foreign (r≠s) routes.

6.2.2 Domestic vs Foreign Mark-Ups

To derive the absolute value of the inverse elasticity of demand requires the derivation of the inverse demand function. The levels neo-Hotelling inverse domestic (r=s) demand for each representative variety ‘i’ by the private household in each region (the same result is applicable to the government and sectoral demands) is given as:[9]

$$PPS_{i,r,s} = \left[\frac{QDFPS_{i,r,s} ZPS_{i,r,s}^{-\sigma_i}}{QP_{i,s}} \right]^{-\frac{1}{\sigma_i}} PP_{i,s} \qquad \text{(M.3)}$$

The absolute value of the inverse elasticity of domestic demand is given as:

$$\left| \frac{1}{\varepsilon} \right|_{i,r,s} = -\frac{\partial PPS_{i,r,s}}{\partial QDFPS_{i,r,s}} \frac{QDFPS_{i,r,s}}{PPS_{i,r,s}} \qquad r = s \qquad \text{(M.4)}$$

Thus, from equation (M.3) this becomes:[10]

$$\left| \frac{1}{\varepsilon} \right|_{i,r,s} = SP_{i,r,s} \left[1 - \frac{1}{\sigma_i} \right] + \frac{1}{\sigma_i} \qquad r = s \qquad \text{(M.5)}$$

where $SP_{i,r,s}$ is the expenditure by private households in 's' on representative variety 'r' as a share of expenditure by private households in 's' on all representative varieties (r=s and r≠s), and σ_i is the elasticity of substitution between representative varieties from each region 'r'. Similar inverse elasticities may be derived for government final demands and each j'th firm's intermediate demands:

---

[8] See appendix A.6.2

[9] See appendix A.6.3.

[10] The derivation follows a similar approach to Harrison *et al.* (1995) and Blake (1998). A full mathematical derivation of this result is given in appendix A.6.4.

$$\left|\frac{1}{\varepsilon}\right|_{i,r,s} = SG_{i,r,s}\left[1-\frac{1}{\sigma_i}\right]+\frac{1}{\sigma_i} \qquad r=s \tag{M.6}$$

$$\left|\frac{1}{\varepsilon}\right|_{i,r,j,s} = SF_{i,r,j,s}\left[1-\frac{1}{\sigma_i}\right]+\frac{1}{\sigma_i} \qquad r=s$$

$$i \in mcomp \qquad j \in prod \qquad r,s \in reg \tag{M.7}$$

To minimise the burden of model size and computational cost, it is assumed that the inverse price elasticity on final and intermediate purchases by agents is the same. Thus, the elasticity expressions (M.5), (M.6) and (M.7) are aggregated over all agents in ‘s’. Since the elasticity of substitution in the Global Trade Analysis Project (GTAP) database is equal for all agents in all regions, σ_i does not change in the aggregate domestic inverse elasticity expression. The aggregate (regional) expenditure share is expressed as:

$$AGGSHR_{i,r,s} = \frac{VPAS_{i,r,s} + VGAS_{i,r,s} + \sum_{j\in prod} VFAS_{i,r,j,s}}{\sum_{r\in reg} VPAS_{i,r,s} + \sum_{r\in reg} VGAS_{i,r,s} + \sum_{r\in reg}\sum_{j\in prod} VFAS_{i,r,j,s}} \tag{M.8}$$

$$i \in mcomp \qquad j \in prod \qquad r,s \in reg$$

where $AGGSHR_{i,r,s}$ is the expenditure by all agents in domestic region 's' on representative variety 'r' as a share of expenditure by all agents in 's' on *all* representative varieties of 'r'.

Using the aggregate share and substituting the *domestic* inverse price elasticity of demand into equation (M.2) gives the *levels* mark-up by symmetric firms on sales of representative varieties to the domestic market (r=s):

$$MARKUP_{i,r,s} = \frac{\Omega_{i,r}}{N_{i,r}} \left|\frac{1}{\varepsilon}\right|_{i,r,s} = \frac{\Omega_{i,r}}{N_{i,r}} \left[AGGSHR_{i,r,s} \left[1 - \frac{1}{\sigma_i} \right] + \frac{1}{\sigma_i} \right] \qquad \text{(M.9)}$$

As well as changes in the conjectural variation ratio ($\Omega_{i,r}/N_{i,r}$), changes in expenditure shares also affect the mark-up price. Thus, increases (decreases) in the market share of a single representative variety 'r', will increase (decrease) the market power of those firms selling in region 'r' and thus increase (decrease) their mark-ups.

To derive the mark-up on *export* sales of each symmetric firm in 'r' to region 's' (r≠s), one must derive the inverse elasticity of demand for exports along each bilateral route (r≠s) of 'r'. Following Blake (1999), and using GTAP model notation (see glossary), the inverse elasticity of demand for exports of 'r' is given as:

$$\left|\frac{1}{\varepsilon}\right|^{M}_{i,r,s} = -\frac{\partial PM_{i,r}}{\partial QS_{i,r,s}} \frac{QS_{i,r,s}}{PM_{i,r}} = \left[\frac{\partial PM_{i,r}}{\partial PMS_{i,r,s}} \frac{PMS_{i,r,s}}{PM_{i,r}} \right] \times \left[- \left[\frac{\partial PMS_{i,r,s}}{\partial M_{i,r,s}} \frac{M_{i,r,s}}{PMS_{i,r,s}} \right] \right] \times \left[\frac{\partial M_{i,r}}{\partial QS_{i,r,s}} \frac{QS_{i,r,s}}{M_{i,r}} \right] \qquad \text{(M.10)}$$

$$M_{i,r,s} = QDFPS_{i,r,s} + QDFGS_{i,r,s} + \sum_{j \in prod} QDFFS_{i,r,j,s} \qquad \text{(M.11)}$$

where the export market price ($PM_{i,r}$) is a function of the import market price ($PMS_{i,r,s}$) which is determined by changes in the aggregate import quantity ($M_{i,r,s}$), itself reliant on changes in export quantities ($QS_{i,r,s}$) of the (composite) representative variety.

In the model, the market clearing accounting conventions of the model impose the constraint that the export and import quantities along a given bilateral trade route are equal, such that:

$$\frac{\partial M_{i,r,s}}{\partial QS_{i,r,s}} \frac{QS_{i,r,s}}{M_{i,r,s}} = 1 \qquad \text{(M.12)}$$

The second expression on the right hand side of (M.10) is interpreted as the inverse elasticity of demand for imports (r≠s) and is derived as:

$$\left|\frac{1}{\varepsilon}\right|^{M}_{i,r,s} = -\frac{\partial PMS_{i,r,s}}{\partial M_{i,r,s}}\frac{M_{i,r,s}}{PMS_{i,r,s}} = AGGSHR_{i,r,s}\left[1-\frac{1}{\sigma_i}\right]+\frac{1}{\sigma_i} \qquad r \neq s$$

(M.13)

Finally, the elasticity of changes in export prices in 'r' with respect to changes in import prices in 's' is given as:[11]

$$\frac{\partial PM_{i,r}}{\partial PMS_{i,r,s}}\frac{PMS_{i,r,s}}{PM_{i,r}} = \frac{PT.TX_{i,r}TXS_{i,r,s}}{PM_{i,r}}+1 \qquad \text{(M.14)}$$

Combining each of these terms into the inverse elasticity of demand for exports of region 'r' (r≠s) and substituting into expression (M.2) gives the *levels* mark-up on export sales:

$$MARKUP_{i,r,s} = \frac{\Omega_{i,r}}{N_{i,r}}\left[AGGSHR_{i,r,s}\left[1-\frac{1}{\sigma_i}\right]+\frac{1}{\sigma_i}\right]\left[\frac{PT.TX_{i,r}TXS_{i,r,s}}{PM_{i,r}}+1\right]$$

$$r \neq s \qquad i \in mcomp \qquad r,s \in reg$$

(M.15)

The presence of a bilateral ($TXS_{i,r,s}$) and generic ($TX_{i,r}$) subsidy (tax) on exports sales affords producers in 'r' increased (reduced) market power which in turn may increase (decrease) the export sales mark-up.[12] Increases in the global transport price, PT, lifts

[11] A full mathematical derivation of this result is given in appendix A.6.5.

[12] In the standard model, export taxes are treated as the ratio of market prices to world prices (free on board):

Tax/subsidy = $PM_{i,r}/PFOB_{i,r,s}$

or similarly it is possible to use value ratios from the data:

the sales price of a given region's exports thus increasing the mark-up. A relative increase in the composite market price of exports, $PM_{i,r}$, leads to a fall in the mark-up. Finally, in the model, both domestic and foreign mark-ups are declared as levels variables which are automatically linearised by the software provided with the GTAP package (General Equilibrium Modelling PACKage – GEMPACK).

6.2.3 Returns to Scale and Market Structure in CGE

In section 2.1.3, the importance of constant returns to scale was discussed with reference to the perfectly competitive market framework, where firms take input and output prices as given, resulting in the pricing rule:

$$P = MC = (AC) \qquad \text{(M.16)}$$

In our application, this standard structure is maintained in the primary agricultural, primary resource and capital goods manufacturing sectors of the model, whereas the remaining sectors (food processing, manufacturing, services) are classified as imperfectly competitive. Moreover, marginal cost pricing is not a characteristic of imperfectly competitive market structures, which gives the modeller an opportunity to incorporate a different treatment of costs.

In our application, each imperfectly competitive industry exhibits an increasing returns to scale technology (IRS) at the firm level. The problem with imposing increasing returns to scale in the model is that one loses the linear homogeneity property which is

---

$$TXS_{i,r,s} = VSMD_{i,r,s} / VSWD_{i,r,s}$$

Thus if the power of the *ad valorem* wedge TXS > 1 then we have a subsidy and vice versa
From the data we do not know *a priori* whether it is the route specific ($TXS_{i,r,s}$) or generic ($TX_{i,r}$) tax/subsidy which accounts more for the wedge between market and free on board values of exports. The presence of an export tax (subsidy) on producers from region 'r' reduces (increases) market power by increasing (decreasing) the world price of r's exports and thus reduces (increases) the mark-up. The opposite is the case for an export subsidy. Thus, in levels terms, both taxes/subsidies are declared as a single variable given by the formula:

$$TL_{i,r,s} = VSMD_{i,r,s} / VSWD_{i,r,s}$$

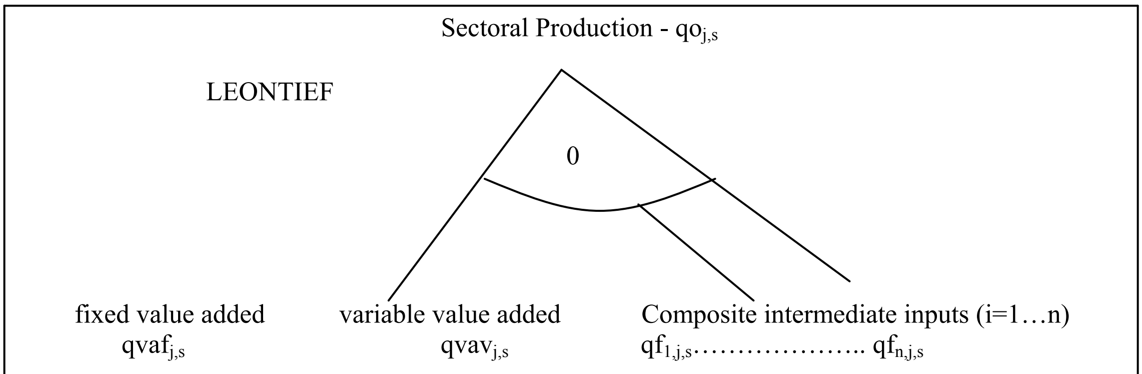
If the size of the tax/subsidy wedge is zero, then $TL_{i,r,s} = 1$. Similarly, if a tax (subsidy) is levied on a particular trade flow, $VSMD_{i,r,s} < (>) VSWD_{i,r,s}$, which using the formula gives a value of $TL_{i,r,s}$ less (greater) than 1. Thus, from the levels mark-up ($r \neq s$) in the chapter, a subsidy produces a higher mark-up than a tax.

required for consistent aggregation in the nesting structure (see section 2.6.1). To overcome this problem, an alternative characterisation of IRS is employed which follows other similar treatments in the CGE literature (Krugman, 1979, Harris, 1984; Harrison *et al*., 1995; Swaminathan and Hertel, 1996). A full discussion of our framework is provided in sub-sections 6.2.4 to 6.2.6.

6.2.4 The Structure of Costs in Imperfectly Competitive Industries

In imperfectly competitive sectors, total long run costs are subdivided into a variable and fixed cost component, where the latter are interpreted as the advertising, research and development costs of product differentiation. Variable costs are composed of both value added (primary) and intermediate input costs and are subject to CRS, which implies that average variable and marginal cost are equal. Fixed costs are assumed to consist entirely of value added costs, which implies that the fixed overheads associated with the production of new products, such as the salaries of engineers and marketing staff engaged in research and development (R&D), are solely primary factor costs. Finally, it is assumed that primary factor intensities are the same in the fixed and variable cost components of value added.

These assumptions are open to criticism. In the first case a lack of information exists on the composition of fixed costs at the specific level of sectoral and regional aggregation in the model. Moreover, data limitations pertaining to capital-labour intensities across fixed and variable costs in all regions also require a simplifying assumption. Hence, the position here is to adopt sensible *ad hoc* rules which are transparent and lend themselves to easy analysis and simple interpretation.



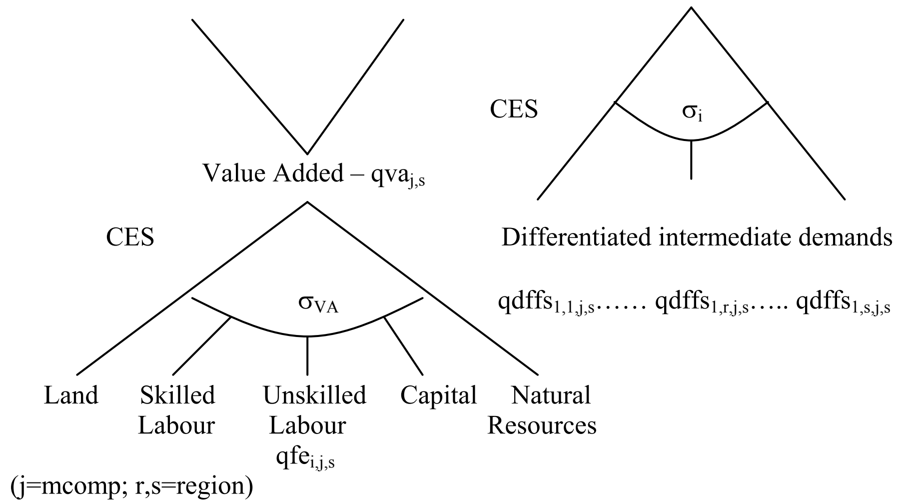


Figure 6.5: A Modified Production Structure

The production nest of each imperfectly competitive sector 'j' is given in figure 6.5. Homogeneous commodity demands ($qhmfs_{n,r,j,s}$) are maintained within the standard Armington framework which is not shown in figure 6.5, although a similar structure is presented in figure 6.4 for private household homogeneous demands. Note that the *perfectly competitive* nest structure (not shown here) has no decomposition of value added cost, although it does exhibit the same intermediate input demand structure (i.e., homogeneous and differentiated demands).

Total value added costs are decomposed as:

$$VA_{j,s} = VAV_{j,s} + VAF_{j,s} \qquad j \in mcomp \quad s \in reg \tag{M.17}$$

where $VAV_{j,s}$ and $VAF_{j,s}$ are the total value of variable and fixed value added demands, respectively. Since all fixed costs are value added, $VAF_{j,s}$ is in effect equal to total sectoral fixed costs.

Referring back to section 6.2.1, under the assumption of long run zero profit (PS=ATC), the mark-up shows fixed cost (and variable cost) per unit as a proportion of output price. Hence, in *total value* terms, total benchmark sectoral fixed costs ($VAF_{j,s}$) are calibrated to the composite mark-up fraction of sectoral sales, where the mark-up values in each sector enables each firm to recoup the costs associated with their R&D and marketing activities:

$$VAF_{j,s} = MRKUP_{j,s} VOA_{j,s} \qquad \text{(M.18)}$$

The composite mark-up (M.19) is a trade share ($TRSHR_{j,r,s}$) weighted average of each of the bilateral mark-ups (domestic and foreign) derived in (M.9) and (M.15):

$$\begin{aligned} MRKUP_{j,s} &= \sum_{r \in reg} \left[TRSHR_{j,r,s} MARKUP_{j,r,s} \right] \\ TRSHR_{j,r,s} &= \frac{VSMD_{j,r,s}}{\sum_{s \in reg} VSMD_{j,r,s}} \end{aligned} \qquad \text{(M.19)}$$

where $VSMD_{j,r,s}$ is the value of sales of imperfectly competitive industry 'j', from 'r' to 's'. Thus, the larger the share, the more emphasis is afforded to that particular bilateral mark-up, ($MARK\text{-}UP_{j,r,s}$). Finally, the proportion of value added going to variable costs is deduced by rearranging (M.17).

Following Hertel and Swaminathan (1996), it is assumed that the quantity of fixed value added ($qvaf_{j,s}$) is proportional to the level of variety (differentiated products) offered by the industry. Thus, if the number of varieties, $n_{j,s}$ changes, then the quantity of fixed sectoral value added changes in proportion. This relationship is summarised by:

$$qvaf_{j,s} = n_{j,s} \qquad \text{(M.20)}$$

As a result of constant returns to scale in variable costs, changes in the demand for variable value added, $qvav_{j,s}$, are proportional to changes in industry output, $qo_{j,s}$. Thus, under the Leontief specification in the top nest of figure 6.5, these demands are given as:

$$qvav_{j,s} = qo_{j,s} \tag{M.21}$$

Linearising (M.17) with respect to quantities gives the percentage change market clearing equation for value added demands ($qva_{j,s}$) in imperfectly competitive industries:

$$VA_{j,s}qva_{j,s} = VAV_{j,s}qvav_{j,s} + VAF_{j,s}qvaf_{j,s} \tag{M.22}$$

Total sectoral variable costs ($VC_{j,s}$) are a composite of both variable value added ($VAV_{j,s}$) and intermediate input costs:

$$VC_{j,s} = \sum_{i \in trad} VFA_{i,j,s} + VAV_{j,s} \tag{M.23}$$

where imperfectly competitive industry 'j' demands both homogeneous and differentiated (representative varieties) tradables, 'i'. Moreover, to maintain the constant returns to scale assumption in *total* variable costs, the percentage change in intermediate input costs is also proportional to changes in output such that (see figure 6.5):

$$\begin{aligned} &qf_{i,j,s} = qo_{j,s} \\ &i \in trad \end{aligned} \tag{M.24}$$

Finally, total sales revenues ($VOA_{j,s}$), which are equal to total costs after long run entry/exit of firms, are defined as:

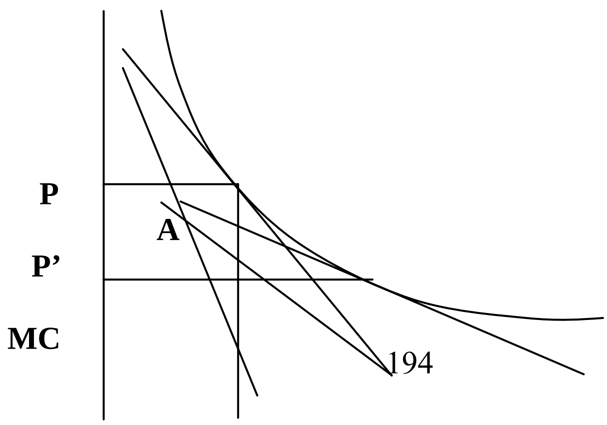
$$VOA_{j,s} = \sum_{i \in trad} VFA_{i,j,s} + VAV_{j,s} + VAF_{j,s} \tag{M.25}$$

6.2.5 A Schematic Representation of Imperfectly Competitive Markets

To help understand the algebraic characterisation of imperfectly competitive behaviour by firms given in section 6.2.6, a *partial equilibrium* representation of a representative symmetric firm (i.e. identical cost and demand conditions) in the industry is presented in figure 6.6, where marginal costs (MC) are represented as perfectly horizontal (CRS), and are equal to average variable cost. Average *total* costs are assumed to fall, with fixed costs being spread over a higher level of firm output and long run zero profits are assumed (P=ATC). At the initial equilibrium, there are N symmetric firms charging price P and producing output Q. Thus, fixed costs A + B are exactly covered by the mark-up revenues of output price 'P' over MC.

For simplicity, assume that the industry 'j' in the figure undergoes sectoral liberalisation on its trade with partner countries. In the absence of general equilibrium effects on factor and intermediate input costs, the marginal and average cost curves remain the same for each symmetric firm. The reduction in the level of protection for industry 'j' results in a fall in the output price, short run losses and an exodus of less efficient firms from the industry with remaining firms sliding down their average cost curves (IRS). This leads to a fall in the long run zero profit output price and a reduction in the mark-up.

The reduction in the mark-up results, *ceteris paribus* (see equation (M.2)), in an increase in the demand elasticity which implies that MC will cut MR' from below at a higher level of per firm output (see figure 6.6). The increase in the elasticity of demand is represented as a rotation of as well as a shift in the AR (demand) curve to the new point of equilibrium, P' and Q'. This reduction in the size of the price distortion to a level closer to that of the perfectly competitive position (P=MC) is known in the literature as the *pro-competitive* effect (Hertel 1994; Vousden, 1990).



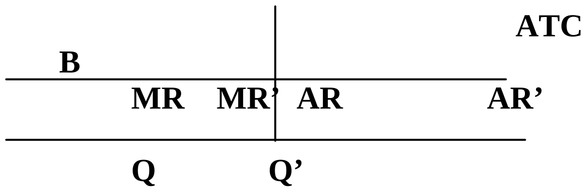


Figure 6.6 : Monopolistic firm behaviour with changing mark-up.
Source : Harrison *et al.,* (1995)

In a *general equilibrium* context, the *final* level of per firm output is influenced much by the size of the change in the elasticity of demand (and thus the mark-up), movements in the cost structure of each firm and changes in the size of the industry. Thus, given that this exposition assumes that general equilibrium cost conditions remain constant, it is not necessarily the case that increases (decreases) in output per firm will be accompanied by falls (rises) in the number of firms (i.e., a rationalisation of the industry). Indeed, from the discussion in section 3.2.2.1, increases in varietal diversity ($n_{j,r}$) in industry 'j' are associated, *ceteris paribus*, with falls in the mark-up (see equations (M.9) and (M.15)), which implies increases in the elasticity of demand for industry 'j' output. Clearly, for this to be the case, industry output must also increase (see chapter 7).

6.2.6 The Relationship between Mark-Ups, Firm Output and the Structure of Costs

This section presents an algebraic exposition of the imperfectly competitive mechanisms used to characterise the relationships between mark-ups, output per firm and cost structure in the modified GTAP model. Thus, having defined the composition and nature of the costs of the firm in section 6.2.4, it is now possible to determine the percentage change in sectoral *total* and *variable* costs.

Since variable costs for each firm are subject to a constant returns to scale (CRS) technology, with fixed input prices total variable costs increase proportionately with output. Thus, *average* variable costs are only a function of changes in value added and intermediate input prices.

However, changes in a firm's average *total* cost (which is also output price under zero profits) can arise from: a) change in a firm's output given constant prices of all inputs and b) change in one or more of the input prices, at constant firm output level. Hence, the change in average total cost that is attributable only to changes in all input prices, *holding the level of output per representative firm constant*, is the *scale-constant average total cost* ($scatc_{j,s}$). Totally differentiating (M.25) *with respect to prices only* yields an index of average total costs at constant scale:

$$VOA_{j,s} scatc_{j,s} = \sum_{i \in trad} VFA_{i,j,s} pf_{i,j,s} + VAV_{j,s} pva_{j,s} + VAF_{j,s} pva_{j,s} \tag{M.26}$$

Since each firm is a micro scaled version of the industry, *changes* in sectoral and firm average costs will be equal.

In this model structure, reference is made to Hertel (1994) where it is assumed that,

> *"average total cost at constant scale will change at the same rate as average variable cost (which equals marginal cost)"(pp401).*

To implement this assumption under CRS implies that the price of the fixed value added factor is constant such that:

$$VAF_{j,s} pva_{j,s} = 0 \tag{M.27}$$

where percentage changes in scale-constant average total costs and average variable costs are equal:

$$scatc_{j,s} = avc_{j,s} \tag{M.28}$$

The *scale effect* (i.e., increasing returns to scale) in the model arises from the decline in fixed costs, ($VAF_{j,s}$) with increases in output per firm. Thus, sectoral average total costs ($atc_{j,s}$) change with input prices *and* the scale of firm's output. It is this effect which characterises *internal* economies of scale (IRS).[13] In the model, a composite firm output variable ($qof_{j,s}$) is introduced, where under the assumption of symmetry, changes in composite firm output are representative of changes in each firm's output. The change in average total cost is:

$$VOA_{j,s} atc_{j,s} = \sum_{i \in trad} VFA_{i,j,r} pf_{i,j,r} + VAV_{j,s} pva_{j,s} + VAF_{j,s} pva_{j,s} - VAF_{j,s} qof_{j,s} \tag{M.29}$$

Thus, if composite output per firm ($qof_{j,s}$) increases, a rationalisation of the industry takes place where each firm *slides down its average total cost curve* (due to the negative sign in front of $VAF_{j,s}$). The cost of production per unit of output now falls as fixed costs are being spread over higher levels of output.

Substituting the expression for scale constant average total costs (M.26) into (M.29), implementing the relationship in (M.28) and assuming zero profits after long run entry and exit of firms, gives the long run zero profit expression, where output price ($ps_{j,s}$) must fall to re-equate the new lower per unit costs of production:

$$VOA_{j,s} ps_{j,s} = VOA_{j,s} avc_{j,s} - VAF_{j,s} qof_{j,s} \tag{M.30}$$

The role of the mark-up in expression (M.30) becomes clear in light of the assumption made in expression (M.28). From equation (M.2), the composite Cournot mark-up may be written as:

$$MRKUP_{j,s} = \frac{PS_{j,s} - AVC_{j,s}}{PS_{j,s}} \tag{M.31}$$

where average variable costs are equal to marginal costs due to the assumption of constant returns to scale. Rearranging in terms of $PS_{j,s}$:

[13] This is the usual approach adopted by imperfectly competitive applications (Krugman, 1979; Harris,

$$PS_{j,s} = \frac{AVC_{j,s}}{\left[1 - MRKUP_{j,s}\right]} \qquad (M.32)$$

and linearising gives:

$$ps_{j,s} = avc_{j,s} + \left\{\frac{MRKUP_{j,s}}{\left[1 - MRKUP_{j,s}\right]}\right\} mp_{j,s} \qquad (M.33)$$

The effect of the regional weighted mark-up on scale effects becomes clear with reference to the zero profit expression (M.30). If $mp_{j,s}$ rises such that $ps_{j,s}$ rises more (falls less) relative to $avc_{j,s}$, *ceteris paribus,* short-run profit will signal an increased number of firms into the industry which in turn will lead to a fall in output per (composite) firm, $qof_{j,s}$.

In levels form, industry output ($QO_{j,s}$) is the number of firms ($N_{j,s}$) multiplied by composite firm output ($QOF_{j,s}$). In linear terms:

$$qo_{j,s} = qof_{j,s} + n_{j,s} \qquad (M.34)$$

Industry output ($qo_{j,s}$) is calculated as a market clearing composite of domestic sales, exports and transport services to the global shipping sector. Composite firm output ($qof_{j,s}$) is controlled by changes in the aggregate (weighted) regional mark-up and the zero profit expression. Thus, the change in the domestic number of firms ($n_{j,s}$) is calculated as the residual to restore sectoral output market clearing.

6.3 Changes to Model Structure to accommodate Non-Nested Differentiated Preferences

Figure 6.7 shows the distribution of sales under the modified model framework from region ‘r’ to ‘s’ for both domestic (r=s) and foreign (r≠s) tradables. Exports and imports

1984; Lancaster, 1991; Hertel, 1994; Francois *et al.*, 1995).

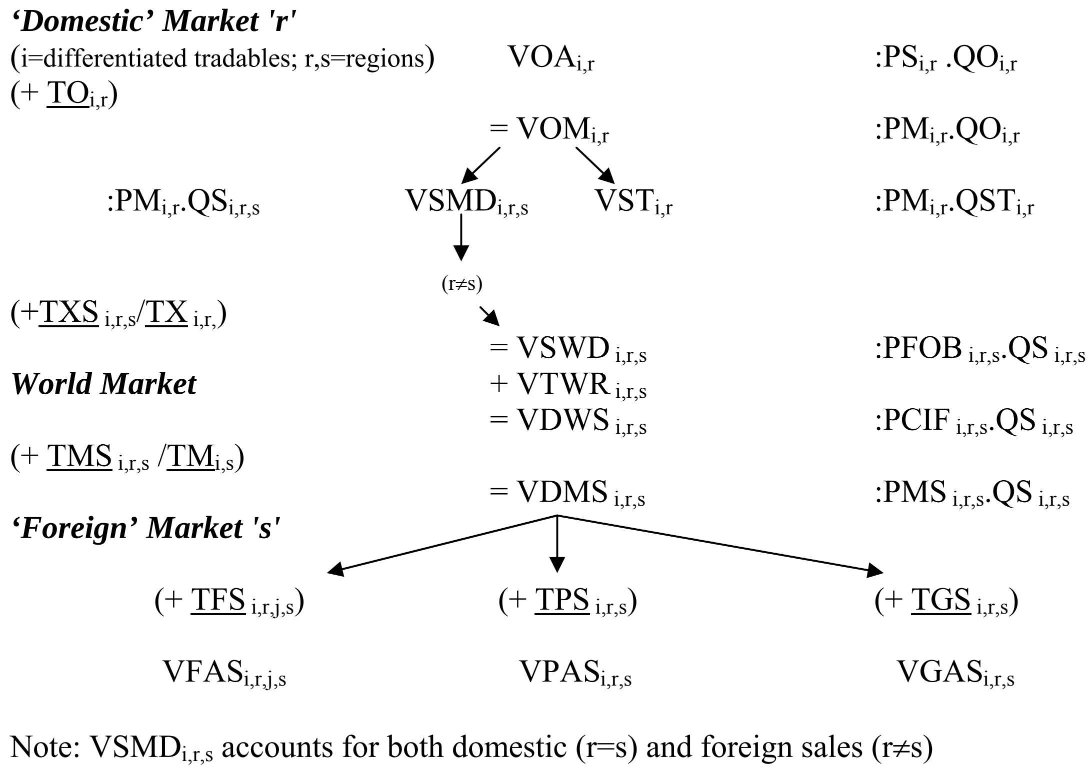


Figure 6.7 Distribution of Sales in the modified Model Framework

are renamed as 'sales' and 'demands' respectively. Thus, $VXMD_{i,r,s}$, $VXWD_{i,r,s}$, $VIWS_{i,r,s}$ and $VIMS_{i,r,s}$ become $VSMD_{i,r,s}$, $VSWD_{i,r,s}$, $VDWS_{i,r,s}$ and $VDMS_{i,r,s}$ respectively, and the value of domestic sales $VDM_{i,s}$ is now equal to $VSMD_{i,s,s}$. Finally, the entries on the right hand side of figure 6.7 are the price and quantity indices for each value in the data.

The values of export demands ($VDMS_{i,r,s}$) by region 's' of homogeneous and differentiated products from country 'r' are disaggregated by agent, in region 's' using Armington *bilateral* (including r=s) market clearing equations for differentiated (MS.1) and homogeneous (MS.2) tradables respectively where *all* demands are valued at the same market price $PMS_{i,r,s}$ and $qs_{i,r,s}$ is the percentage change in bilateral exports from region 'r' to 's':

$$VDMS_{i,r,s}.qs_{i,r,s} = \qquad i \in mcomp$$
$$VPMS_{i,r,s}.qdfps_{i,r,s} + VGMS_{i,r,s}.qdfgs_{i,r,s} + VFMS_{i,r,j,s}.qdffs_{i,r,j,s} \qquad \text{(MS.1)}$$

$$VDMS_{i,r,s}.qs_{i,r,s} = \quad i \in homog$$
$$VPMS_{i,r,s}.qhmps_{i,r,s} + VGMS_{i,r,s}.qhmgs_{i,r,s} + VFMS_{i,r,j,s}.qhmfs_{i,r,j,s} \quad \text{(MS.2)}$$

$VPMS_{i,r,s}$ - The market value of final bilateral import purchases by the private household

$VGMS_{i,r,s}$ - The market value of final bilateral import purchases by the government household

$VFMS_{i,r,j,s}$ - The market value of intermediate bilateral import purchases by firms

Reference to equations (MS.1) and (MS.2) shows that agents demand both homogenous and differentiated products. This is reflected in the terminology, where, for example, intermediate input demands for homogeneous and differentiated commodities by firms are separated into Q**HM**$FS_{i,r,j,s}$ and Q**DF**$FS_{i,r,j,s}$. The same is the case for corresponding private household (Q**HM**$PS_{i,r,s}$ and Q**DF**$PS_{i,r,s}$) and government final demands (Q**HM**$GS_{i,r,s}$ and Q**DF**$GS_{i,r,s}$).

Adding bilateral taxes/subsidies ($TPS_{i,r,s}$, $TGS_{i,r,s}$, $TFS_{i,r,j,s}$) gives the values of demands at *agents* prices ($PPS_{i,r,s}$, $PGS_{i,r,s}$, $PFS_{i,r,j,s}$). These flows are summarised in figure 6.8. For *homogeneous* commodities, the two level nested Armington framework is maintained. Thus, foreign demands (r≠s) by agents in 's' are aggregated in the lower Armington nest into composite import demands by private household, government household and firms ($QPM_{i,s}$, $QGM_{i,s}$, $QFM_{i,j,s}$ respectively). Similarly, agents' composite *homogeneous* import prices ($PPM_{i,s}$, $PGM_{i,s}$, $PFM_{i,j,s}$), which enter the upper level Armington demands, are derived as weighted averages of agents' bilateral prices. In the upper Armington nest, foreign composite demands, (i,s) compete with each agent's domestic substitute, (i,s,s), as shown in figure 6.4 above.

<u>Agents' Prices:</u>

Private Household	$VPAS_{i,r,s}$	i=homog	$QHMPS_{i,r,s}.PPS_{i,r,s}$

		i=mcomp	$QDFPS_{i,r,s}.PPS_{i,r,s}$
Government Household	$VGAS_{i,r,s}$	i=homog	$QHMGS_{i,r,s}.PGS_{i,r,s}$
		i=mcomp	$QDFGS_{i,r,s}.PGS_{i,r,s}$
Firms	$VFAS_{i,r,j,s}$	i=homog	$QHMFS_{i,r,j,s}.PFS_{i,r,j,s}$
		i=mcomp	$QDFFS_{i,r,j,s}.PFS_{i,r,j,s}$
Market Prices:			
Private Household	$VPMS_{i,r,s}$	i=homog	$QHMPS_{i,r,s}.PMS_{i,r,s}$
		i=mcomp	$QDFPS_{i,r,s}.PMS_{i,r,s}$
Government Household	$VGMS_{i,r,s}$	i=homog	$QHMGS_{i,r,s}.PMS_{i,r,s}$
		i=mcomp	$QDFGS_{i,r,s}.PMS_{i,r,s}$
Firms	$VFMS_{i,r,j,s}$	i=homog	$QHMFS_{i,r,j,s}.PMS_{i,r,j,s}$
		i=mcomp	$QDFFS_{i,r,j,s}.PMS_{i,r,j,s}$

Figure 6.8 A Summary of Agent and Market Values in the Modified Model

6.4 Data Requirements

As a result of the modifications to the demand structure, changes must also be made to the GTAP data base. The first modification is with respect to the sets in which the indices in the model domain are defined. To implement imperfect competition requires the addition of three extra sets. Tradable commodities are now subdivided into perfectly competitive homogeneous (PCOMP) and imperfectly competitive (MCOMP) differentiated products/industries. Moreover, it is assumed that the *non-tradable* capital goods producing sector is perfectly competitive such that the intersection of the subsets PCOMP and CGDS yields the new set PCGDS.

The second element of data manipulation pertains to the parameters file. As there are now two main subsets of the set of *tradables*, this requires the declaration of a separate elasticity of substitution parameter. Thus, $ESUBD_i$ and $ESUBM_i$ now index the set PCOMP_COMM only, and a new parameter, $SIGMA_i$ pertains to the set MCOMP_COMM.

Changes must also be made to the format of the data. Thus, the first stage of the standard GTAP data transformation involves the sourcing of aggregate imports directly to agents. Since the full Armington structure is maintained for homogeneous goods, the sourcing of aggregate imports could just be applied to differentiated products only.

However, sourcing all imports to agents allows the modeller to choose imperfectly competitive characterisations for *any sector* in the model without the need to rerun the data transformation program.

Thus, defining the variable:

$$MSHRS_{i,r,s} = \frac{VIMS_{i,r,s}}{\sum_{r \in reg} VIMS_{i,r,s}} \qquad (D.1)$$

$$i \in trad \qquad r,s \in reg$$

gives the share of export source 'r' in composite imports of 'i' to region 's' valued at market prices. Having derived each share value, it is possible to multiply each agent's imports of the composite 'i' from the standard data ($VIPM_{i,s}$, $VIGM_{i,s}$, $VIFM_{i,j,s}$) to yield sourced purchases of imports of 'i' from 'r' by each agent in 's' at market price, ($VPMS_{i,r,s}$, $VGMS_{i,r,s}$, $VFMS_{i,r,j,s}$). Where r=s, each agent's purchases of domestic good 'i' at market prices ($VDPM_{i,s}$, $VDGM_{i,s}$, $VDFM_{i,s}$) become the domestic values of sourced purchases of imports from the same region 's' ($VPMS_{i,s,s}$, $VGMS_{i,s,s}$, $VFMS_{i,s,s}$).

The second part of the data transformation is to calculate the same sourced market price demands at *agent's prices.* This is accomplished by calculating an *average tax* based on the ratio of total standard data purchases by each agent at agent's and market prices. For example, the average tax on private household demand is:

$$TP_{i,s} = \left[\frac{VIPA_{i,s} + VDPA_{i,s}}{VIPM_{i,s} + VDPM_{i,s}} \right] \qquad (D.2)$$

$$i \in trad \qquad s \in reg$$

Having calculated the average tax rates, one simply multiplies the sourced *market* demands by region of origin 'r' at market prices derived above, by the average tax for each agent (i.e. private households, government, firms) to derive the same flows at *agent's* prices. Thus, the two steps above remove the distinction between composite import demands and domestic demands and replaces these with a single value flow which sources purchases from 's' by region of origin 'r' (including r=s).

As the monopolistically competitive version of the model is now larger in dimensions than its standard perfectly competitive counterpart, this hampers the solution process of the model. In order to ease the burden on computational facility, *model condensation* is necessary before implementation of any closure application. There are several operations within GEMPACK which are used to reduce model size. For further details, see GEMPACK user documentation (Harrison and Pearson, 1994).

6.5 A Stylised Numerical Example

An effective way of understanding the model structure is to provide a simple example and examine changes in the endogenous variables of interest. The data aggregation is a three region, three tradable commodity example. The tradables are: Agriculture (AGR); Manufacturing (MANU); and Services (SERVS). The three regions are the European Union (EU), The United States of America (US) and the Rest of the World (ROW).

The model structure employs the imperfectly competitive mechanisms discussed above, where manufacturing is imperfectly competitive, and agriculture and service sectors are perfectly competitive. In the manufacturing sector, the values of the preference heterogeneity (γ_i) and elasticity of substitution (σ_i) parameters are set at 0.75 and 6 respectively. Moreover, the number of firms (N=3) in each region's manufacturing sector is chosen arbitrarily, and the conjecture of each firms' mark-up follows the traditional Cournot conjecture (i.e., $\Omega_{i,r}/N_{i,r} = 1/ N_{i,r}$). The calibrated base value of the mark-ups are presented in table 6.1.

Region	EU	US	ROW
EU	0.292	0.129	0.146
US	0.128	0.282	0.138
ROW	0.174	0.193	0.302

Table 6.1: Bilateral Manufacturing Mark-ups in the Benchmark data

The choice of scenario shock is to simulate the complete abolition of the EU import tariff on USA agricultural exports. In the model structure, tariffs are represented as *ad* *valorem* rates where, for example, the *power* of the *ad valorem* import tariff is given as the ratio of market value ($VDMS_{i,r,s}$) to world value ($VDWS_{i,r,s}$) of imports:

$$TMS_{i,r,s} = \frac{VDMS_{i,r,s}}{VDWS_{i,r,s}} \qquad \text{(N.1)}$$

A percentage reduction in $tms_{agr,us,eu}$ of –20.72% is required to eliminate the distortion between market and world prices along this particular bilateral route. In other words, the EU is liberalising its agriculture sector unilaterally to the US alone. A brief summary of the main results is presented in the subsections below.

6.5.1 Domestic Resource Reallocations

In the absence of other exogenous tariff shocks, the elimination the EU import tariff on US agricultural exports leads to a reduction of the EU domestic market import price, $pms_{agr,us,eu}$, and thus agents' prices, $pfs_{agr,us,j,eu}$, $pps_{agr,us,eu}$ and $pgs_{agr,us,eu}$ all fall by the same percentage.

The effect of this relative price fall leads to a substitution effect in favour of US agricultural exports by all agents in the EU (i.e., $qhmps_{agr,us,eu}$, $qhmgs_{agr,us,eu}$ and $qhmfs_{agr,us,j,eu}$ all increase 200%), which in turn displaces domestic goods demands in the EU. This displacement of demands results in a contraction of the EU agriculture industry ($qo_{agr,eu}$ = -0.97%) and therefore a fall in the Leontief composite intermediate input ($qf_{i,agr,eu}$) and value added ($qva_{agr,eu}$) demands.

In this aggregation, land is characterised as "sluggish" and is only purchased by a single aggregated agriculture sector in each region. Thus, land is effectively sectorally 'trapped' which implies that relative factor price movements have no effect on location (i.e. $qoes_{land,agr,eu} = qfe_{land,agr,eu} = 0$). In larger aggregations, the responsiveness of the agriculture sector in each of the regions is governed by both the elasticity of substitution for value added (σ^{VA}_{agr}) and the elasticity of transformation (σ^{T}_{land}). Thus, if σ^{VA}_{agr} is large, then agricultural supply response will be greater as farms in different sectors are more capable of substituting labour and capital for land, although this may be dampened by land supply restrictions governed by the transformation elasticity.

Thus, a sensitivity analysis of σ^{T}_{land} and σ^{VA}_{agr} can vary the degree of output response in agriculture and thus the extent of resource reallocations.

	EU	US	ROW
$\mathbf{n_{manu,r}}$	0.3637	-0.9248	0.2149
$\mathbf{qof_{manu,r}}$	0.1443	-0.3836	0.1160
$\mathbf{mp_{manu,r}}$	-0.1050	0.2842	-0.0823

Table 6.2: Pro-competitive and scale effects from the base data (% changes)

Contraction of the EU agriculture sector releases resources to other sectors of the economy such that output in manufacturing and services in the EU increases, with the largest diversions of resources going to EU manufacturing ($qo_{manu,eu}$ = 0.51%) due to *pro-competitive* effects (see table 6.2). Indeed, the fall in the EU regional mark-up ($mp_{manu,eu}$) results in *scale effects* ($qof_{manu,eu}$), as well as increases in the number of firms ($n_{manu,eu}$).

As primary factors are immobile *between regions*, factor returns are only equated across sectors. In the EU, the reallocation of resources to other sectors leads to increased factor rewards to labour ($ps_{labour,eu}$ = 0.45%) and capital ($ps_{capital,eu}$ = 0.45%). In this aggregation, the land resource which is released due to the contraction of EU agriculture, cannot be employed in other sectors, so land rents in the EU fall ($ps_{land,eu}$ = -0.73%).

Expansion of agriculture in the US puts pressure on scarce resources resulting in factor price rises. Moreover, the expansion of the agriculture sector ($qo_{agr,us}$ = 3.09%) is accompanied by contractions in US manufacturing ($qo_{manu,us}$ = -1.3%) and services ($qo_{serv,us}$ = -0.03%). Thus, intermediate input and primary factor demands fall in these sectors. The fall in US manufacturing is quite significant due to (negative) pro-competitive effects ($mp_{manu,us}$) and scale effects ($qof_{manu,us}$) (see table 6.2).

6.5.2 Trade Flows

As a result of the bilateral tariff reduction, trade flows increase overall. The values of aggregate exports, ($vxwreg_r$), and imports, ($viwreg_r$), increase for the US and the EU. EU bilateral exports only increase from the manufacturing sectors which exhibit pro-competitive and scale effects, with slight falls in the services sector. In the US, the increase in the value of exports ($vxwreg_{us}$ = 3.03%) is dominated by the increase in sales of agriculture to the EU ($qs_{agr,us,eu}$ = 198.16%), with slight increases in service exports. Imports of manufacturing by the US and agriculture by the EU dominate respective aggregate import flows.

The ROW experiences a reduction in both exports ($vxwreg_{row}$ = -0.51%) and imports ($viwreg_{row}$ = -0.66%) suggesting a contraction of the economy. This may be dominated by agricultural effects. For example, the benchmark data show that the ROW's share of agricultural exports to the EU is large. Thus, increased EU agricultural imports from the US displace ROW exports significantly ($qs_{agr,row,eu}$ = -10.78%). Moreover, expansion in the EU's other sectors also lessens the level of imports from the ROW. Although negative pro-competitive effects result in increased US imports of manufacturing goods from the ROW, there are declines in agricultural and services imports.

Finally, increases in the level of trade increases the demand for transport services resulting in an increase in the supply of services by each region ($qst_{svces,r}$) and thus the global shipping good (qt=1.17%). Increased demands for shipping services leads to a corresponding rise in the price (pt = 0.19%) of global shipping services offered by the global shipping sector.

6.5.3 Welfare

Welfare effects may be classified into four categories: The terms of trade effect; efficiency effects, which are strongly linked to pro-competitive effects; varietal effects, relating to the levels of varietal diversity offered to consumers; and regional equivalent variation changes.

The terms of trade results are small. This is symptomatic of the simpler investment-savings mechanism chosen in this simulation run (see section 4.1.6). For the EU and the US, the terms of trade (tot_r – see table 6.3) have deteriorated very slightly, with in both cases the price of exports falling more than the price of imports. In the EU, this is partly due to falls in manufacturing export prices due to the pro-competitive effects. For the US, reallocation of resources into agriculture, aided by the negative pro-competitive effect, contributes towards lower priced agricultural exports. In the ROW, the terms of trade has improved, where export prices (psw_{ROW} = 0.0043%) have risen relative to import prices, (pdw_{ROW} = -0.03%).

	EU	US	ROW
tot_r (%)	-0.0346	-0.0358	0.0341
$qgdp_r$ (%)	0.1813	-0.3225	0.1394
u_r (%)	0.1993	-0.3669	0.1664
EV_r ($US 1995)	11,685	-19,288	15,117

Table 6.3: Welfare Effects from the base data

With factor endowments in the model fixed, increases in productive capacity only occur through reallocative resource effects. More specifically, changes in the quantity of GDP output ($qgdp_r$) in each economy measures the growth in output for a region (with fixed endowments, changes in $qgdp_r$ will typically be small). Thus, for the EU, $qgdp_{eu}$ increases (see table 6.3) suggesting efficiency gains. This is due to the reallocation of resources from the less efficient agricultural sector to the manufacturing and service sectors. The presence of the pro-competitive effect in monopolistically competitive manufacturing contributes significantly to the overall increase in real EU GDP. In the US, the gains from specialisation in agriculture, are offset by large negative pro-competitive effects in manufacturing leading to a fall in real GDP. In the ROW, $qgdp_{row}$ increases which in part are aided by the positive pro-competitive effects in manufacturing.

Table 6.2 shows that the number of varieties/firms ($n_{manu,r}$) of EU and ROW differentiated (manufacturing) products has increased, whereas in the US it has fallen. Thus, representative varieties of European and ROW manufacturing goods are moving closer to agents' ideals on the varietal spectrum, vis-à-vis the USA representative variety, which is becoming less popular.

	EU	US	ROW
$zp_{manu,r}$	0.2377	-0.4740	0.1477
$zg_{manu,r}$	0.2351	-0.6050	0.1471

$zf_{manu,agr,r}$	0.2613	-0.6664	0.1567
$zf_{manu,manu,r}$	0.2350	-0.5469	0.1462
$zf_{manu,svces,r}$	0.2633	-0.6508	0.1579
$zf_{manu,cgds,r}$	0.2203	-0.4781	0.1380

Table 6.4: Varietal effects from the base data (% change)

Clearly, expansion of the EU and the ROW manufacturing sectors leads to long run entry of firms and so higher levels of varietal diversity. Thus, bilateral utility variables ($zps_{i,r,s}$, $zfs_{i,r,j,s}$ and $zgs_{i,r,s}$) (see table 6.4) all increase in the EU and ROW which, *ceteris paribus*, has a positive effect on representative demands for EU and ROW manufacturing goods by all regions. The level of *composite* ($zp_{i,s}$, $zg_{i,s}$, $zf_{i,j,s}$) hierarchical utility also increases in the EU and ROW, but falls in the US (see table 6.4). This suggests an overall increase in the level of varietal diversity for agents in the former regions, but a fall in the latter. Moreover, increases in composite varietal diversity reduces the per unit expenditure ($pp_{i,s}$, $pg_{i,s}$, $pf_{i,j,s}$) required to attain an extra unit of composite utility ($qp_{i,s}$, $qg_{i,s}$, $qf_{i,j,s}$) in the nest.

The net result of the three welfare effects above can be summarised by the equivalent variation (EV_r) figure (table 6.3) calculated from changes in the superhousehold regional utility variable u_r. In the EU and the ROW, the level of regional utility increases whereas in the USA, regional utility falls.

6.6 Conclusions

The modifications to the standard treatment made in this chapter are twofold: First our application incorporates a neo-Hotelling type demand structure which exhibits ‘non-nested’ hierarchical preferences, where the domestic representative variety is always most preferred. The modeller is also given freedom to alter the degree of ‘preference heterogeneity’, where a consumer’s perception of ‘variety’ may be high (low) and proliferations/reductions in varietal choice may create dramatic (minimal) changes in demand patterns.

The second major modification to the model is the incorporation of an imperfectly competitive increasing returns to scale characterisation of the food processing, manufacturing and services sectors (primary agriculture, primary resource and capital goods sectors remain perfectly competitive). The specification employed in our application allows for endogeneity in the mark-up of output price over average variable costs. Moreover, a conjectural variation approach is used which allows the modeller freedom to characterise different degrees of Cournot collusion by rival firms in each imperfectly competitive sector.

To incorporate non-nested hierarchical preferences in the model (section 6.3), where domestic and foreign representative varieties compete directly in each agent's demand nest, one must modify parts of the model data such that demands are sourced directly to consumers. These data manipulation techniques are discussed in section 6.4. The chapter concludes with a simple aggregation (3 region, 3 commodity) numerical example (section 6.5).

Appendix A: Mathematical Derivations of Modifications to the Standard Model Structure

A.6.1: Deriving the Mark-Up

Starting with the profit function to each symmetric firm in industry 'i':

$$\Pi_i = P.Q_i - TC_i \tag{A.1}$$

Under Cournot conjecture, maximise profit with respect to quantity. Using the product rule gives:

$$\frac{\partial \Pi_i}{\partial Q_i} = P + Q_i \frac{\partial P}{\partial Z}\frac{\partial Z}{\partial Q_i} - \frac{\partial TC_i}{\partial Q_i} \tag{A.2}$$

where Z is industry output. Rearranging:

$$P - MC_i = -Q_i \frac{\partial P}{\partial Z}\frac{\partial Z}{\partial Q_i} \tag{A.3}$$

Multiply both sides by (P/P)(Z/Z) and manipulating gives:

$$\frac{P - MC_i}{P} = \frac{\Omega_i}{N}.\left|\frac{1}{\varepsilon}\right| \tag{A.4}$$

where

$$\Omega_i = \frac{\partial Z}{\partial Q_i} \qquad \frac{1}{N} = \frac{Q_i}{Z} \qquad \left|\frac{1}{\varepsilon}\right| = \frac{\partial P}{\partial Z}\frac{Z}{P} \tag{A.5}$$

A.6.2: Characterising Different Oligopoly Structures within the model

Due to the assumption of symmetry between rival firms, the reciprocal of the number of firms is actually equal to the output share of each i^{th} firm:

$$\frac{1}{N} = \frac{Q_i}{Z} \tag{B.1}$$

Moreover, the conjectural variation parameter which measures changes in industry output (Z) with respect to changes in firm output (Q_i) is given as:

$$\Omega_i = \frac{\partial Z}{\partial Q_i} \tag{B.2}$$

Thus, Ω_i/N is equal to the conjectural *elasticity* of variation:

$$\frac{\Omega_i}{N} = \frac{\partial Z}{\partial Q_i}\frac{Q_i}{Z} \tag{B.3}$$

or the percentage change in industry output brought about by a percentage change in the i^{th} firm's output.

A.6.3: Deriving the Levels Inverse Demand Function

Using the private household as an example, which is equally applicable to other agents, the Neo-Hotelling demand for representative varieties given in (H.22) is represented in levels form as:

$$QDFPS_{i,r,s} = QP_{i,s} \cdot \left[\frac{PPS_{i,r,s}}{PP_{i,s}}\right]^{-\sigma_i} ZPS_{i,r,s}^{\sigma_i} \tag{C.1}$$

Rearranging (C.1) in terms of $PPS_{i,r,s}$ gives the inverse neo-Hotelling levels demand function:

$$PPS_{i,r,s} = \left[\frac{QDFPS_{i,r,s} ZPS_{i,s}^{-\sigma_i}}{QP_{i,s}}\right]^{-\frac{1}{\sigma}} PP_{i,s} \tag{C.2}$$

A.6.4: Deriving the Inverse Elasticity of Demand for Domestic (r=s) Representative Varieties

Starting with expression (C.2), take the derivative (product and chain rules) with respect to domestic (r=s) representative varieties:

$$\frac{\partial PPS_{i,r,s}}{\partial QDFPS_{i,r,s}} = -\frac{1}{\sigma_i}\frac{PPS_{i,r,s}}{QDFPS_{i,r,s}} + \frac{1}{\sigma_i}\frac{PPS_{i,r,s}}{QP_{i,s}}\frac{\partial QP_{i,s}}{\partial QDFPS_{i,r,s}} + \frac{PPS_{i,r,s}}{PP_{i,s}}\frac{\partial PP_{i,s}}{\partial QDFPS_{i,r,s}} \qquad \text{(D.1)}$$

Multiplying by ($QDFPS_{i,r,s}/PPS_{i,r,s}$) and applying the derivative:

$$\frac{\partial PP_{i,s}}{\partial QDFPS_{i,r,s}}\frac{QDFPS_{i,r,s}}{PP_{i,r,s}} = \frac{\partial PP_{i,s}}{\partial QP_{i,s}}\frac{QP_{i,s}}{PP_{i,s}} \times \frac{\partial QP_{i,s}}{\partial QDFPS_{i,r,s}}\frac{QDFPS_{i,r,s}}{QP_{i,s}} \qquad \text{(D.2)}$$

Yields the inverse elasticity:

$$\frac{\partial PPS_{i,r,s}}{\partial QDFPS_{i,r,s}}\frac{QDFPS_{i,r,s}}{PPS_{i,r,s}} = -\frac{1}{\sigma_i} + \frac{\partial QP_{i,s}}{\partial QDFPS_{i,r,s}}\frac{QDFPS_{i,r,s}}{QP_{i,s}}\left[\frac{1}{\sigma_i} + \frac{\partial PP_{i,s}}{\partial QP_{i,s}}\frac{QP_{i,s}}{PP_{i,s}}\right] \qquad \text{(D.3)}$$

Taking the derivative with respect to representative demands ($QDFPS_{i,r,s}$) of the neo-Hotelling utility function:

$$QP_{i,s} = \left[\sum_{r \in reg} \delta_{i,r,s} QDFPS_{i,r,s}^{-\rho_i} ZPS_{i,r,s}\right]^{-\frac{1}{\rho_i}} \qquad \text{(D.4)}$$

and multiplying by ($QDFPS_{i,r,s}$ /$QP_{i,s}$) gives :

$$\frac{\partial QP_{i,s}}{\partial QDFPS_{i,r,s}}\frac{QDFPS_{i,r,s}}{QP_{i,s}} = SP_{i,r,s} = \frac{PPS_{i,r,s}.QDFPS_{i,r,s}}{\sum_{r \in reg} PPS_{i,r,s}.QDFPS_{i,r,s}} = \frac{VPAS_{i,r,s}}{\sum_r VPAS_{i,r,s}} \qquad \text{(D.5)}$$

(see expressions (A12) and (A13) in appendix section A.2.3.2 for the derivation of this result). Substitute this result into (D.3) and take the negative of the inverse elasticity of the derivative to obtain the *absolute* value of the inverse elasticity of demand for domestic (r=s) representative varieties.

$$\left|\frac{1}{\varepsilon}\right|_{i,r,s} = -\frac{\partial PPS_{i,r,s}}{\partial QDFPS_{i,r,s}}\frac{QDFPS_{i,r,s}}{PPS_{i,r,s}} = SP_{i,r,s}\left[-\frac{\partial PP_{i,s}}{\partial QP_{i,s}}\frac{QP_{i,s}}{PP_{i,s}} - \frac{1}{\sigma_i}\right] + \frac{1}{\sigma_i} \tag{D.6}$$

Moreover, following Blake *et al.* (1998), Harrison *et al.* (1995), assume that the absolute value of the inverse elasticity of demand for the composite good ($QP_{i,s}$) is equal to unity:

$$\left|\frac{1}{\varepsilon}\right|_{i,r,s} = SP_{i,r,s}\left[1 - \frac{1}{\sigma_i}\right] + \frac{1}{\sigma_i} \tag{D.7}$$

A.6.5: Deriving the Inverse Elasticity of Demand for Foreign (r≠s) Representative Varieties

Following Blake *et al.* (1998), the inverse elasticity of demand for exports from 'r' is given as:

$$\begin{aligned}\left|\frac{1}{\varepsilon}\right|^{M}_{i,r,s} = -\frac{\partial PM_{i,r}}{\partial QS_{i,r,s}}\frac{QS_{i,r,s}}{PM_{i,r}} = \left[\frac{\partial PM_{i,r}}{\partial PMS_{i,r,s}}\frac{PMS_{i,r,s}}{PM_{i,r}}\right] \times \\ -\left[\frac{\partial PMS_{i,r,s}}{\partial M_{i,r,s}}\frac{M_{i,r,s}}{PMS_{i,r,s}}\right] \times \left[\frac{\partial M_{i,r}}{\partial QS_{i,r,s}}\frac{QS_{i,r,s}}{M_{i,r}}\right]\end{aligned} \tag{E.1}$$

where:

$$M_{i,r,s} = QDFPS_{i,r,s} + QDFGS_{i,r,s} + \sum_{j \in prod} QDFFS_{i,r,j,s} \tag{E.2}$$

From the discussion in the chapter:

$$\frac{\partial M_{i,r,s}}{\partial QS_{i,r,s}} \frac{QS_{i,r,s}}{M_{i,r,s}} = 1 \qquad \text{(E.3)}$$

and:

$$\left|\frac{1}{\varepsilon}\right|_{i,r,s}^{M} = -\frac{\partial PMS_{i,r,s}}{\partial M_{i,r,s}} \frac{M_{i,r,s}}{PMS_{i,r,s}} = AGGSHR_{i,r,s}\left[1-\frac{1}{\sigma_i}\right]+\frac{1}{\sigma_i} \qquad r \neq s$$

(E.4)

To calculate the elasticity of changes in export prices in 'r' with respect to changes in import prices in 's' start from the levels expressions in the model for the "free on board" ($PFOB_{i,r,s}$) export price and the "market" ($PMS_{i,r,s}$) and "cost insurance freight" ($PCIF_{i,r,s}$) import prices:

$$PFOB_{i,r,s} = \frac{PM_{i,r}}{TX_{i,r}.TXS_{i,r,s}} \qquad \text{(E.5)}$$

$$PMS_{i,r,s} = PCIF_{i,r,s}.TM_{i,r}TMS_{i,r,s} \qquad \text{(E.6)}$$

$$PCIF_{i,r,s} = PFOB_{i,r,s} + PT \qquad \text{(E.7)}$$

where

$TX_{i,r}$/ $TXS_{i,r,s}$ – Generic/Bilateral specific export tax/subsidy.

$TM_{i,r}$/ $TMS_{i,r,s}$ – Generic/Bilateral specific import tax/subsidy.

$PM_{i,r}$ – Export market price in region 'r'.

PT – Global shipping sector per unit freight price

Substitute (E.5) into (E.7)

$$PCIF_{i,r,s} = \frac{PM_{i,r}}{TX_{i,r}.TXS_{i,r,s}} + PT \qquad \text{(E.8)}$$

Substitute (E.8) into (E.6):

$$PMS_{i,r,s} = PM_{i,r}.TX_{i,r}^{-1}.TXS_{i,r,s}^{-1}.TM_{i,r}.TMS_{i,r,s} + PT.TM_{i,r}.TMS_{i,r,s} \tag{E.9}$$

Rearrange in terms of $PM_{i,r}$:

$$PM_{i,r} = PMS_{i,r,s}TX_{i,r}.TXS_{i,r,s}TM_{i,r}^{-1}.TMS_{i,r,s}^{-1} - PT.TX_{i,r}.TXS_{i,r,s} \tag{E.10}$$

Taking the derivative gives:

$$\frac{\partial PM_{i,r}}{\partial PMS_{i,r,s}} = TM_{i,r}^{-1}.TMS_{i,r,s}^{-1}.TX_{i,r}.TXS_{i,r,s} \tag{E.11}$$

Multiplying by market import and export prices, substituting (E.9) and canceling terms gives:

$$\frac{\partial PM_{i,r}}{\partial PMS_{i,r,s}}\frac{PMS_{i,r,s}}{PM_{i,r}} = \frac{PT.TX_{i,r}.TXS_{i,r,s}}{PM_{i,r}} + 1 \tag{E.12}$$

Combining each of these terms into the inverse elasticity of demand for exports of region 'r' (r≠s) (expression E.1) gives:

$$\left|\frac{1}{\varepsilon}\right|_{i,r,s}^{M} = -\frac{\partial PM_{i,r}}{\partial QS_{i,r,s}}\frac{QS_{i,r,s}}{PM_{i,r}} = \left[\frac{PT.TX_{i,r}.TXS_{i,r,s}}{PM_{i,r}} + 1\right] \times \left[AGGSHR_{i,r,s}\left[1 - \frac{1}{\sigma_i}\right] + \frac{1}{\sigma_i}\right] \times 1 \tag{E.13}$$

and substituting into the mark-up expression (M.2) gives the mark-up on foreign sales (r≠s) in expression (M.15):

Chapter 7

The Costs of the Common Agricultural Policy (CAP)

The results presented in this chapter focus on a number of different issues pertaining to CAP costs. The earlier sections place emphasis on measuring the costs of CAP abolition vis-à-vis the alternative of full implementation of the Uruguay Round (UR) reforms. Although the model structure incorporates all of the stylised modifications detailed in chapters 5 and 6, (i.e., imperfect competition, varietal preferences, explicit CAP modelling etc.), preference heterogeneity is held as weak. This allows better focus on the policy scenarios themselves, which are then compared with other estimates of CAP costs in the computable general equilibrium (CGE) trade literature (chapter 1).

Under the exact same model specification, the latter part of the chapter evaluates the cost of agricultural policies under conditions of high preference heterogeneity. Firstly, results are provided assessing the impact of varietal perception under a given scenario (CAP abolition), which is followed by model estimates on the cost of CAP abolition against the alternative of the UR reforms. Moreover, experiments are also carried out to ascertain the effect of variations in industry concentration and collusion levels in imperfectly competitive sectors on the costs of CAP abolition under both sets of heterogeneity conditions.

Thus, the structure of the chapter is as follows: Sections 7.1 and 7.2 evaluate the costs of the CAP under low preference heterogeneity. Sections 7.3 and 7.4 examine the impact of different preference heterogeneity conditions, concentration levels and collusive behaviour on CAP costs. Section 7.5 concludes.

7.1 The Cost of EU Agricultural Policy – Experimental Design

Section 7.1 reports estimates of the costs of the CAP by comparing the results of full implementation of the Uruguay Round (UR) agreement (experiment (i)) against the alternative of CAP abolition (experiment (ii)). The UR scenario includes full implementation of the agreed import tariff, export subsidy and output subsidy commitments by each region. The CAP abolition scenario includes the UR commitments *and* complete removal of output subsidy, export subsidy and import tariff wedges pertaining to all food and agricultural sectors in both EU regions (UK and EU-14).

Experiments (i) and (ii) both include model projections on factor productivity and endowment growth through to 2005 and are evaluated under conditions of imperfect competition in the food processing, manufacturing and services sectors, with remaining sectors characterised as perfectly competitive (i.e., primary agriculture and the natural resource sector). A full schematic representation of the experiments is presented in figure 7.1.

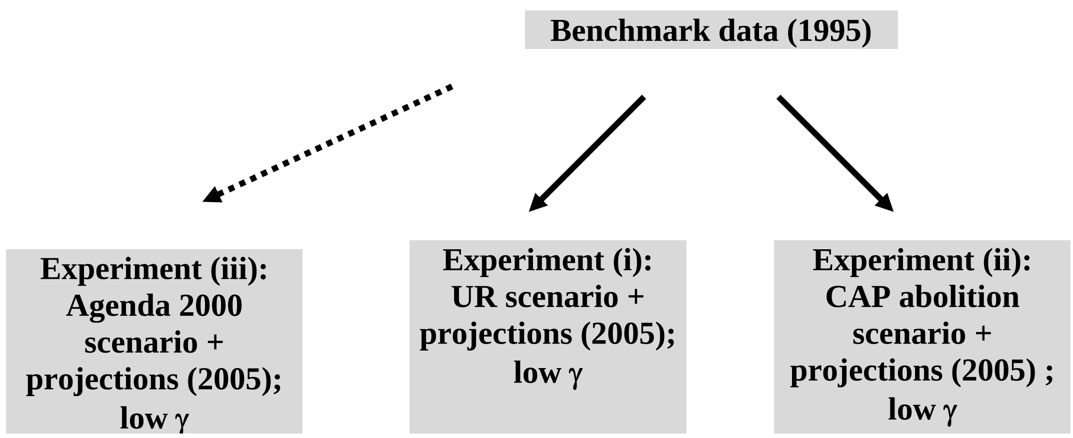


Figure 7.1: A Schematic Representation of the Experimental Design

From the discussion in section 6.1.3, the value of the preference heterogeneity parameter, γ_i, is assumed to range from between zero and one, where values of γ_i greater than one lead to instability in the model solution. Hence, an arbitrarily low value of γ_i is chosen (γ_i = 0.01) in both experiments such that model results concentrate more on the effects of the policy scenarios themselves. This contrasts with the latter part of the chapter, where the model examines the impacts of preference heterogeneity by employing a much higher value of γ_i (= 0.75). In the absence of data on imperfectly competitive firm concentration ratios for this specific aggregation, the benchmark data are calibrated to five symmetric firms (N=5), where it is assumed that rivals compete under standard Cournot conjecture (Ω/N = 1/N).

Finally, a third policy experiment examining the costs of the Agenda 2000 scenario, vis-à-vis the UR case, is also included under identical conditions and assumptions to experiments (i) and (ii). The inclusion of the Agenda 2000 reforms is restricted to the results tables in appendix A, the numbering of which corresponds to that in the main text.

7.2 Overview of agricultural liberalisation scenarios

In each of the policy scenarios, prices and outputs are affected by a number of factors, where in the case of price effects, it is difficult to predict, *a priori*, the final direction and magnitude of the results. In the first instance, the relative levels of subsidy support and tariff protection in the EU primary agricultural and food industries are high compared to other regions in the GTAP data. Thus, partial/complete removal of these wedges will render these EU sectors relatively less competitive.

Subsequent reductions in EU agricultural and food demands have a depressing effect on the prices of these goods within the EU. Moreover, reductions in EU exports on world markets is expected to have an inflating effect on world prices. Finally, increases in EU imports encourage price and output increasing effects in those countries which have a comparative advantage in agricultural production.

The *typical* supply response effect within the EU regions is that mobile resources from agricultural sectors are reallocated into non-agricultural sectors which are less heavily protected.[1] Since the agricultural industry has sector specific factors (cereals and non cereals land), the reduction in output will be somewhat slower than the increase of output in the manufacturing and services sectors where all factors are mobile, such that the latter has a higher supply elasticity. Thus, resource re-allocation increases aggregate demands for value added, bidding up rent and wage payments to mobile capital and labour factors, which has an inflationary effect on output prices. Contraction of the agricultural sector will result in falling land rents, where these sector specific factors have no uses outside of primary agriculture.

[1] In the EU regions, there are *no* subsidies in the production of manufacturing or services goods in the benchmark data.

A number of other factors increase the degree of indeterminacy of price effects within the model. Firstly, in the EU primary agricultural sectors, the land endowment (which is fixed) and unskilled labour endowment (which is projected to *fall* in the EU regions *only*) become more scarce, which has a cost-inflationary effect on factor returns in these sectors. Moreover, these effects are in opposition to strong productivity projections in arable and livestock sectors, which along with falling returns to land, has a depressing effect on agricultural output prices. Finally, endowments of capital and skilled labour (and unskilled labour in non-EU regions) are projected to rise under the projections, where greater abundance of these factors reduces their respective factor rewards.

7.2.1 Experiment (i)

Experiment (i) includes shocks which project the world economy through to 2005 and the Uruguay Round (UR) constraints. Table 7.1 shows the percentage changes in market prices and output in 2005 from the 1995 benchmark data.[2] In the EU regions, prices in many of the agricultural sectors fall. The exceptions are the quota constrained sectors (raw sugar / raw milk), where large increases in the tariff equivalent rent variable (tq) are required to keep output at a fixed level, particularly the milk sector. The rise in the quota constrained primary sugar price is only slight (0.14%). In the UK primary sugar sector, imports of primary sugar (and sugar processing) are larger in absolute terms then the EU-14.[3] Thus, the relaxation of protection in the UK under the UR reforms attracts large increases in primary and processed sugar imports into the UK from the LDC region (*32%* and *56%* respectively).[4] As a result, UK sugar processing contracts and reduces the quantity of its purchases of primary sugar (-*22%*) which dampens the upstream sugar price rise. There is no intervention buying in any of the EU sectors, although the fall in the price of 'other grains' is very close to the support trigger.

---

[2] In the standard implementation of the model, the global demand and supply of investment is the Walrasian n[th] market (see section 5.2.5), where the clearing price (psave) is held as the numeraire variable. Thus, 1995 price changes in each of the following tables in this chapter are relative to this exogenous numeraire variable. Finally, note that the percentage changes may in some cases be as a proportion of a very small benchmark level.

[3] This is due to the preferential trade links with the African, Carribean and Pacific Countries (ACP), which in this aggregation mainly appears in the LDC composite region.

[4] All italicised results are not presented in the main text.

	UK	EU-14	USA	CAIRNS	LDCs	ROW
Market Price						
Other agriculture	-10.51	-7.55	3.51	3.57	-5.96	3.99
Other primary	46.47	43.24	48.94	44.27	43.69	49.38
Wheat	-10.90	-9.62	6.04	-7.32	-6.90	1.86
Other grains	-9.14	-10.16	5.65	1.91	-3.79	3.43
Oilseeds	-0.71	1.20	6.02	-1.66	5.71	6.48
Raw Sugar	0.14	29.89	9.84	-7.09	-0.72	4.72
Cattle & sheep	-13.12	-8.24	-11.59	-6.52	-12.25	-6.90
Raw milk	41.98	39.65	-6.85	-13.65	-8.77	-5.35
Meat processing	-1.25	-1.34	-12.32	-0.90	-7.14	-3.76
Other meat processing	-1.77	-2.20	-3.51	6.26	0.73	3.53
Other food processing	6.11	6.49	6.03	1.23	-5.13	5.20
Milk processing	24.60	26.66	-1.52	-7.80	-9.85	-1.21
Sugar processing	1.77	14.39	5.59	-3.10	-1.43	1.38
Manufacturing	10.60	10.10	10.58	4.35	-6.54	7.33
Services	6.45	6.83	6.86	-8.39	-26.29	3.90
Output						
Other agriculture	45.08	36.51	33.52	42.56	52.30	33.28
Other primary	19.83	21.95	21.22	42.58	45.86	22.98
Wheat	22.67	21.21	20.07	56.96	54.68	5.34
Other grains	18.44	11.19	27.03	39.27	50.18	-1.89
Oilseeds	27.79	25.89	25.65	49.04	41.78	19.55
Sugar beet	0.00	0.00	-3.38	60.25	41.32	12.67
Cattle & sheep	15.05	17.79	44.75	46.00	54.08	35.33
Raw milk	0.00	0.00	39.59	66.63	50.46	42.05
Meat processing	17.53	25.23	59.83	59.33	59.72	37.09
Other meat processing	33.36	35.79	49.93	43.88	53.30	36.72
Other food processing	25.87	24.24	34.34	57.06	58.74	35.69
Milk processing	0.46	2.55	43.93	82.65	76.04	46.68
Sugar processing	0.35	8.08	10.54	67.13	51.83	31.97
Manufacturing	19.92	22.51	25.45	49.76	70.59	37.41
Services	24.80	25.03	35.49	64.49	69.34	39.40

Table 7.1: Experiment (i): (% changes from the 1995 benchmark)

7.2.2 CAP Abolition – Outputs and Prices

Tables 7.2 and 7.3 detail the percentage changes in outputs and market prices from the CAP abolition scenario compared to the UR case (experiment (i)). Thus, removal of all forms of CAP support leads to significant UK and EU-14 output falls in most primary agricultural sectors compared to the UR case, with concurrent increases in UK and EU-14 non-agricultural outputs (i.e., manufacturing and services) (table 7.2). The largest falls in UK primary agricultural output occur in the 'cattle and sheep' (-35%), 'sugar' (-25%), 'other grains' (-13%) and 'other agriculture' (-8%) sectors, with significant market price (table 7.3) falls in many primary agricultural sectors (particularly unrestricted quota sectors raw milk (-68%) and sugar (-31%)). In some UK sectors, (‘oilseeds’, ‘primary livestock’) complete removal of compensation (input subsidies) has led to price rises (17% and 12% respectively). In the UK cereals sectors, large reductions in cereals land prices (see table 7.7) lead to output price falls despite removal of compensation (i.e., input subsidies). In both EU regions, these price and output effects are passed onto downstream food processing sectors.

Sector	UK	EU14	USA	CAIRNS	LDCs	ROW
Other agriculture	-8.04	-4.06	0.11	-0.85	0.18	0.15
Other primary	-0.13	-0.06	-0.11	-0.19	-0.07	-0.05
Wheat	-1.14	-0.82	0.14	-0.01	-0.27	0.51
Other grains	-13.29	-8.69	1.91	0.80	0.18	1.42
Oilseeds	-8.73	-22.34	2.44	1.18	0.51	2.52
Sugar	-25.02	6.55	-0.25	-0.08	1.03	3.42
Cattle & Sheep	-34.50	-37.01	2.61	12.23	2.59	7.72
Raw Milk	26.40	19.42	0.36	2.69	0.13	3.61
Meat Processing	-49.16	-24.12	2.26	18.14	8.58	4.30
Other Meat Processing	-3.32	-2.66	-0.21	0.40	0.40	0.41
Other Food Processing	4.48	0.49	-0.06	-0.75	0.46	-0.39
Milk Processing	21.31	21.51	0.33	3.73	6.19	6.81
Sugar Processing	-36.77	2.10	-0.03	-0.06	4.85	4.17
Manufacturing	0.32	0.82	-0.19	-0.79	-0.84	-0.22
Services	0.14	0.01	0.02	0.03	-0.06	-0.01

Table 7.2: Percentage changes in sectoral output under CAP abolition

Sector	UK	EU14	USA	CAIRNS	LDCs	ROW
Other agriculture	0.96	1.51	1.18	1.88	0.84	0.85
Other primary	-0.25	-0.25	-0.33	-0.35	-0.37	-0.37
Wheat	-3.23	-3.18	1.10	1.21	0.88	0.81
Other grains	-5.76	-3.69	1.34	1.82	0.90	0.99
Oilseeds	16.63	17.27	1.42	1.61	1.13	1.18
Sugar	-30.58	-59.48	1.76	1.41	1.03	1.07
Cattle & Sheep	12.31	7.12	1.02	1.79	0.85	0.92
Raw Milk	-68.42	-63.93	0.96	1.22	0.96	0.90
Meat Processing	3.32	1.77	0.76	0.14	0.10	0.60
Other Meat Processing	1.46	0.36	0.72	1.29	0.80	0.77
Other Food Processing	-3.93	-2.01	0.22	0.83	0.39	0.33
Milk Processing	-36.23	-36.09	0.61	0.72	0.46	0.32
Sugar Processing	-11.94	-20.50	0.93	1.18	0.31	0.78
Manufacturing	0.23	-0.01	0.03	0.20	0.07	0.09
Services	0.01	-0.10	0.04	0.19	0.00	0.14

Table 7.3: Percentage changes in market prices under CAP abolition

The pattern is much the same in the EU-14 region, although sugar beet production *rises* (7%) after CAP support is removed. This is primarily due to *pro-competitive* (see section 6.2) effects in the downstream sugar processing sector, where a fall in the mark-up is associated with increases in output per firm which implies increases in hierarchical intermediate input purchases.[5] In both EU regions, the largest single user of sugar is the downstream sugar processing industry, where UK sugar processing experiences strong negative pro-competitive (mark-up increases *12%*) effects which affects primary sugar production significantly in this region (-25%).[6] Hence, large market price falls in the UK for primary sugar appear to be outweighed by negative pro-competitive effects further down the supply chain resulting in a net fall in sugar production under CAP abolition compared to the UR case. In the EU-14, this is not the case, with the mark-up falling *1.6%*, output rises in both processed and sugar beet sectors.

In the raw milk sectors, quota-free production increases 26% and 19% in the UK and EU-14 regions respectively, compared to the UR scenario. This is due to the large market price falls from abolition of the quota leading to increased demand. Further, the milk processing sector in the GTAP data accounts for *64%* and *82%* of total domestic raw milk production in the UK and EU-14 regions, respectively. In milk processing, the mark-ups fall in the UK (*8.6%*) and EU-14 (*8.4%*) regions with positive varietal effects, which further encourages the production of raw milk compared to the UR case.

Table 7.4 shows percentage changes in aggregate consumer prices under CAP abolition compared to the UR case. The aggregate consumer price is an expenditure weighted share average of imported and domestically consumed goods, where the domestic price tends to dominate the composite price as domestic expenditure shares are significantly larger. Thus, changes in the consumer price will generally shadow changes in domestic market prices. A notable exception, however, is in the meat processing sector in both EU regions, where market prices (table 7.3) have risen, but aggregate consumer prices have fallen.

In the UK, the domestic expenditure share in the 'meat' sector is smaller than in other sectors, such that domestic price rises in meat have smaller inflationary effects on the consumer composite price. More importantly, there are significant increases in imports

[5] Intermediate input demand results are not tabulated since the number of subscripts (four) would require prohibitively large number of results tables.
[6] Under CAP abolition, elimination of the UK import tariff on processed sugar further encourages imports from the LDC region, which leads to further contractions in UK sugar processing.

to the UK (176%) and EU-14 (231%) (see table 7.6 below) of relatively lower priced meat processing products into *both* EU regions, resulting in net reductions in the composite consumer tradable price. Proliferations/reductions in product variants under conditions of *high* preference heterogeneity would have a much more significant effect on the composite consumer price. This will be discussed further in sub-section 7.4.5.

Sector	UK	EU14	USA	CAIRNS	LDCs	ROW
Other agriculture	0.56	0.60	1.19	1.83	0.86	0.90
Other primary	-0.30	-0.32	-0.33	-0.35	-0.37	-0.37
Wheat	-3.58	-3.33	1.11	1.16	0.85	0.85
Other grains	-6.69	-5.80	1.37	1.75	0.98	1.06
Oilseeds	6.04	4.26	1.56	1.54	1.17	1.53
Sugar	-32.07	-58.28	1.13	1.44	0.87	1.29
Cattle & Sheep	5.50	0.39	1.14	1.82	0.98	1.18
Raw Milk	-68.42	-63.93	0.96	1.22	0.95	0.90
Meat Processing	-11.88	-2.58	0.74	0.12	0.52	0.88
Other Meat Processing	1.16	-0.19	0.76	1.29	0.91	0.89
Other Food Processing	-3.82	-2.19	0.21	0.76	0.32	0.29
Milk Processing	-36.15	-35.85	0.70	0.96	1.50	0.88
Sugar Processing	-23.60	-20.67	0.89	1.20	0.58	1.35
Manufacturing	0.47	0.17	0.04	0.15	0.05	-0.07
Services	0.01	0.10	0.03	0.19	0.01	-0.14

Table 7.4: Percentage changes in aggregate consumer prices under CAP abolition

7.2.3 CAP Abolition – Trade Effects

Tables 7.5 and 7.6 show the percentage changes in aggregate exports and imports by sector for each region under CAP abolition compared to the UR case. Under CAP abolition, each EU region's exports reflect the domestic output changes (compare tables 7.2 and 7.5), although in the case of UK milk processing and EU-14 milk and sugar processing sectors, exports fall despite domestic output increases. The reason for this lies in the strong domestic demand effects, both from final and intermediate consumers.

For example, in the UK and EU-14 milk processing sectors, domestic private demands account for approximately *54%* and *52%* respectively of total milk processing production in the database. Significant increases in domestic private demand (UK – *38%*; EU-14 - *38%*) capture much of the increase in domestic output (21% in both regions – table 7.2). Moreover, the milk processing sector also uses much of its own output as an intermediate input (particularly in the EU-14), where these demands also increase *11%* and *18%* in the UK and EU-14 regions respectively.

Sector	UK	EU14	USA	CAIRNS	LDCs	ROW
Other agriculture	-11.21	-8.61	3.25	-2.72	7.52	16.52
Other primary	-0.52	-0.80	-0.04	-0.07	0.61	0.15
Wheat	-3.34	-2.20	-0.27	-0.53	7.90	3.15
Other grains	-41.57	-42.33	5.58	6.71	11.53	20.64
Oilseeds	-65.11	-66.72	6.86	9.00	6.32	12.98
Sugar	-19.24	-21.56	0.56	1.03	2.07	-0.60
Cattle & Sheep	-80.48	-85.46	120.57	17.06	24.87	185.49
Raw Milk*	-	-	-	-	-	-
Meat Processing	-39.00	-73.77	33.98	120.05	156.39	245.08
Other Meat Processing	-10.73	-11.16	4.29	6.05	10.49	28.74
Other Food Processing	15.11	7.48	2.61	-0.15	11.13	8.46
Milk Processing	-0.29	-35.63	10.50	30.12	45.52	83.56
Sugar Processing	-37.77	-38.63	7.72	3.31	59.73	46.62
Manufacturing	0.03	0.34	-1.22	-1.94	-2.55	-1.34
Services	0.10	0.37	-0.17	-1.27	-0.05	0.63

Table 7.5: Percentage changes in aggregate sectoral exports under CAP abolition

* Raw Milk is non-tradable.

The reasons for these large increases in domestic demands are twofold. Firstly, the private and government household utility functions in the second level of the utility tree are specified as Cobb-Douglas. Consequently, income and own-price elasticities of demand are equal to 1 and –1 respectively. The implication is that increases in EU real incomes under CAP abolition leads to strong domestic final demand effects for *all* composite commodities. These effects are further compounded in the milk sectors, where large price falls under CAP abolition lead to concurrently large increases in domestic final demands for composite milk tradables. Secondly, significant increases in UK and EU-14 milk processing output to meet increases in final demands lead to large intermediate input purchases by processed milk sectors.

Similar effects are also responsible for the significant falls in EU-14 primary and processed sugar exports (despite increases in output) relative to the UR case, where large domestic market price falls in primary sugar and therefore processed sugar, result in significant increases in domestic demands. Moreover, output increases in EU-14 sugar processing increases domestic intermediate demands for EU-14 primary sugar which also undergoes export falls despite increases in output (table 7.2).

In the *non-EU* regions, sectoral exports react to the strength of the EU market. CAP abolition leads to rises in non-EU exports in primary agricultural and food sectors (e.g.

sugar, other grains, oilseeds, meat and other meat, milk and sugar processing sectors – table 7.5).

Sector	UK	EU14	USA	CAIRNS	LDCs	ROW
Other agriculture	1.65	9.84	-0.87	1.38	-2.11	-1.70
Other primary	0.53	0.85	-0.10	-0.52	-0.62	-0.27
Wheat	0.96	4.22	-0.45	0.13	-0.26	-1.89
Other grains	0.75	27.52	-1.49	-1.00	-2.60	-3.46
Oilseeds	4.48	13.78	-1.08	0.15	-2.75	0.09
Sugar	20.49	-59.30	0.16	1.23	1.10	3.93
Cattle & Sheep	104.81	127.17	-1.44	-3.36	-34.33	-28.26
Raw Milk*	-	-	-	-	-	-
Meat Processing	175.90	233.17	1.77	-2.55	-31.21	-9.59
Other Meat Processing	5.72	29.12	-10.99	-1.44	-5.57	-5.91
Other Food Processing	1.60	17.43	2.16	6.28	2.89	-3.31
Milk Processing	41.12	77.52	-31.33	-32.72	-27.33	-26.45
Sugar Processing	52.24	128.11	0.23	-4.31	-14.61	-14.43
Manufacturing	-0.91	-4.90	-0.05	0.53	0.03	-0.71
Services	-0.47	-0.25	0.41	1.12	0.11	-0.84

Table 7.6: Percentage changes in aggregate sectoral imports under CAP abolition

* Raw Milk is non-tradable.

In table 7.6, the tendency is for EU-15 imports to rise in food related sectors under CAP abolition compared to the UR case. On the other hand, EU-14 sugar beet imports fall markedly (-59%), where domestic production has increased. Moreover, in UK and EU-14 manufacturing and services sectors, increases in domestic output also result in falling import demands.

7.2.4 Land Uptake in the EU Agricultural Sectors

Table 7.7 shows the percentage changes in the price and use of land in the primary agricultural sectors of the EU under CAP abolition compared to the UR case. The bottom row shows the percentage change in cereals land required to abolish all set-aside. The total endowment of non-cereals (i.e. pasture) land area stays exogenous in all simulation scenarios.

CAP abolition has a noticeable impact on land allocation in the EU regions. In both the UK and the EU-14 regions, there is a further shift towards the cereals sectors' uptake of cereals land, (although significant cereals land price falls are required for cereals sectors to take up former set-aside land), with concurrent reductions in land use for livestock pasture (-23% and -27% for the UK and EU-14 respectively). On the other hand, changing land use patterns suggests that there is a clear shift of emphasis in raw sugar production from the UK to the EU-14. In the case of raw milk, abolition of the binding quota results in significant increases in land uptake in both regions.

	UK	EU-14
Aggregate Factor Price		
Non-Cereals Land	-26.74	-13.69
Cereals Land	-71.63	-63.26
Quantity Demanded		
Other Agriculture	-1.53	-0.99
Wheat	17.98	17.31
Other Grains	14.85	16.97
Oilseeds	14.24	6.57
Raw Sugar	-17.23	7.59
Cattle & Sheep	-22.82	-26.66
Raw Milk	27.05	18.33
Non-Cereals Land Area	0.00	0.00
Cereals Land Area	16.57	15.60

Table 7.7: Percentage changes in land use and aggregate factor prices under CAP abolition

Finally, the return on both land types under CAP abolition, compared to the UR scenario, declines dramatically. This is due to contractions in most EU primary agricultural sectors, where the return on sectorally trapped land falls. Moreover, the abundance of the cereals land endowment is further increased with complete elimination of all forms of set-aside.

7.2.5 Agricultural Household Income

Tables 7.8 and 7.9 show the component parts of incomes to the agricultural producers and asset holders in each of the EU regions. The composition of the total income is disaggregated into factor incomes minus depreciation, CAP support and quota rents. Each of the cells in both tables gives values in millions of dollars (1995 prices). The final column on the right hand side compares the component changes in agricultural household income between the UR and CAP scenarios.

In the UR case, most of the increase in ‘agricultural household’ income comes in the form of the increase in the quota rent in the milk sector. With the quota still in place, large price increases are required to keep milk output levels within binding limits (the price increase is a shortcoming of the chosen characterisation of the quota, and is discussed further in chapter 8). Net factor incomes rise US$3,192m and US$34,260m

UK Region				
	1995 data	UR	CAP	CAP vs. UR
Cereals Land	324	369	86	-283
Non Cereals Land	4,252	5,205	4,068	-1,137
Natural Resources	0	0	0	0
Skilled Labour	473	488	460	-28
Unskilled Labour	10,797	12,987	12,262	-725
Capital	2,983	2,975	3,047	72
Depreciation	2,033	2,036	1,976	-60
NET FACTOR INCOME	**16,796**	**19,988**	**17,947**	**-2,041**
Headage Payments	584	525	0	-525
Set-Aside Compensation:				
Wheat	201	201	0	-201
Other Grains	111	111	0	-111
Oilseeds	71	71	0	-71
Price Support Compensation:				
Wheat	1,273	1,463	0	-1,463
Other Grains	707	766	0	-766
Oilseeds	276	340	0	-340
Quota Rent:				
Raw Milk	1,633	5,654	0	-5,654
TOTAL	**21,652**	**29,119**	**17,947**	**-11,172**

Table 7.8: Decomposition of Agricultural Producer and Asset Holders Regional Income in the UK ($US millions)

EU-14 Region				
	1995 data	UR	CAP	CAP vs. UR
Cereals Land	2,452	2,349	652	-1,697
Non Cereals Land	31,811	42,630	38,275	-4,355
Natural Resources	0	0	0	0
Skilled Labour	6,433	6,816	6,576	-240
Unskilled Labour	94,640	117,148	113,280	-3,868
Capital	31,685	32,470	32,256	-214
Depreciation	22,894	22,906	20,692	-2,214
NET FACTOR INCOME	**144,247**	**178,507**	**170,347**	**-8,160**
Headage Payments	2,083	1,955	0	-1,955
Set-Aside Compensation:				
Wheat	1,057	1,057	0	-1,057
Other Grains	1,100	1,100	0	-1,100
Oilseeds	613	613	0	-613
Price Support Compensation:				
Wheat	6,694	6,752	0	-6,752
Other Grains	6,977	6,050	0	-6,050
Oilseeds	2,672	2,587	0	-2,587
Quota Rent:				
Raw Milk	9,895	32,777	0	-32,777
TOTAL	**175,338**	**231,398**	**170,347**	**-61,051**

Table 7.9: Decomposition of Agricultural Producer and Asset Holder’s Regional Income in the EU-14 ($US millions)

from the 1995 benchmark for the UK and EU-14 respectively, with minor changes to de-coupled area compensation. Set-aside compensation is left unchanged under the UR scenario.

Under CAP abolition, all forms of de-coupled support and quota rent are eliminated. As a result, much of the loss in income to agricultural producers and asset holders under CAP abolition compared to the UR base case (US$11,172m and US$61,051 for the UK and EU-14 respectively) is attributed to these reforms, although there are also reductions in net factor incomes to both regions of US$2,041 and US$8,160 from the UK and EU-14 regions respectively.

7.2.6 The CAP Budget

Details of the modelling behind the CAP budget were given in section 5.6.10, and the results for each policy scenario are presented in Table 7.10, with figures for the UK, the EU-14 and the entire EU. Reductions in export and output expenditures in the UR scenario, as well as reductions in tariff rates, result in falls in CAP expenditures and revenues compared to the benchmark 1995 data. With significant falls in CAP expenditure in the UR case, UK and EU-14 resource contributions fall US$1,849.33m and US$6,220.82m respectively relative to the 1995 benchmark. The net contributory position in the UK improves, which implies that the EU-14 net contributory position worsens to preserve zero CAP budget balance.

US $millions	1995 data	UR	CAP
UK			
CAP Expenditure	5,756	4,359	0
Tariff Revenue	804	787	0
Resource Contribution	8,952	7,103	0
Net Contribution	-4,000	-3,531	0
EU-14			
CAP Expenditure	36,911	29,992	0
Tariff Revenue	2,799	2,569	0
Resource Contribution	30,112	23,892	0
Net Contribution	4,000	3,531	0
EU-15			
CAP Expenditure	42,667	34,351	0
Tariff Revenue	3,603	3,356	0
Resource Contribution	39,064	30,995	0
Net Contribution	0	0	0

Table 7.10: Changes in the CAP Budget ($millions 1995)

Under CAP abolition, all payments/receipts with respect to the FEOGA budget are discontinued. Thus, the saving to the EU-15, in terms of import tariffs and resource contributions (i.e., GDP and VAT contributions) compared to the UR scenario, is US$34bn. Disaggregating this figure by both EU regions, the UK and EU-14 save approximately US$8bn and US$26bn in FEOGA contributions compared to the UR case.

7.2.7 Welfare Effects

Table 7.11 shows each region's change in regional real incomes under CAP abolition. Before discussing the results, a few caveats must be mentioned. Firstly, it seems intuitively appealing to gauge the costs of a policy compared to the existing state of agriculture under the Uruguay Round reforms plus factor endowment and productivity projections, rather than comparing results to a simulation solely consisting of projections. In the latter case, it is likely that such a comparison would suggest exaggerated gains in EU real incomes. Secondly, because much of the support under the CAP has been characterised as either partially or completely de-coupled from production, it can be expected that the estimated benefit/loss of a policy scenario will be smaller compared to most studies where CAP support is treated as an *ad valorem* output subsidy wedge. Finally, the presence of imperfect competition in the model is likely to raise the size of the estimates somewhat, where pro-competitive effects lead to increased output magnitudes, and varietal effects increase consumer utility, particularly under high preference heterogeneity which will be discussed in detail in the next section.

	EV ($mill) change from UR scenario	**EV (% change)**
UK	8,814	0.90
EU-14	17,770	0.29
EU-15	**26,584**	**0.54**
USA	170	+0.00
CAIRNS	2,100	0.09
LDCs	-2,610	-0.12
ROW	-10,820	-0.16
Total EV	**15,424**	**0.06**

Table 7.11: Changes in equivalent variation (EV) under CAP abolition

Under CAP abolition, real incomes in the UK and EU-14 increase 0.90% and 0.29% respectively relative to the UR case, with increases in EU-15 real incomes of 0.54%.[7] Clearly, removal of all support and quantity constraints results in resource allocation effects in favour of more efficient industries, which is reflected by real output ($qgdp_r$) increases of *0.49%* and *0.31%* for the UK and EU-14 respectively. The USA and CAIRNS regions are in improved positions after CAP abolition, although LDC and ROW real incomes fall. Global welfare improves 0.06% from the UR case. Finally, changes in real food expenditure (not shown) by food consumers in each EU region shadows changes in real incomes (EV) relative to the base case. This is due to unitary income elasticities for composite tradables by both private and public households.

7.3 Varietal Effects and Agricultural Policy Costs – Experimental Design

The results the following sections focus on the influence on welfare of patriotic product perceptions by UK consumers. Thus, the CAP abolition case (experiment (ii) in section 7.1) is compared to a corresponding scenario where *only UK* consumers exhibit *high* preference heterogeneity (experiment (iv), see figure 7.2).

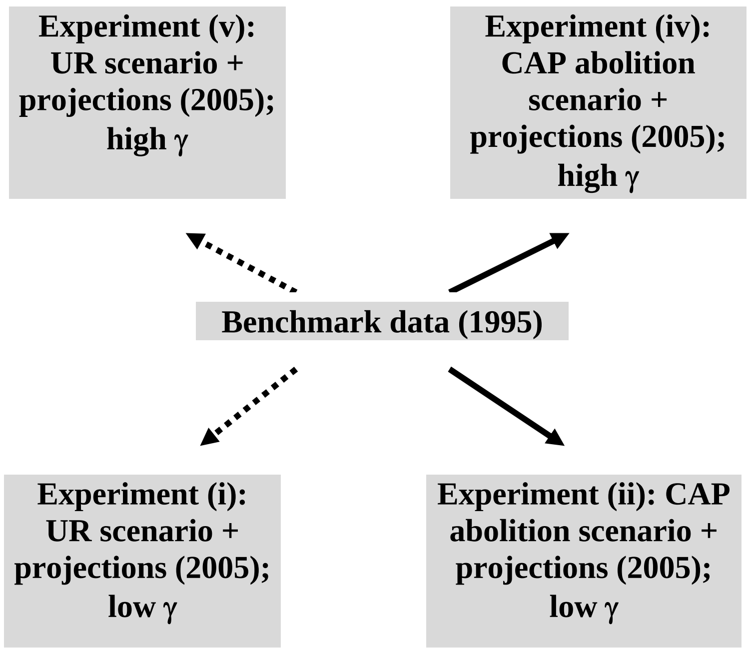


Figure 7.2: A Schematic Representation of the Experimental Design

[7] Clearly, with abolition of the CAP budget, the UK (which is a net loser in 1995) stands to gain large additions to its income (i.e., US$3.5bn. of the US$8.8bn EV gain comes from the abolition of the CAP budget. In the case of the EU-14, being a net gainer in 1995, the opposite is the case where the EU-14 loses some income from abolition of the CAP budget.

In light of constraints on the preference heterogeneity parameter ($0 \leq \gamma_i \leq 1$) and in the absence of any detailed data, the value of γ_i (= 0.75) is chosen arbitrarily to reflect an extreme behavioural position relative to that of low preference heterogeneity under experiment (ii). A similar experiment is carried out under the UR low (experiment (i)) and high (experiment (v)) heterogeneity cases, although these results are not presented here. A full list of tables for this comparison is provided in appendix B. Figure 7.2 presents a full schematic interpretation of these experiments.

Once again, each imperfectly competitive sector is calibrated to a five firm concentration ratio with standard Cournot conjectural behaviour exhibited by each firm. Further experiments are carried out to isolate the effects of changes in imperfectly competitive concentration ratios as well as conjectural variation scenarios other than the standard Cournot case.

7.4 Overview of Preference Heterogeneity Conditions

The emphasis of this section is to examine the effects of preference heterogeneity. In experiment (ii), *all* agents exhibit low preference heterogeneity. The implications of this are twofold. Firstly, different representative varieties yield a narrower band of benchmark hierarchical utility levels. Secondly, proliferations/reductions in product variants in the choice set of representative varieties have negligible effects on consumer behaviour. Experiment (ii) is used as the comparator for experiment (iv), where *only UK* consumers exhibit high preference heterogeneity. Thus, preference orderings are 'strong', with favoured representative varieties yielding significantly larger levels of benchmark hierarchical utility. Moreover, the responsiveness of purchasing behaviour to proliferations/reductions in product variants is high, where variety perceptions (based on region of origin) are considered by UK consumers to be much more important.

7.4.1 Benchmark Representative Variety Preferences

This approach follows the work of Kaynak *et al.* (1983), Howard (1989), Morris and Hallaq (1990) and Juric *et al.* (1996) (see chapter 3), where consumers of food products have a strong tendency to favour the domestic variety. To capture this patriotic bias in the preference hierarchy using a suitably tailored criterion, hierarchical preferences for representative varieties are calibrated using trade shares by agent, where typically the domestic variety trade share is the largest.

	Region of Origin						
Representative Varieties	**UK**	**EU-14**	**USA**	**CAIRNS**	**LDC**	**ROW**	**Total**
Meat processing	0.735	0.068	0.003	0.164	0.025	0.005	1
Other meat processing	0.834	0.156	0.002	0.006	0.001	0.001	1
Other food processing	0.813	0.126	0.010	0.018	0.016	0.017	1
Milk processing	0.893	0.072	0.001	0.031	0.001	0.002	1
Sugar processing	0.546	0.054	0.004	0.013	0.379	0.004	1
Manufacturing	0.451	0.318	0.066	0.027	0.035	0.103	1
Services	0.943	0.022	0.015	0.003	0.005	0.012	1

Table 7.12: UK Private Consumer Preferences ($V_{i,r,s}$) by Representative Variety

	Region of Origin						
Representative Varieties	**UK**	**EU-14**	**USA**	**CAIRNS**	**LDC**	**ROW**	**Total**
Meat processing	0.537	0.119	0.005	0.287	0.043	0.009	1
Other meat processing	0.739	0.244	0.003	0.010	0.002	0.002	1
Other food processing	0.654	0.233	0.018	0.033	0.029	0.033	1
Milk processing	0.459	0.369	0.003	0.156	0.002	0.011	1
Sugar processing	0.853	0.018	0.001	0.004	0.123	0.001	1
Manufacturing	0.591	0.236	0.049	0.020	0.026	0.078	1
Services	0.973	0.010	0.007	0.002	0.002	0.006	1

Table 7.13: UK Public Consumer Preferences ($V_{i,r,s}$) by Representative Variety

The rankings for UK private and public consumers are given in tables 7.12 and 7.13 respectively. Larger rankings are associated with higher hierarchical benchmark utilities, where these utility differences are controlled by the heterogeneity parameter, γ_i. Note that in some sectors, the strength of this patriotic preference is considerably weaker than in other sectors. For example, UK manufacturing has relatively small private and public preference values (0.451 and 0.591 respectively), implying weaker patriotic preference

7.4.2 Varietal Diversity and Hierarchical Utility

Changes in UK domestic support and protection lead to resource reallocations which may result in proliferations/reductions in the number of domestic product variants. With UK consumers now exhibiting high preference heterogeneity, changes in diversity associated with a given representative variety result in significant movements in hierarchical utility which lead to changes in final and intermediate consumer demands. As a result, relative changes in demand patterns will lead to resource shifts in industry output. Moreover, in some sectors where patriotic preference is not strong in the benchmark case, large proliferations in second or even third favoured foreign representative varieties may have detrimental effects on UK domestic outputs and sectoral trade balances.

It must be made clear that *absolute* changes in varietal diversity from the 1995 benchmark data are as important as *relative* changes in varietal diversity between low and high preference heterogeneity scenarios. For example, a 25% absolute increase in varietal diversity under *both* sets of preference heterogeneity conditions will have a much more significant effect on hierarchical utility under high preference heterogeneity, although there is a zero percent *relative* change in variety between low and high preference heterogeneity scenarios.

On the other hand, it may be the case that the level of relative varietal diversity has fallen under high preference heterogeneity. It is still possible for hierarchical utility to rise relative to the low heterogeneity case, provided there is an absolute increase in the level of variety from the 1995 benchmark under high heterogeneity. Table 7.14 presents percentage changes in varietal diversity in absolute terms.

		Meat	**Other meat**	**Other food**	**Milk**	**Sugar**	**Manu**	**Service**
UK	**LOW**	-31.73	12.76	11.70	5.61	-29.35	7.24	10.56
	HIGH	-54.62	16.01	13.47	7.29	-49.60	4.77	11.25
EU-14	**LOW**	-6.44	13.98	9.37	8.83	1.74	9.06	10.57
	HIGH	-6.25	13.88	9.33	8.83	1.72	9.26	10.54
USA	**LOW**	25.17	20.37	13.91	18.75	0.18	9.11	14.99
	HIGH	25.17	20.36	13.93	18.74	0.23	9.16	14.99
CAIRNS	**LOW**	30.93	18.79	23.04	35.29	27.22	20.95	26.74
	HIGH	33.11	18.70	23.02	35.28	27.02	20.98	26.73
LDC	**LOW**	28.18	22.74	24.04	39.34	23.85	30.94	28.12
	HIGH	28.52	22.73	24.05	39.34	25.09	30.99	28.09
ROW	**LOW**	15.89	15.11	14.35	21.83	14.83	15.33	16.50
	HIGH	16.03	15.13	14.36	21.89	14.96	15.43	16.49

Table 7.14: Absolute percentage changes in the number of firms/product variants ($n_{i,r}$) under low (experiment (ii)) and high (experiment (iv)) preference heterogeneity

Thus, UK meat processing, sugar processing and manufacturing sectors show declines in varietal diversity *relative* to experiment (ii). On the other hand there are relative rises in the number of product variants compared to experiment (ii) in ‘other meat’, ‘other food’, ‘milk processing’, and ‘services’ sectors in the UK.

In the EU-14, changes in the number of firms are of the same *sign* as in the UK, except for sugar processing, where the number of firms increases. Under high preference heterogeneity, increases in LDC sugar variants have a greater impact on UK consumer choice, such that UK sugar processing imports from the LDCs increase which leads to further contractions in the UK sugar processing sector.

Relative changes in variety between low and high preference heterogeneity scenarios are small. Indeed, relative varietal diversity changes in all the non-EU regions are insignificant. Clearly, large resource re-allocative effects from high preference heterogeneity within a ‘small-country’ such as the UK, have negligible effects on non-UK sectors.

Changes in varietal diversity are reflected in the levels of hierarchical utility associated with the consumption of a representative variety (see section 6.1). Table 7.15 shows changes in UK hierarchical utility under experiment (iv) relative to experiment (ii) for final consumers.[8] In all cases, relative increases/decreases in the number of product variants of the domestic representative variety lead to associated increased/reduced hierarchical utility. For example, reference to table 7.14 shows that UK meat processing undergoes a reduction in varietal diversity of -22.89% relative to experiment (ii). This is reflected in table 7.15 by reductions in domestic hierarchical utility of 19.26% and 16.03% for private and public final consumers, respectively, relative to experiment (ii).

	Domestic private (zps_{irs}) and public (zgs_{irs}) hierarchical utility	
	zps_{irs}	zgs_{irs}
Meat processing	-19.26	-16.03
Other meat processing	5.21	4.88
Other food processing	4.36	3.84
Milk processing	2.52	1.68
Sugar processing	-15.35	-19.53
Manufacturing	1.08	1.28
Services	3.95	4.01

Table 7.15: UK private and public domestic representative hierarchical utility under experiment (iv) relative to experiment (ii) (% changes)

[8] Intermediate hierarchical utility ($zfs_{i,r,j,s}$) results are not tabulated since the number of subscripts (four) would require prohibitively large number of results tables.

In the case of UK manufacturing, the number of product variants is still rising in absolute terms under experiment (iv), although compared to the low heterogeneity experiment (ii) there is a fall. In this case, hierarchical utility *still* increases for the domestic product under high preference heterogeneity, where the importance of absolute increases in the number of product variants under high preference heterogeneity outweighs the relative varietal fall.

A separate but related hierarchical utility effect on final demands is the resulting changes in *composite* hierarchical utility. Composite hierarchical utility (see appendix 6.1, (A13)) is an expenditure weighted share of changes in hierarchical utility from the consumption of representative varieties from each region. Thus, changes in *domestic* varietal diversity (where domestic expenditure shares dominate), command changes in composite hierarchical utility in a given region. Table 7.16 shows changes in composite hierarchical utility in the UK. In most cases composite hierarchical utility shadows hierarchical utility movements in the dominant domestic variety (compare table 7.16 with table 7.15).

	Private (zp_{is}) and public (zg_{is}) hierarchical composite utility	
	$zp_{i,UK}$	$zg_{i,UK}$
Meat processing	-10.02	-3.27
Other meat processing	4.56	4.08
Other food processing	3.67	2.85
Milk processing	2.30	2.03
Sugar processing	-4.05	-14.94
Manufacturing	1.16	1.15
Services	3.73	3.90

Table 7.16: UK private and public domestic composite hierarchical utility under experiment (iv) relative to experiment (ii) (% change)

At constant prices, a proliferation in the level of *overall* (i.e., composite) variety (dominated by the *favoured* domestic variety) on each consumer's varietal spectrum lowers the per unit expenditure (i.e., composite price) necessary to attain the same amount of utility (section 6.1.5). Falls in the composite price of a particular commodity under Cobb-Douglas preferences (i.e., price elasticity = -1), will lead to rises in final demands for composite differentiated commodity 'j', which will also have positive effects on final demands for regional representative varieties of commodity 'j' in the nest.

Thus, in those sectors where proliferations occur, final demands will rise, which will further encourage pro-competitive effects and vice-versa. Moreover, following Francois *et al.* (1995) the implications of including non-nested Armington structures into representative variety demands enlarges the size of the market, where domestic and foreign firms compete *directly*, resulting in larger pro-competitive effects. Given the 'small country' assumption, significant reallocative effects within the UK have muted effects on foreign prices and outputs. It is for this reason that the results in the following sections concentrate mainly on the UK.

7.4.3 UK Final Demands

Table 7.17 shows changes in UK private and public agents' final demands for domestic and foreign representative varieties when moving from low to high preference heterogeneity in the UK under CAP abolition. In the UK 'other meat', 'other food', 'milk', 'manufacturing' and 'services' sectors, increases in domestic hierarchical utility (see table 7.15) lead to increases in domestic final demands (see table 7.17). For example, relative to experiment (ii), the UK 'other food' sector experiences a rise in varietal diversity of *1.77%* (calculated from table 7.14), which leads to an increase in final demand of 9.69% and 10.53% for private and public final consumers respectively.

		Meat	**Other meat**	**Other food**	**Milk**	**Sugar**	**Manu**	**Service**
DOMESTIC	**PHH**	-36.11	10.18	9.69	8.02	-43.81	1.30	4.83
	GHH	-33.45	10.96	10.53	1.23	-27.50	3.35	4.64
EU-UK	**PHH**	46.40	-3.44	-1.14	4.63	11.27	13.71	3.19
	GHH	8.95	1.51	4.13	7.02	86.87	12.94	2.37
USA-UK	**PHH**	193.84	-13.11	-3.94	6.28	36.84	8.55	4.01
	GHH	59.85	-10.21	-0.09	3.16	195.73	9.89	3.18
CAIRNS-UK	**PHH**	210.99	-8.46	-3.77	17.91	50.05	9.48	4.96
	GHH	109.47	-7.67	1.45	45.01	249.14	11.09	4.13
LDC-UK	**PHH**	176.62	-11.54	-4.18	8.06	99.36	14.19	7.59
	GHH	62.97	-9.05	1.51	4.30	277.69	16.17	6.24
ROW-UK	**PHH**	119.98	-7.90	-3.60	5.77	43.38	12.50	4.43
	GHH	33.21	-7.32	0.73	3.97	221.15	13.39	3.60

Table 7.17: Percentage change in final demands (private and public) by UK consumers under experiment (iv) compared to experiment (ii) (% changes)

Final Demands: PHH – Private HouseHold; GHH – Government HouseHold.

The opposite occurs in the UK 'meat' and 'sugar' sectors, where large reductions in varietal diversity result in significant falls in UK final demands relative to experiment (ii). For example, in the 'meat' sector, private and public final demands for the UK representative variety fall 36% and 33% respectively. Moreover, relative reductions in UK sugar and meat sector product varieties are accompanied by large absolute increases in rival foreign product variants (table 7.14). Thus, non-UK variety final demands for 'sugar' and 'meat' by UK consumers increase significantly relative to the low preference heterogeneity case (see table 7.17).

Increases in UK private and public final demands for domestic 'milk' (8% and 1%), 'manufacturing' (1% and 3%) and 'service' (5% for both) varieties are accompanied by concurrent increases in non-UK 'milk', 'manufacturing' and 'service' representative variety demands by UK agents relative to experiment (ii). This is due to falls in corresponding foreign sector market prices relative to the UK (due to significant rises in UK domestic factor prices - see table 7.20) when moving to the high preference heterogeneity experiment (ii).

Increases in UK final demands for non-UK manufacturing representative varieties are also linked to weak patriotic preference (section 7.4.1). Since UK manufacturing is weakly preferred by UK consumers, strong absolute proliferations in foreign manufacturing product varieties (table 7.14) leads to increased UK manufacturing imports by final consumers relative to the low heterogeneity case.

Percentage differences in *foreign demands* (not shown here) for UK products between the low and high heterogeneity experiments under each policy scenario are small for two reasons. Firstly, foreign demands are still characterised by low preference heterogeneity. Secondly, UK representative varieties typically have a low ranking value on foreign private and public consumers' varietal spectrums. Thus, proliferations/reductions in varietal diversity in the UK only has a small positive/negative effect on foreign purchasing decisions. Finally, all percentage changes in foreign demands are based on small benchmark UK export trade values.

7.4.4 UK Pro-Competitive and Output Effects

The mark-up characterises the size of the wedge between the output price and long run average variable costs of the firm. Thus, if the mark-up is 0.15, then average variable cost per unit is 85% of the output price. Clearly reductions in the mark-up narrow the gap between output price and average variable costs, which by implication leads to pricing policies closer to those of perfect competition.

	Regional Mark-Ups					
	UK	**EU-14**	**USA**	**CAIRNS**	**LDC**	**ROW**
Meat processing	0.152	0.187	0.189	0.187	0.187	0.165
Other meat processing	0.168	0.192	0.192	0.185	0.182	0.179
Other food processing	0.163	0.185	0.187	0.180	0.177	0.189
Milk processing	0.173	0.195	0.196	0.187	0.171	0.180
Sugar processing	0.136	0.190	0.173	0.185	0.185	0.162
Manufacturing	0.127	0.172	0.163	0.145	0.151	0.172
Services	0.190	0.195	0.195	0.191	0.191	0.195

Table 7.18: 1995 Regional Weighted Mark-Ups

The regional benchmark mark-ups for each sector, presented in table 7.18, are weighted by sales share over all markets (i.e. domestic and export), where domestic market mark-ups have a dominant weight. Table 7.19 presents percentage changes in UK industry output, output per firm and sectoral mark-ups in the UK in experiment (iv) compared to experiment (ii).

	Industry output	Firm output	Mark-up
Other agriculture	-0.93	-	-
Other primary	-1.80	-	-
Wheat	-2.76	-	-
Other grains	-3.25	-	-
Oilseeds	-1.49	-	-
Raw Sugar	-18.10	-	-
Cattle & sheep	-3.71	-	-
Raw milk*	3.21	-	-
Meat processing	-25.70	-3.76	4.09
Other meat processing	5.48	1.74	-1.21
Other food processing	2.22	0.24	-0.17
Milk processing	3.33	1.42	-0.99
Sugar processing	-25.64	-11.26	11.58
Manufacturing	-4.11	-1.41	1.07
Services	1.04	0.27	-0.18

Table 7.19: Industry/Firm Output and Mark-ups in the UK in experiment (iv) compared to experiment (ii) (% change).

(*Raw Milk is non-tradable)

Domestic demand changes have significant effects on sectoral output. For example, large falls in meat and sugar processing final (see table 7.17) and intermediate hierarchical demands result in 26% falls in sectoral outputs in both of these sectors relative to experiment (ii) (table 7.19). The same effect occurs in the opposite direction in the ‘other meat’, ‘other food’, ‘milk processing’ and ‘services’ sectors, which experience increases in industry output of 5%, 2%, 3% and 1% respectively.

In the UK manufacturing sector, significant increases in factor prices (see table 7.20), weak patriotic preference and significant manufacturing product proliferations in non-UK regions, leads to a contraction of 4% in UK manufacturing relative to experiment (ii). Significant output falls under high preference heterogeneity in primary ‘sugar’ and ‘cattle and sheep’ sectors are due to contractions in their downstream counterparts (i.e. ‘sugar’ and ‘meat’ processing), although raw milk production increases in response to rising intermediate input demands by the downstream milk processing sector. Falls in other primary sectors are largely due to resource reallocations in favour of expanding food processing and service sectors. Pro-competitive effects (i.e., mark-up falls) improve in the ‘other meat’ (-1.21%), ‘other food’ (-0.17%), ‘milk’ processing (-0.99%) and ‘services’ (-0.18%) sectors relative to experiment (ii). In all cases, changes in industry and firm output are all positively correlated relative to experiment (ii).

7.4.5 Price Effects

Table 7.20 shows percentage changes in prices in the UK compared to experiment (ii). Increases in raw milk production are sufficient to bid up the relative price of non-cereals land (3.79%) despite output contractions in all other non-cereals land using sectors (i.e., ‘other agriculture’, ‘sugar beet’, ‘cattle and sheep’, see table 7.19). The ‘cereals land’ factor price falls 0.17% relative to experiment (ii) since the cereals sectors also contract (see table 7.19) relative to the low heterogeneity case.

The natural resource factor is specific to the ‘other primary’ sector, and falls 15.57% relative to experiment (ii) due to reductions in output in this sector. In the perfectly mobile labour and capital markets, factor prices are bid up by expanding food processing and services sectors (particularly the unskilled labour endowment which is projected to fall in the UK), although these factor price rises are dampened by reductions in manufacturing primary factor demands. Market prices in all productive sectors increase due to rises in mobile and non-cereals land factor prices.

Aggregate consumer prices are a weighted average of domestic (which are much more heavily weighted) and imported goods prices. In all primary agricultural sectors, increases in aggregate consumer prices are primarily due to the increases in *domestic* market price rises which are passed onto consumers. However, in most imperfectly competitive sectors, under both policy scenarios, consumer price changes are now generally dictated by varietal effects through changes in composite hierarchical utility (see section 6.1.5). This contrasts with the model estimates in section 7.2, where preference heterogeneity is low.

	CAP Abolition	
	Market/factor Price	**Consumer Price**
Cereals Land	-0.17	-
Non-Cereals land	3.79	-
Unskilled labour	9.78	-
Skilled labour	8.83	-
Capital	8.48	-
Natural resources	-15.57	-
Other agriculture	2.21	1.89
Other primary	0.50	0.39
Wheat	2.96	1.16
Other grains	2.98	0.14
Oilseeds	3.18	0.11
Raw Sugar	3.29	0.03
Cattle & sheep	3.08	2.66
Raw milk	3.47	2.97
Meat processing	2.73	12.53
Other meat processing	1.24	-4.81
Other food processing	1.52	-3.56
Milk processing	1.50	-1.38
Sugar processing	3.23	3.55
Manufacturing	2.40	-0.56
Services	3.75	-1.62

Table 7.20: UK Prices under experiment (iv) compared to experiment (ii) (% changes)

For example, in table 7.16, composite hierarchical utility in the meat processing sector falls 10% and 3% for UK private and public final consumers respectively. As a result, this increases the composite consumer price 13%. In other words, since varietal diversity in the meat sector in the UK has fallen under high preference heterogeneity, the cost of attaining an extra unit of utility from meat processing consumption has risen 13% relative to experiment (ii).

Moreover, private and public household demands are characterised by Cobb-Douglas preferences, which implies a unitary price elasticity of demand. Hence, if the composite meat processing price rises, composite final demands for meat processing will fall which, in the absence of bilateral hierarchical and price effects, exerts downward pressure on all bilateral meat demands in the nest.

7.4.6 Trade Effects

Table 7.21 shows percentage changes in UK sector exports and imports in experiment (iv) relative to experiment (ii). Since non-UK preferences are still characterised by low preference heterogeneity, and the benchmark ranking of the UK representative variety on foreign varietal spectrums is typically very low, foreign imports of proliferating UK representative varieties do not change dramatically. Hence, the main source of relative changes in UK trade compared to experiment (ii) comes from relative demand and output changes from *within* the UK.

	CAP Abolition	
	Exports	**Imports**
Other agriculture	-13.80	4.76
Other primary	-1.71	-1.73
Wheat	-13.05	6.53
Other grains	-10.25	5.50
Oilseeds	-13.67	4.71
Sugar	-13.68	5.08
Cattle & sheep	0.07	11.65
Raw Milk*	-	-
Meat processing	-8.03	139.88
Other meat processing	-4.94	-6.50
Other food processing	-7.26	-4.74
Milk processing	-5.45	3.71
Sugar processing	-13.14	44.47
Manufacturing	-9.25	9.98
Services	-12.69	0.12
UK Total	-9.64	-
UK Total	-	7.54

Table 7.21: Percentage changes in sectoral trade under experiment (iv) compared to experiment (ii)
(*Raw milk is non-tradable).

Reductions in UK primary agricultural output (see table 7.19) under high preference heterogeneity result in falls in exports and rises in imports, although the exception is the primary livestock export market. Indeed, since the meat processing sector contracts significantly (-26% see table 7.19), intermediate inputs of cattle and sheep from this sector are affected accordingly. Since UK meat processing is the second biggest user of UK cattle and sheep production, some cattle and sheep output is diverted towards export markets, despite falls in domestic primary livestock production, resulting in a rise in exports of 0.07% relative to experiment (ii).

In the ‘other meat processing’, ‘other food processing’ and ‘service’ sectors, output increases (table 7.19) relative to experiment (ii) are met by strong relative increases in domestic final (table 7.17) and intermediate demands in both scenarios, which are in response to strong domestic product proliferations in these sectors. This has the effect of diverting exportable produce under the corresponding low heterogeneity scenarios onto domestic markets. Moreover, UK exports are also relatively less competitive due to relative market price rises (from relative factor price increases) in the UK under high preference heterogeneity.

Overall, relative reductions in final (table 7.17) and intermediate demands for ‘other meat’ and ‘other food’ leads to falls in sectoral imports of 6.5% and 4.74% respectively relative to experiment (ii). In the service sector, there are rises in final demands for foreign service products (table 7.17) leading to an overall increase in regional services imports of 0.12%.

Relative increases in final and intermediate demands under high heterogeneity conditions for milk processing, outstrip domestic output increases (table 7.19) which leads to reductions in exports as well as a concurrent increase in imports. Moreover, strong absolute proliferations in foreign milk product variants also increase imports (3.71%) of milk into the UK compared to the low heterogeneity case.

In the case of meat and sugar processing, relative falls in varietal diversity in the domestic sector, lead to increases in UK imports and concurrent reductions in UK exports. This effect is also increased by relative increases in UK market prices. Manufacturing sector exports also decline relatively due to significant increases in UK manufacturing prices, which reduce the competitiveness of the domestic representative variety. Moreover, the reduction in competitiveness coupled with weaker patriotic preference for UK manufacturing varieties and strong proliferations abroad, results in a 10% increase in manufacturing imports relative to experiment (ii). The bottom two rows of table 7.21 show that UK regional exports decline 9.64% with concurrent increases in UK imports of 7.54% relative to experiment (ii).

Table 7.22 presents benchmark 1995 sectoral trade balances in the UK. Table 7.23 shows the changes in sectoral trade balances and the UK trade balance under low and high preference heterogeneity conditions under CAP abolition as well as the relative change compared to the low heterogeneity case. The main result here is that the largest contributors to the deterioration in the UK trade balance are the manufacturing and services sectors.

Sector	**Trade Balance**	**Sector**	**Trade Balance**
Other agriculture	-5,669	**Meat processing**	16
Other primary	1,621	**Other meat processing**	-1,706
Wheat	390	**Other food processing**	-535
Other grains	70	**Milk processing**	-586
Oilseeds	-403	**Sugar processing**	-879
Sugar beet	-662	**Manufacturing**	-31,659
Cattle and sheep	153	**Services**	20,717
Raw milk*	-	**Total Balance**	-19,131

Table 7.22: Benchmark sectoral trade balances in the UK ($US million 1995)
(*Raw milk is non-tradable)

Sectors	**CAP Abolition**		
	Low (experiment (ii))	**High (experiment (iv))**	**Change: (iv) – (ii)**
Other agriculture	-209	-728	-519
Other primary	2,010	2,041	31
Wheat	92	30	-62
Other grains	-165	-217	-52
Oilseeds	-150	-178	-28
Sugar beet	-368	-409	-41
Cattle and sheep	-559	-582	-23
Raw milk	-	-	-
Meat processing	-3,912	-6,020	-2,108
Other meat processing	-713	-581	132
Other food processing	1,970	1,919	-51
Milk processing	-1,350	-1,466	-116
Sugar processing	-1,096	-1,682	-586
Manufacturing	-22,277	-57,745	-35,468
Services	-8,244	-15,349	-7,105
UK Trade Balance	-34,974	-80,969	-45,995

Table 7.23: Changes in UK sectoral and total trade balances under low and high preference heterogeneity ($US Millions 1995)

The changes in table 7.24 show the effects of introducing high preference heterogeneity on the aggregate exports and imports by other regions in the model aggregation. Note that each of the partner countries' trade balances improves at the cost of the UK when high preference heterogeneity is introduced into the model.

% Changes	EU-14	USA	CAIRNS	LDCs	ROW
Aggregate exports	0.70	0.36	0.28	0.42	0.73
Aggregate Imports	-0.85	-0.75	-0.48	-0.45	-1.11

Table 7.24: Aggregate exports and imports in other regions following the introduction of high preference heterogeneity (%)

7.4.7 Welfare Effects in the UK

Table 7.25 shows that UK equivalent variation (EV) increases significantly when high preference heterogeneity is introduced into UK final and intermediate demands. Global product proliferations and resulting relative increases in composite hierarchical utility (see table 7.17) in most UK sectors lead to falls in representative variety composite prices. Thus, with Cobb-Douglas final demands, composite representative variety purchases ($qp_{i,s}$, $qg_{i,s}$) increase significantly which influences regional utility (u_r) at the top of the utility tree.

Thus, in table 7.25, EV increases in the UK when varietal effects are more heavily weighted. The terms of trade in the UK improves under high preference heterogeneity. As expected, real food expenditure by private and public consumers increases under each scenario with increases in regional incomes and Cobb-Douglas preferences (income elasticity of unity). The agricultural household fares better under high preference heterogeneity as agriculturally owned factor prices (mainly labour and capital factors) are bid up by increased activity in imperfectly competitive sectors.

	CAP Abolition	
	Low (experiment (ii))	**High (experiment (iv)**
EV $billion	280.690	382.423
EV %	28.63	39.15
Terms of Trade (%)	3.12	4.64
Private food consumers EV $billion	20.002	26.471
Public food consumers EV $billion	0.680	0.900
Agric hhld EV $billions	0.199	2.151

Table 7.25: Welfare changes in the UK under the CAP scenario

Finally, the costs of the CAP to the UK are re-examined in table 7.35 by comparing the Uruguay Round and CAP abolition scenarios (experiments (v) and (iv)) under high preference heterogeneity. Table 7.26 compares these results with the low heterogeneity CAP costs in section 7.2.7. In a world characterised by high preference heterogeneity exhibited by UK consumers only, real income in the UK increases 1.08% which is greater than the 0.90% increase under low heterogeneity conditions. For the EU-14, there is no change in EV (due to the small country assumption). Thus, EU-15 real incomes increase 0.54% and 0.57% under low and high preference heterogeneity respectively. These welfare improvements are due to increases in varietal diversity which are now considered as more important (i.e., higher utility) by high preference heterogenous consumers in the UK.

		EV (US$billions)	EV (% change)
CAP low vs. UR low:	**UK**	8.814	0.90
	EU-14	17.770	0.29
	EU-15	**26.584**	**0.54**
CAP high vs. UR high:	**UK**	10.534	1.08
	EU-14	17.940	0.29
	EU-15	**28.474**	**0.57**

Table 7.26: The costs of the CAP under low and high preference heterogeneity

7.4.8 Further experiments

Further simulations were run to examine the effects of changes in the imperfectly competitive structure under conditions of low and high preference heterogeneity. In each case, the comparisons are between the Uruguay Round scenario and the CAP abolition scenario. In this way, a range of estimates may be found for the costs of the CAP.

The first set of experiments conducted involved calibrating the model to different numbers of firms in each imperfectly competitive sector (firm concentrations) in the benchmark. In the absence of any data on firm concentration levels to the sector/region aggregation of the model, the number of firms chosen for each sector in each experiment are the same, (3, 5, 10 and 15 firms under each experiment). Strategic conjecture between firms remains as standard Cournot, where firms do not react to output changes by rivals. The results of this experiment are displayed in table 7.27, where figures in parenthesis show the percentage change in EV from the corresponding UR case.

In the EU regions, the results clearly show that the higher the concentration ratio (i.e., smaller number of firms) in the benchmark, the larger are the potential welfare gains under both heterogeneity scenarios. This is because the initial mark-up distortions are larger which allows scope for larger pro-competitive effects and subsequent resource re-allocations when protection is removed in the imperfectly competitive sectors.

Under low preference heterogeneity, the costs of the CAP to the EU-15 range from 0.44% to 0.67%. Under high preference heterogeneity, these welfare results are slightly larger and range between 0.47% and 0.73%. The LDC and ROW regions experience welfare losses, which diminish with reductions in concentration levels. In the USA and CAIRNS region, the welfare gain rises very slightly under both scenarios with lower firm concentration ratios. Finally, the global welfare results are also larger under higher firm concentration ratios (i.e., global pro-competitive effects are larger), where the EV range *over both heterogeneity* scenarios is between 0.05% and 0.09% of global GDP.

	N=3	N=5	N=10	N=15
Low heterogeneity				
UK	11.540 (1.18)	8.814 (0.90)	8.378 (0.86)	8.023 (0.82)
EU-14	21.360 (0.34)	17.770 (0.29)	14.510 (0.24)	13.651 (0.22)
EU-15	**32.900 (0.67)**	**26.584 (0.54)**	**22.888 (0.46)**	**21.674 (0.44)**
USA	0.087 (0.00)	0.173 (0.00)	0.340 (0.00)	0.390 (0.00)
CAIRNS	1.400 (0.05)	2.100 (0.09)	2.400 (0.11)	2.440 (0.11)
LDC	-3.783 (-0.14)	-2.610 (-0.09)	-1.550 (-0.06)	-1.380 (-0.05)
ROW	-13.640 (-0.19)	-10.820 (-0.15)	-9.830 (-0.14)	-9.146 (-0.13)
Global EV	**16.964 (0.07)**	**15.424 (0.06)**	**14.248 (0.06)**	**13.978 (0.05)**
High heterogeneity				
UK	12.424 (1.28)	10.534 (1.08)	9.849 (1.01)	9.633 (0.99)
EU-14	24.340 (0.39)	17.940 (0.29)	14.660 (0.24)	13.940 (0.23)
EU-15	**36.764 (0.73)**	**28.474 (0.57)**	**24.509 (0.49)**	**23.573 (0.47)**
USA	0.064 (0.00)	0.120 (0.00)	0.290 (0.00)	0.330 (0.00)
CAIRNS	1.700 (0.08)	2.260 (0.10)	2.620 (0.12)	2.670 (0.13)
LDC	-5.820 (-0.21)	-2.660 (-0.10)	-1.550 (-0.06)	-1.380 (-0.05)
ROW	-11.170 (-0.16)	-11.090 (-0.16)	-10.050 (-0.14)	-9.780 (-0.14)
Global EV	**21.538 (0.09)**	**17.104 (0.07)**	**15.819 (0.06)**	**15.413 (0.06)**

Table 7.27: The Costs of the CAP ($US billions and % change in parenthesis) with different concentration ratios under both sets of heterogeneity conditions

A second set of experiments explores the implications of changes in strategic conjecture between firms in each industry. A recapitulation of the structure of the mark-up (see section 6.2.1) reveals that price-cost ratios vary inversely with the number of firms and the market elasticity of demand, where Ω/N ranges between zero (perfect competition) and one (pure collusion). In the absence of detailed data on collusion levels throughout the imperfectly competitive sectors of the world, low and high arbitrary values of

Ω/N (0.05 and 0.7 respectively) are employed in the CAP abolition scenario under both heterogeneity conditions, and compared to the corresponding UR case.

As before, the aim is to acquire a range of CAP costs under different conditions of collusion. The EV results (US$ billions 1995) are presented in table 7.28, where figures in parenthesis show the percentage change in EV from the UR case under both sets of heterogeneity conditions. For completeness, the standard Cournot conjecture (1/N) results are included in the table. In the case where rivals' reactions to a given firm's increase in output (0.05) are minimal, the UK and the EU-14 gain $US8bn (0.81%) and $US13bn (0.20%), respectively from abolition of the CAP, with the EU-15 gaining $US21bn (0.42%) of EU GDP. With the increased effects of variety, the high heterogeneity case leads to larger EU-15 welfare gain of $US26bn (0.52%), with most of this coming from the UK with a gain of $US14bn (1.39%).

Conjectural Variation Parameter	= 0.05	=1/N	= 0.70
Low Heterogeneity			
UK	7.910 (0.81)	8.814 (0.90)	7.171 (0.74)
EU-14	12.690 (0.20)	17.770 (0.29)	-1.321 (-0.02)
EU-15	**20.600 (0.42)**	**26.584 (0.49)**	**5.850 (0.12)**
USA	0.420 (0.01)	0.173 (0.00)	7.860 (0.12)
CAIRNS	2.490 (0.10)	2.100 (0.09)	11.690 (0.49)
LDC	-1.210 (-0.04)	-2.610 (-0.09)	5.460 (0.19)
ROW	-9.260 (-0.13)	-10.820 (-0.15)	10.390 (0.14)
Global EV	**13.040 (0.05)**	**15.424 (0.06)**	**41.250 (0.16)**
High Heterogeneity			
UK	13.537 (1.39)	10.534 (1.08)	11.784 (1.21)
EU-14	12.670 (0.20)	17.940 (0.29)	-2.802 (-0.05)
EU-15	**26.207 (0.52)**	**28.474 (0.57)**	**8.982 (0.18)**
USA	0.290 (0.00)	0.120 (0.00)	6.890 (0.11)
CAIRNS	4.320 (0.19)	2.260 (0.10)	11.980 (0.53)
LDC	-1.380 (-0.05)	-2.660 (-0.10)	5.100 (0.19)
ROW	-10.300 (-0.15)	-11.090 (-0.16)	7.580 (0.11)
Global EV	**19.137 (0.08)**	**17.104 (0.07)**	**40.532 (0.17)**

Table 7.28: Changes ($US billions and % change in parenthesis) in EV under different conjectures compared to the 'base case'

In the case of highly collusive sectors, the EU-14 actually *loses* slightly from abolition of the CAP relative to the UR case, although the UK's gains ($US7bn (0.74%) and $US12bn (1.21%) increases in real income under low and high preference heterogeneity, respectively) results in relative real income welfare gains to the EU-15 of

$US6bn (0.12%) and $US9bn (0.18%) under low and high heterogeneity conditions, respectively. The other notable result is that all non-EU regions gain under the high collusion scenario, which leads to significant global welfare gains under both low and high preference heterogeneity, respectively.

7.5 Conclusions

Estimates in the CGE literature in the 1980s placed the cost of the CAP between 0.27% and 2.7% of EU GDP. In the 1990s, these estimates have been revised downwards, with gains somewhere between 0.22% and 0.8% of EU GDP (see chapter 1). The corresponding estimate from sub-section 7.2.7, measured against the UR scenario (experiment (i)), places the cost of the CAP as 0.54% of EU GDP with welfare gains to the UK and EU-14 regions of 0.90% and 0.29% of regional GDP, respectively.

Despite contractions in EU agricultural sectors under CAP abolition, land use patterns suggest that cereals production is still of considerable relative importance in primary agricultural sectors. Moreover, the pattern of sugar production moves in favour of the EU-14 and away from the UK. Raw milk production also increases considerably in both regions relative to the UR case, where the reduction in market prices (from removal of the quota) attracts considerable increases in domestic final demand.

Under CAP abolition, the UK trade balance deteriorates (*US$4bn*) relative to the UR case, although in the EU-14 there is an improvement (*US$2bn*). In the UK, considerable falls/rises in agri-food exports/imports are not compensated for by improvements in the manufacturing trade balance, as in the EU-14. Removal of all forms of support under CAP abolition reduces agricultural household incomes by US$11bn and US$61bn for the UK and EU-14, respectively, compared to the UR scenario. Finally, the analysis suggests that abolition of the CAP saves the EU US$34bn in resource and import tariff costs, of which approximately US$8bn of this saving accrues to the UK.

Sections 7.3. and 7.4 examined the impacts of high preference heterogeneity in the UK under the CAP abolition scenario. Relative (to the UR case) and absolute (positive percentage change) product proliferations occur in the 'other meat', 'other food', 'milk' and 'services' sectors. In the 'meat' ('manufacturing') sector, varietal diversity is falling (rising) under CAP abolition, although by less than under the corresponding low heterogeneity case. In the ‘sugar’ sector, there is a significant relative and absolute (i.e., negative percentage change) fall in varietal diversity.

There are two main price effects under these policy experiments. Firstly, proliferations/reductions in domestic variety generally dictates composite representative variety price falls/rises which leads to increases/falls in final demands in the UK. Secondly, increases in factor prices in response to large sectoral supply shifts are passed onto output prices, which result in reduced competitiveness in many UK tradable export markets.

The net effect in the UK is that, while in many cases, increases in UK final patriotic demands encourages increases in domestic sectoral outputs, many of these sectors may also suffer trade balance deteriorations relative to the low heterogeneity case. Examples of this include the ‘other meat’, ‘other food’, ‘milk’ and ‘services’ sectors.

In the case of manufacturing, weak patriotic benchmark preferences, significant foreign manufacturing product proliferations and factor/output price rises in the UK contribute to significant relative falls in manufacturing output (4.11%) and exports (9.25%) and a large concurrent increase in the sectoral trade balance deficit (US$46bn). The importance of this is evident when examining the UK trade balance, where the manufacturing sector accounts for much of the deterioration in the overall UK trade deficit.

In terms of welfare, proliferations in many UK sectors, as well as strong global product proliferations, result in increases in composite hierarchical utility to UK final and intermediate consumers. With reductions in per unit expenditure (i.e., composite representative variety prices) to achieve the same level of utility, composite utilities rise significantly under Cobb-Douglas preferences, which leads to significant increases in regional utility in the top nest of the utility tree.

Further, comparison of CAP abolition with the Uruguay Round scenario under high preference heterogeneity in the UK only, shows that the UK gains 1.08% of GDP, with the EU-14 gaining 0.29% of GDP (the same as the low preference heterogeneity case). As a result, the EU-15 gains 0.57% of GDP from CAP abolition under high preference heterogeneity, which is greater than the corresponding low heterogeneity case (0.53%). The improvement to the EU-15 comes from the UK, where the utility gain from richer varietal diversity to UK consumers (on a global scale) gives an extra gain of 0.18% of UK GDP from CAP abolition compared to the corresponding low heterogeneity scenario.

Further EV welfare experiments show that increases in firm concentration ratios yield higher relative welfare gains from CAP abolition to the EU regions, with gains ranging from 0.44%-0.67% of EU-15 GDP for low preference heterogeneity, and 0.47%-0.73% of EU-15 GDP under high preference heterogeneity. Similarly, global gains increase from between 0.05%-0.09% of GDP over both heterogeneity scenarios. Finally, under different conjectural variation scenarios, higher collusion results in smaller welfare gains to the EU-15, mainly due to relative falls in EV for the EU-14 relative to the UR case. Global gains are, however, significant under high collusion, with all non-EU regions experiencing welfare gains.

Appendix A: The Cost of the Agenda 2000 Reforms compared to the UR scenario. The numbering of the tables in the appendix corresponds to those in the main text.

	UK	EU-14	USA	CAIRNS	LDCs	ROW
Other agriculture	0.86	0.13	0.04	0.05	0.01	0.01
Other primary	-0.03	-0.03	0.00	0.01	0.00	0.00
Wheat	3.41	2.43	-0.50	-0.61	-0.22	-0.18
Other grains	4.20	1.91	-0.21	-0.12	-0.06	-0.14
Oilseeds	-0.28	-2.23	0.29	0.22	0.04	0.25
Raw Sugar	0.00	0.00	0.04	0.05	0.04	0.01
Cattle & sheep	4.59	5.39	-0.17	-0.53	-0.19	-0.67
Raw milk	1.50	1.50	-0.01	-0.13	0.00	-0.20
Meat processing	1.48	4.39	-0.09	-0.69	-0.36	-0.14
Other meat processing	2.88	0.29	0.01	-0.02	-0.04	-0.02
Other food processing	0.49	0.28	-0.01	0.01	-0.01	-0.01
Milk processing	1.49	1.36	-0.01	-0.18	-0.12	-0.35
Sugar processing	0.04	0.09	0.03	0.05	0.04	0.04
Manufacturing	-0.09	-0.08	0.01	0.04	0.03	0.03
Services	-0.11	-0.05	-0.01	-0.01	0.00	0.00

Table A7.2: Percentage changes in sectoral output under Agenda 2000

	UK	EU-14	USA	CAIRNS	LDCs	ROW
Other agriculture	-0.15	0.05	-0.07	-0.09	-0.04	-0.06
Other primary	-0.01	-0.01	0.00	-0.01	-0.01	-0.01
Wheat	-3.42	-2.50	-0.14	-0.09	-0.04	-0.07
Other grains	-3.25	-2.37	-0.09	-0.09	-0.03	-0.07
Oilseeds	0.50	1.64	-0.05	-0.07	-0.07	-0.04
Raw Sugar	0.22	0.77	-0.09	-0.06	-0.04	-0.06
Cattle & sheep	-6.93	-6.89	-0.07	-0.08	-0.04	-0.07
Raw milk	-3.22	-2.92	-0.06	-0.06	-0.03	-0.06
Meat processing	-1.58	-3.34	-0.05	-0.01	-0.01	-0.06
Other meat processing	-1.68	-0.34	-0.04	-0.07	-0.04	-0.06
Other food processing	-0.25	-0.16	-0.04	-0.05	-0.04	-0.04
Milk processing	-1.69	-1.73	-0.04	-0.04	-0.03	-0.04
Sugar processing	0.07	0.14	-0.06	-0.07	-0.04	-0.05
Manufacturing	0.05	0.06	-0.02	-0.02	-0.01	-0.02
Services	0.06	0.05	-0.01	-0.02	-0.01	-0.02

Table A7.3: Percentage changes in sectoral market prices under Agenda 2000

	UK	EU-14	USA	CAIRNS	LDCs	ROW
Other agriculture	-0.13	0.03	-0.06	-0.09	-0.04	-0.06
Other primary	0.00	0.00	-0.01	-0.01	0.00	0.00
Wheat	-2.44	-2.40	-0.13	-0.10	-0.11	-0.08
Other grains	-1.91	-2.11	-0.08	-0.09	-0.05	-0.07
Oilseeds	0.50	0.27	-0.04	-0.07	-0.03	-0.01
Raw Sugar	-0.04	0.73	-0.05	-0.07	-0.04	-0.06
Cattle & sheep	-6.29	-6.13	-0.08	-0.09	-0.05	-0.11
Raw milk	-3.22	-2.92	-0.07	-0.06	-0.03	-0.06
Meat processing	-1.26	-3.07	-0.05	-0.01	-0.06	-0.07
Other meat processing	-1.47	-0.34	-0.05	-0.07	-1.04	-0.06
Other food processing	-0.22	-0.15	-0.03	-0.05	-0.04	-0.04
Milk processing	-1.56	-1.68	-0.03	-0.05	-0.05	-0.06
Sugar processing	0.02	0.14	-0.05	-0.07	-0.04	-0.04
Manufacturing	0.04	0.04	-0.01	-0.02	-0.01	-0.01
Services	0.05	0.05	-0.02	-0.02	0.00	-0.02

Table A7.4: Percentage changes in aggregate consumer prices under Agenda 2000

	UK	EU-14	USA	CAIRNS	LDCs	ROW
Other agriculture	0.97	-0.38	0.13	0.27	0.08	0.20
Other primary	0.00	-0.04	-0.01	0.00	-0.02	-0.02
Wheat	10.38	10.70	-0.97	-1.97	-3.79	-2.72
Other grains	10.37	6.12	-0.79	-1.18	-1.08	-2.75
Oilseeds	-1.38	-8.43	0.83	1.39	0.53	1.38
Raw Sugar	-0.80	-0.46	0.09	0.17	0.50	0.06
Cattle & sheep	21.17	14.50	-13.17	-2.21	-2.36	-21.38
Raw milk	-	-	-	-	-	-
Meat processing	3.20	7.31	-1.51	-4.43	-4.27	-9.20
Other meat processing	6.92	-0.89	-0.21	-0.23	-0.46	-0.60
Other food processing	0.85	0.43	-0.12	-0.01	-0.14	-0.15
Milk processing	1.34	1.41	-0.37	-1.65	-1.74	-4.62
Sugar processing	-0.01	-0.20	0.09	0.17	0.49	0.67
Manufacturing	-0.13	-0.24	0.05	0.07	0.06	0.08
Services	-0.20	-0.21	0.10	0.14	0.12	0.09

Table A7.5: Percentage changes in aggregate sectoral exports under Agenda 2000

	UK	EU-14	USA	CAIRNS	LDCs	ROW
Other agriculture	0.43	0.34	-0.04	-0.09	0.05	-0.03
Other primary	-0.09	-0.05	0.00	0.03	0.01	-0.01
Wheat	-0.62	-0.81	-0.17	0.30	1.22	0.70
Other grains	0.56	-2.16	0.14	0.18	0.50	0.37
Oilseeds	0.52	1.78	-0.01	-0.06	-0.25	0.08
Raw Sugar	0.66	2.31	-0.02	-0.09	0.08	0.05
Cattle & sheep	-3.48	-9.66	0.13	0.86	5.75	3.31
Raw milk	-	-	-	-	-	-
Meat processing	0.50	-11.51	-0.14	0.27	2.70	0.39
Other meat processing	-4.01	1.39	0.32	0.24	-0.38	0.39
Other food processing	-0.15	-0.05	0.26	0.10	0.20	0.21
Milk processing	-0.28	-2.52	1.13	1.12	0.60	1.15
Sugar processing	0.57	1.39	-0.03	-0.11	0.05	-0.06
Manufacturing	0.03	0.19	-0.06	-0.08	-0.05	-0.13
Services	0.11	0.27	-0.16	-0.14	-0.04	-0.13

Table A7.6: Percentage changes in aggregate sectoral imports under Agenda 2000

	UK	EU-14
	AG2000	**AG2000**
Aggregate Factor Price		
Non-Cereals Land	4.24	2.39
Cereals Land	-3.50	-1.78
Quantity Demanded		
Other Agriculture	-0.06	-0.30
Wheat	15.31	11.45
Other Grains	15.12	11.77
Oilseeds	-2.01	-7.10
Raw Sugar	-0.62	-0.33
Cattle & Sheep	-0.40	0.55
Raw Milk	0.63	0.90
Non-Cereals Land Area	0.00	0.00
Cereals Land Area	13.14	8.84

Table A7.7: Percentage Change in land use and aggregate factor prices under the Agenda 2000 scenario

UK Region				
	1995 data	UR	AG2000	AG2000 vs. UR
Cereals Land	324	369	403	34
Non Cereals Land	4,252	5,205	5,386	181
Natural Resources	0	0	0	0
Skilled Labour	473	488	492	4
Unskilled Labour	10,797	12,987	13,112	125
Capital	2,983	2,975	2,566	-409
Depreciation	2,033	2,036	2,369	333
NET FACTOR INCOME	**16,796**	**19,988**	**19,590**	**-398**
Headage Payments	584	525	1,398	873
Set-Aside Compensation:				
Wheat	201	201	194	-7
Other Grains	111	111	107	-4
Oilseeds	71	71	68	-3
Price Support Compensation:				
Wheat	1,273	1,463	1,750	287
Other Grains	707	766	925	159
Oilseeds	276	340	266	-74
Quota Rent:				
Raw Milk	1,633	5,654	5,472	-182
TOTAL	**21,652**	**29,119**	**29,770**	**651**

Table A7.8: Decomposition of Agricultural Producer and Asset Holder's Regional Income in the UK ($US millions)

UK Region				
	1995 data	UR	AG2000	AG2000 vs. UR
Cereals Land	2,452	2,349	2,606	257
Non Cereals Land	31,811	42,630	43,392	762
Natural Resources	0	0	0	0
Skilled Labour	6,433	6,816	6,850	34
Unskilled Labour	94,640	117,148	117,729	581
Capital	31,685	32,470	30,896	-1,574
Depreciation	22,894	22,906	23,059	153
NET FACTOR INCOME	**144,247**	**178,507**	**178,414**	**-93**
Headage Payments	2,083	1,955	5,068	3,113
Set-Aside Compensation:				
Wheat	1,057	1,057	1,016	-41
Other Grains	1,100	1,100	1,057	-43
Oilseeds	613	613	590	-23
Price Support Compensation:				
Wheat	6,694	6,752	8,259	1,507
Other Grains	6,977	6,050	7,621	1,571
Oilseeds	2,672	2,587	1,948	-639
Quota Rent:				
Raw Milk	9,895	32,777	31,737	-1,040
TOTAL	**175,338**	**231,398**	**235,803**	**4,405**

Table A7.9: Decomposition of Agricultural Producer and Asset Holder's Regional Income in the EU-14 ($US millions)

US $millions	1995 data	UR	AG2000
UK			
CAP Expenditure	5,756	4,359	5,003
Tariff Revenue	804	787	772
Resource Contribution	8,952	7,103	8,027
Net Contribution	-4,000	-3,531	-3,796
EU-14			
CAP Expenditure	36,911	29,992	33,265
Tariff Revenue	2,799	2,569	2,468
Resource Contribution	30,112	23,892	27,001
Net Contribution	4,000	3,531	3,796
EU-15			
CAP Expenditure	42,667	34,351	38,268
Tariff Revenue	3,603	3,356	3,240
Resource Contribution	39,064	30,995	35,028
Net Contribution	0	0	0

Table A7.10: Changes in the CAP Budget ($millions 1995)

	Agenda 2000	
	EV ($mill) change from UR scenario	EV (% change)
UK	-744	-0.08
EU-14	-450	-0.00
EU-15	**-1,194**	**-0.02**
USA	-230	-0.01
CAIRNS	-280	-0.01
LDCs	-40	-0.00
ROW	-190	-0.00
Total EV	**-1,934**	**-0.01**

Table A7.11: Changes in EV ($million and %) under the Agenda 2000 reforms

Appendix B: An evaluation of the cost of high preference heterogeneity under the UR simulation (i.e., experiment (v) vs. experiment (i)). The numbering of the tables in the appendix corresponds to those in the main text.

		Meat	Other meat	Other food	Milk	Sugar	Manu	Service
UK	**LOW**	3.42	14.47	10.04	-3.58	-4.73	6.97	10.50
	HIGH	2.24	17.81	11.84	-4.73	-10.45	4.37	11.16
EU-14	**LOW**	9.17	15.21	9.54	-0.41	1.72	8.51	10.60
	HIGH	9.19	15.10	9.51	-0.41	1.71	8.71	10.57
USA	**LOW**	24.80	20.46	14.01	18.51	0.29	9.16	14.98
	HIGH	24.79	20.45	14.03	18.50	0.30	9.21	14.98
CAIRNS	**LOW**	24.40	18.85	23.47	33.70	27.22	21.29	26.72
	HIGH	24.60	18.82	23.48	33.92	27.20	21.36	26.72
LDC	**LOW**	25.10	22.57	24.13	35.33	21.37	31.25	28.14
	HIGH	25.13	22.57	24.15	35.40	21.68	31.32	28.11
ROW	**LOW**	13.93	14.87	14.61	19.25	12.28	15.37	16.50
	HIGH	13.94	14.88	14.61	19.33	12.28	15.47	16.49

Table B7.14: Absolute percentage changes in the number of firms/product variants ($n_{i,r}$) under low (experiment (i)) and high (experiment (v)) preference heterogeneity

	Domestic private (zps_{irs}) and public (zgs_{irs}) hierarchical utility	
	zps_{irs}	zgs_{irs}
Meat processing	0.70	0.57
Other meat processing	5.79	5.41
Other food processing	3.85	3.38
Milk processing	-1.67	-1.12
Sugar processing	-2.83	-3.67
Manufacturing	0.99	1.18
Services	3.92	3.99

Table B7.15: UK private and public domestic representative hierarchical utility under experiment (v) relative to experiment (i) (% change)

	Private (zp_{is}) and public (zg_{is}) hierarchical composite utility	
	$zp_{i,UK}$	$zg_{i,UK}$
Meat processing	1.01	1.67
Other meat processing	5.06	4.52
Other food processing	3.23	2.55
Milk processing	-1.43	0.21
Sugar processing	0.31	-2.85
Manufacturing	1.09	1.07
Services	3.70	3.87

Table B7.16: UK private and public domestic composite hierarchical utility under experiment (v) relative to experiment (i) (% change)

		Meat	Other meat	Other food	Milk	Sugar	Manu	Service
DOMESTIC	**PHH**	2.32	10.21	9.13	1.74	-4.59	0.92	4.71
	GHH	-2.84	10.56	9.42	-6.35	5.62	2.96	4.58
EU-UK	**PHH**	9.72	-4.87	0.37	21.40	3.54	13.47	3.32
	GHH	5.74	0.45	5.28	6.73	14.47	13.32	2.52
USA-UK	**PHH**	17.22	-12.59	-2.08	48.35	5.07	9.11	4.13
	GHH	7.69	-10.09	0.99	18.76	22.94	9.96	3.33
CAIRNS-UK	**PHH**	31.19	-7.39	-1.37	70.15	8.86	10.31	5.30
	GHH	32.38	-5.82	2.94	56.72	32.33	11.29	4.49
LDC-UK	**PHH**	14.45	-10.18	-1.76	58.46	32.85	15.13	7.97
	GHH	9.27	-8.18	2.84	23.35	39.18	15.78	6.63
ROW-UK	**PHH**	8.86	-7.12	-1.66	136.46	6.54	13.18	4.53
	GHH	3.96	-5.74	1.79	14.43	27.37	13.38	3.72

Table B7.17: Percentage change in final demands (private and public) by UK consumers under experiment (v) compared to experiment (i). (% change)

Final Demands: PHH – Private HouseHold; GHH – Government HouseHold.

	Industry output	Firm output	Mark-up
Other agriculture	0.51	-	-
Other primary	-1.81	-	-
Wheat	-2.19	-	-
Other grains	-3.46	-	-
Oilseeds	-1.88	-	-
Raw Sugar	0.00	-	-
Cattle & sheep	0.48	-	-
Raw milk*	0.00	-	-
Meat processing	-0.60	0.58	-0.51
Other meat processing	5.58	1.70	-1.17
Other food processing	2.51	0.51	-0.37
Milk processing	-0.71	0.49	-0.39
Sugar processing	-6.96	-1.11	0.91
Manufacturing	-4.32	-1.48	1.14
Services	0.96	0.23	-0.17

Table B7.19: Industry/Firm Output and Mark-ups in the UK in experiment (v) compared to experiment (i) (% change)

(*Raw Milk is non-tradable)

	Uruguay Round	
	Market/factor Price	Consumer Price
Cereals Land	-2.76	-
Non-Cereals land	11.51	-
Unskilled labour	9.75	-
Skilled labour	8.76	-
Capital	8.45	-
Natural resources	-15.80	-
Other agriculture	-2.72	2.35
Other primary	0.48	0.37
Wheat	3.10	1.21
Other grains	3.07	0.14
Oilseeds	3.21	0.06
Raw Sugar	3.92	-0.01
Cattle & sheep	3.31	3.38
Raw milk	4.18	7.43
Meat processing	2.01	-0.03
Other meat processing	1.40	-5.27
Other food processing	1.43	-3.23
Milk processing	3.76	5.41
Sugar processing	-0.71	-0.96
Manufacturing	2.45	-0.44
Services	3.77	-1.56

Table B7.20: UK Prices under experiment (v) compared to experiment (i) (% change)

	Uruguay Round	
	Exports	Imports
Other agriculture	-17.31	6.55
Other primary	-1.59	-1.93
Wheat	-12.76	7.62
Other grains	-12.30	6.39
Oilseeds	-21.01	5.57
Sugar	12.61	1.21
Cattle & sheep	-14.20	11.37
Raw Milk*	-	-
Meat processing	-7.37	18.54
Other meat processing	-5.42	-7.41
Other food processing	-6.29	-2.78
Milk processing	-10.17	23.19
Sugar processing	2.93	12.97
Manufacturing	-9.53	10.25
Services	-12.79	0.21
UK Exports	-9.84	-
UK Imports	-	7.27

Table B7.21: Percentage changes in sectoral trade under experiment (v) compared to experiment (i)
(*Raw milk is non-tradable).

UK Regional sectors	Uruguay Round		
	Low (experiment (i))	High (experiment (v))	Change: (v) – (i)
Other agriculture	162	-524	-686
Other primary	2,196	2,284	88
Wheat	122	59	-63
Other grains	-8	-69	-61
Oilseeds	-78	-111	-33
Sugar beet	-218	-223	-5
Cattle and sheep	-62	-118	-56
Raw milk	-	-	-
Meat processing	-861	-1,205	-344
Other meat processing	-482	-331	151
Other food processing	904	708	-196
Milk processing	-885	-1,458	-573
Sugar processing	-362	-514	-152
Manufacturing	-23,622	-60,115	-36,493
Services	-7,869	-15,171	-7,302
Total UK Trade Balance	-31,062	-76,790	-45,728

Table B7.23: Changes in UK sectoral and total trade balances under low and high preference heterogeneity ($US Millions 1995)

% Changes	EU-14	USA	CAIRNS	LDC	ROW
Aggregate exports	0.71	0.37	0.24	0.40	0.72
Aggregate Imports	-0.87	-0.73	-0.53	-0.46	-1.07

Table B7.24: Aggregate exports and imports in other regions under experiment (v) compared to experiment (i). (% change)

	Low (experiment (i))	High (experiment (v))	Change (v) – (i)
EV $billion	270.877	371.888	101.011
EV %	27.73	38.07	10.34
Terms of Trade (%)	2.94	4.51	1.57
Private food consumers EV $billion	19.507	25.876	6.369
Public food consumers EV $billion	0.663	0.880	0.217
Agric hhld EV $billions	4.170	6.224	2.054

Table B7.25: Welfare changes under the UR scenario

Chapter 8

Conclusions

8.1 Summary

At the outset, the CAP was seen as the centre piece of a more co-operative Europe seeking to restore political and economic stability in the aftermath of the Second World War. However, the CAP's effectiveness in fulfilling the criteria laid down under the Treaty of Rome was mixed. In some respects, it was judged to be an unbridled success (greater food security and agricultural productivity), although in others, it was heavily criticised (higher food prices, oversupply). In more recent times, it is the latter which has created further cause for concern. Indeed, from the late 1970s, the EU became a net-exporter in most commodities, and budgetary costs associated with export restitutions and stock piling soared.

Although the CAP has evolved to alleviate some of these problems, it still remains under internal and external political pressure to reform, particularly in light of the upcoming Millennium World Trade Organisation (WTO) Round negotiations. There is also internal pressure to reduce support from a budgetary viewpoint, and looking slightly further afield, there are the challenges of expansion to the East.

Much of the conventional wisdom relating to the policy questions surrounding the CAP, seems to support the notion of further reductions in EU agricultural support. Comparative advantage gains in EU non-food related sectors will lead to real income gains as well as increases in world prices (Anderson and Tyers, 1988, 1993). Multi-regional computable general equilibrium (CGE) model structures have played a particularly important role in addressing these types of questions, where developments in computational facility have led to a burgeoning of CGE applications in the trade literature over the last fifteen years or so.

This study develops the standard CGE model approach in several ways. Firstly, the application here draws on evidence from the agri-business and marketing literature which assesses the influence of country of origin on food product preferences (Kaynak *et al.*, 1983; Howard, 1989; Morriss and Hallaq, 1990; Juric *et al.*, 1996), where consumers generally favour the home variety over the foreign substitute (patriotic preference). Thus, using a suitably tailored aggregation of the GTAP database biased towards primary agricultural and food processing sectors, a model was developed to incorporate the neo-Hotelling preference structure (Lancaster, 1979, 1984; Helpman, 1981; Economides, 1984) to examine the influence of hierarchical product preferences (with patriotic preference behaviour) in the context of the welfare costs of the CAP. This contrasts with previous CGE studies of the CAP which measure the more traditional specialisation and efficiency gains associated with perfectly competitive market structures.

A related issue is the influence of preference heterogeneity on CAP costs. More specifically, the degree of perceived product differentiation is controlled, where consumers exhibit a clearly defined ranking structure, with favoured representative varieties yielding higher levels of benchmark hierarchical utility. Moreover, the responsiveness of purchasing behaviour to proliferations/reductions in product variants is high, where variety level perceptions (based primarily on region of origin) are of considerable importance. This is contrasted with preference structures exhibiting more homogeneous preferences. In this case, consumer perceptions between regional varieties (including domestic varieties) are not significantly different, and the ranking structure holds less importance. The study also follows the treatments of Harrison *et al.* (1995), and Francois (1998), where Cournot conjecture is employed to model producer behaviour in food processing, manufacturing and service sectors.

Finally, efforts have also been made to characterise the varied nature of the policy regimes of the CAP. In the standard CGE model treatments such policies are incorporated within *ad valorem* output subsidy wedges, which is not in step with the true (de-coupled) nature of some of the support payments afforded to various sectors. Hence, within the model there is explicit incorporation of milk and sugar quotas, area and set-aside compensation to cereal sectors, headage premia to livestock, intervention purchases and the CAP budget. Further, the world economy has also been projected forward to 2005, by which time all of the Uruguay Round GATT commitments will in principle be completed.

A summary of the thesis is as follows: Chapter 1 chronologically reviews the PE and CGE literature pertaining to the costs of the CAP placing a range of estimates between 0.22% and 2.7% of EU GDP. Moreover, the chapter also reports on the evolution of CGE characterisations of the CAP (particularly in light of the MacSharry reforms), where efforts have been made to more accurately characterise the precise mechanisms of CAP support in CGE models (Harrison *et al.*, 1995; Weyerbrock, 1998; Blake *et al.*, 1999). This has had the effect of revising the range of CAP cost estimates in the CGE trade literature downwards.

Chapter 2 gives a summary of the key issues in CGE model design and implementation. The chapter begins with a discussion of the properties of 'convenient' functions often used in CGE modelling. Other issues such as 'closure', 'calibration', 'solution methods' and 'nesting' are also discussed. Further, the distinction between the levels and linear representations of CGE models are highlighted. The chapter also presents a simple stylised closed economy CGE model structure.

Chapter 3 draws on the imperfectly competitive trade literature, and explores the nature of some of the leading imperfectly competitive trade theories (oligopoly, neo-Hotelling, neo-Chamberlinian). Having identified these theories, the chapter proceeds to review the use and evolution of such theories in the CGE trade modelling literature and the range of policy questions to which these model types have been applied. Finally, reference is made to the agri-business and marketing literature on the role of food related preferences and region of origin.

Chapter 4 describes a standard CGE multi-region model framework. In the second part of the chapter, there is an overview of the Social Accounting Matrix (SAM) and Input-Output (I-O) data sources which are used to create benchmark data sets such as the Global Trade Analysis Project (GTAP) database. The discussion is then broadened to include the GTAP parameters and sets data and further issues pertaining to GTAP data construction and reconciliation procedures. The final part of the chapter gives a description of the accounting conventions within the GTAP data.

Chapter 5 is in two parts. The first part of this chapter explains the rationale behind the chosen aggregation of the Global Trade Analysis Project (GTAP) database used in the final model implementation. Further discussion is provided on the specific trading positions and protective structures pertaining to each region. The second part of the chapter discusses the techniques employed to explicitly incorporate CAP support instruments (i.e., set-aside, cereals compensation, headage premia, CAP budget, intervention buying) as well as additional modelling issues pertaining to the Uruguay Round constraints and model projections.

Chapter 6 brings together the trade and agri-business/marketing literature reviewed in chapter 3 with a detailed discussion on a stylised linearised CGE approach incorporating Cournot behaviour by rival firms, as well as neo-Hotelling preferences which exhibit a hierarchical ranking structure where the domestic variety is always preferred.

Chapter 7 splits the results into two sections. The first section compares the costs of CAP abolition against the alternative scenario of full implementation of the Uruguay Round constraints. These scenarios are conducted under low preference heterogeneity, five-firms per imperfectly competitive sector and standard Cournot conjecture. Under CAP abolition, the EU-15 gains 0.53% of GDP, with subsequent gains to the UK and EU-14 of 0.90% and 0.29% of respective GDPs. The EU-15 gains are found to fit in with more recent estimates of CAP costs in the literature (0.22%-0.8% of GDP). Global welfare rises 0.06% of global GDP, although losses accrue to the LDC and ROW regions.

The second set of results examine the effects of *high* preference heterogeneity by UK consumers *only*, under conditions of CAP abolition. These results are compared to the case where all agents in all regions exhibit *low* preference heterogeneity. Accounting for the extra effects of global varietal proliferations, UK welfare gains in both policy scenarios are “scaled up” accordingly. Comparing the costs of CAP abolition under high preference heterogeneity with the corresponding Uruguay Round scenario, the EU-15 gains 0.57% of GDP. The increase of 0.04% of EU-15 GDP compared to the first set of results is due to welfare increases in the UK from 0.90% to 1.08% of GDP, where varietal diversity is considered by UK consumers to be of greater importance.

Examining different firm concentration ratios (15 firms per sector up to 3 firms per sector) the costs of the CAP to the EU-15 range from 0.44% to 0.67% of GDP under low preference heterogeneity and 0.47% to 0.73% under high preference heterogeneity conditions. Finally, with high levels of collusion and 5 firm concentration levels the gains from CAP abolition to the EU-15 may be as low as 0.12% and 0.18% of GDP under low and high heterogeneity conditions, respectively. In both cases, the low estimates are due to slight welfare *losses* in the EU-14 region.

8.2 Limitations and Further Work

It is perhaps not too surprising that the incorporation of high levels of preference heterogeneity into the model yields significantly higher welfare outcomes, where utility gains (from global proliferations) 'scale' up the results. However, the size of these gains may be rather high, given that the preference heterogeneity parameter (γ_i) is specified rather arbitrarily. Indeed, searches of the literature give no indication on what the value of γ_i should be. This parameter holds the key to the magnitude of the welfare gains.

On the other hand, these results do highlight the importance of variety and hierarchical utility based welfare gains which are often ignored, or subordinated, in standard CGE work. Moreover, one could argue that many of the other parameters (substitution elasticities, investment parameters) in CGE model applications are also somewhat arbitrary or based on old data and are thus subject to similar criticism.

A related issue here surrounds the benchmark preference structure. In this application, it was desirable to find a suitably tailored criterion upon which to base estimates of benchmark preferences, with domestic representative varieties ranked highest. The method we use is to calibrate these preferences to the expenditure shares, where domestic representative varieties have the largest share. However, further work should be conducted in ascertaining other criteria for assigning values to benchmark preference values.

On the characterisation of imperfectly competitive sectors, some distinction must be drawn on the nature of the food processor. For example, are we to assume that the downstream food industries solely process primary agricultural produce into "finished products" (i.e. biscuits, yoghurt, alcohol etc) or are they also responsible for retailing? This has implications on the level of concentration as well as the type of conjectural variation responses by rivals, which in turn will affect welfare results.

In the final results section, a full range of CAP estimates is presented under different concentration ratios and conjectural variation levels. More research needs to be conducted to ascertain the nature of the welfare gains to each region. A closely related point is the disaggregation of the EU welfare results. In CGE models, the exact *sources* of the welfare gains can be ascertained through a more detailed welfare decomposition of the results. Work such as this has been pioneered for the GTAP model by Huff and Hertel (1996) and is an important source of further research.[1]

Another drawback of the model implementation is the characterisation of quotas in the model. More specifically, this study follows several other applications (Peerlings, 1993; Frandsen *et al*. 1998; Blake *et al*. 1998) which exogenise output in a sector to simulate a binding quota, where the output variable is swapped with some quota rent tariff equivalent variable to maintain correct closure. Thus, the use of model projections on endowments and productivity leads to inevitable output increases in all sectors under the UR scenario (see section 7.5.1). The CGE response of allowing the quota rent equivalent variable to adjust endogenously, leads to very large market price increases under CGE market clearing mechanisms to deter demand and maintain output at a fixed level. Relative to the UR scenario, CAP abolition leads to large price falls where the quantitative constraint is no longer in place. Such price effects are, however, unlikely to occur in the real world, which leads to some contention over the estimated magnitudes

[1] While the source of welfare gains may be identified, the *causes* of the welfare change are much more difficult to ascertain. This would involve running a prohibitive number of simulations for each policy variable (tax/subsidy). Moreover, the sum of the results of these simulations, are unlikely to be the same

of the price and output estimates in the raw milk and sugar sectors in this study and others like it. Thus, some modification to this CGE modelling technique must be developed, which avoids these ‘side-effects’.

Finally, the last issue pertains to the use of functional form. This study follows a large body of work which characterise final demands with a convenient (i.e., Cobb Douglas, Constant Elasticity of Substitution) functional form. However, the welfare changes in the simulation runs in this study are rather higher than expected due to the use of Cobb-Douglas preferences by private and public household agents. With increases in real incomes and falls in consumer prices (particularly under high preference heterogeneity), final demands may react rather too sensitively, resulting in exaggerated resource reallocation effects between sectors. Clearly, income and price elasticities for agricultural (and food) products are rather less elastic than those specified by the Cobb-Douglas function. Thus, the need here is to further understand the use of alternative ‘semi-flexible’ functions, which may allow for calibration of price- and income-inelastic parameter values within the model.

---

as the single simulation with all policy variables changing simultaneously due to the ‘general equilibrium’ effects within the model.

References

Agra Europe (1999) March 12, No. 1840, London.

Allanson, P. (1989) Homotheticity and Separability, mimeo, University of Dundee.

Alston, J.M., Carter, C.A., Green, R. and Pick, D. (1990). Whither Armington Trade Models?, American Journal of Agricultural Economics, 72, pp455-467.

Anderson, K. and Tyers, R. (1988) Liberalising OECD Agricultural Policies in the Uruguay Round: Effects on Trade and Welfare, Journal of Agricultural Economics, 39, pp197-216.

Anderson, K. and Tyers, R. (1993) More on Welfare Gains to Developing Countries from Liberalising World Food Trade, Journal of Agricultural Economics, 44, pp189-204.

Anderson, S., De Palma, A. and Thisse, J.F. (1989) Demand for Differentiated Products, Discrete Choice Models, and the Characteristics Approach, Review of Economic Studies, 56, pp21-35.

Anderson, W.T. and Cunningham, W.H. (1972) Gauging Foreign Product Promotion, Journal of Advertising Research, Feb. 1972, pp29-34.

Arce, H.M. and Reinhart, K.A. (1994) Aggregation and the Welfare Analysis of US Tariffs, Journal of Economic Studies, 21, (6), pp 26-30.

Armington, P. (1969). A Theory of Demand for Products Distinguished by Place of Production, IMF staff papers, 16, pp159-178.

Arrow, K.J., Chenery, H.B, Minhas, B. and Solow, R.M. (1961) Capital – Labor Substitution and Economic Efficiency, Review of Economics and Statistics, 43, pp225-50.

Atkin, M. (1993) *Snouts in the Trough*, Woodhead Publishing, Cambridge.

Balassa, B. (1975) *European Economic Integration*, Amsterdam, North-Holland.

Baldwin, R.E. and Francois, J.F. (1996) Scale Economies, Imperfect Competition and the Eastern Expansion of the EU, Paper presented at the Global Trade Analysis conference, Giessen, October 15-17, 1996.

Bannister, J.P. and Saunders, J.A. (1978) UK Consumers' Attitudes Towards Imports: The Measurement of National Stereotype Image, European Journal of Marketing, 12, pp562-570

Beattie, B.R. and Taylor, C.R. (1985) *The Economics of Production*, J.Wiley.

Bilkey, W.J. and Nes, E. (1982) Country-of-Origin Effects on Product Evaluations, Journal of International Business Studies, (8), pp89-99.

Blake, A.T., Rayner, A.J. and Reed, G.V. (1998) A CGE Analysis of Agricultural Liberalisation: The Uruguay Round and CAP Reform, First Annual Conference on Global Economic Analysis, Purdue University, USA.

Blake, A.T., Hubbard, L.J., Philippidis, G., Rayner, A.J. and Reed, G.V. (1999) General Equilibrium Modelling of the Common Agricultural Policy, Report to the MAFF and HM Treasury, March 1999.

Blake, A.T. (1999) General Equilibrium Modelling of the Uruguay Round, unpublished PhD Thesis, University of Nottingham.

Boadway, R. and Treddenick, J.M. (1978). A General Equilibrium Computation of the Effects of the Canadian Tariff Structure, Canadian Journal of Economics, 11, pp424-446.

Brown, D.K. and Whalley, J. (1980). General Equilibrium Evaluations of Tariff Cutting Proposals in the Tokyo Round and Comparisons with more Extensive Liberalisation of World Trade, Economic Journal, 90, pp838-866.

Brown, D.K. (1987) Tariffs, the Terms of Trade and National Product Differentiation, Journal of Policy Modelling, 9.

Brown, D.K. (1991) Tariffs and Monopoly Utilisation by Monopolistically Competitive Firms, Journal of International Economics, 30, pp371-381

Brown, D.K., Deardorff, A.V., Fox, A.K. and Stern, R.M. (1995) *Computational Analysis of Goods and Services Liberalisation in the Uruguay Round*, Presented at the World Bank Conference, Jan. 26-27.

Buckwell, A.E., Harvey, D.R., Thomson, K.J. and Parton, K.A. (1982) *The Costs of the Common Agricultural Policy*, Croom Helm, Canberra and London.

Burniaux, J.M. and Waelbroeck, J. (1985) The Impact of the CAP on Developing Countries: A General Equilibrium Analysis, in, *Pressure Groups, Policies and Development*, Stevens, C. and Verloren van Themat, J. (eds), Hodder and Stoughton, London.

Caddy, V. (1976) Empirical Estimation of the Elasticity of Substitution, Mimeo, Industuries Assisitance Commission, Melbourne, Australia.

Calder, W., McDougall, R. and Strzelecki, A. (1993) Procedures for Later Stage Processing of Single Region Input-Output Data for SALTER, SALTER working paper, No.18, June.

Caves, R. (1960) *Trade and Economic Structure : Models and Methods,* Cambridge, Mass. Harvard University Press.

Chaing, A.C. (1984) *Fundamental Methods of Mathematical Economics*, McGraw-Hill.

Chambers, R.G. (1988) *Applied Production Analysis*, Cambridge University Press.

Chipman, J.S. (1965) A Survey of the Theory of International Trade : Part 2, The Neo-Classical Theory, Econometrica, 33, pp685-760.

Cobb, C.W. and Douglas, P.H. (1928) A Theory of Production, American Economic Review, Papers and Proceedings, 28, pp139-165.

Cournot, A. (1838) Researches into the Mathematical Principles of the Theory of Wealth, Hachette, Paris.

de Janvry, A. and Sadoulet, E. (1987) Agricultural Price Policy in General Equilibrium Models: Results and Comparisons, American Journal of Agricultural Economics, 69, pp230-246.

Deardorff, A.V. and Stern, R.M. (1981) A Dissaggregated Model of World Production and Trade : An Estimate of the impact of the Tokyo Round, Journal of Policy Modelling, 3, pp127-152.

Demekas, D.C., Bartholdy, K., Gupta, S., Lipschitz, L. and Mayer, T. (1988) The effects of the CAP of the European Community: A Survey of the Literature, Journal of Common Market Studies, 27 (2), December, pp113-145.

Dixit, A.K. and Stiglitz, J.E. (1977) Monopolistic Competition and Optimum Product Diversity, American Economic Review, 67, pp297-308.

Dixit, A.K. and Norman, V. (1980) *Theory of International Trade*, Welwyn and James Nisbet and co. Ltd.

Dixon, P.B., Parmenter, B.R., Sutton, J. and Vincent, D.P. (1982). *ORANI: A Multisectoral Model of the Australian Economy*, Amsterdam, North-Holland.

Dixon, P.B. , Parmenter, B.R., Powell, A.A. and Wilcoxen, P.J. (1992). *Notes and Problems in Applied General Equilibrium Analysis*, North-Holland, Amsterdam.

Drud, A. , Grais, W. and Pyatt, G. (1986). Macroeconomic Modelling Based on Social Accounting Principles, Journal of Policy Modelling, 8, pp25-36.

Eastman, H. and Skykolt, S. (1967) A Model for the Study of Protected Oligopolies, Economic Journal, 70, pp336-347.

Eaton, J. and Kierzkowski, H. (1984) Oligopolistic Competition, Product Variety and International Trade, Ch. 5 in Kierzkowski, H. (ed), *Monopolistic Competition and International Trade*, Oxford, Clarendon Press.

Economedes, N. (1981) Oligopoly in Markets for Products Differentiated by their Characteristics, Ph.D. Dissertation, University of California at Berkeley.

Economedes, N. (1984) Do Increases in Preference Similarity (across countries) Induce Increases in Trade? An Affirmative Example, Journal of International Economics, 17, pp375-381.

European Commission (1994) EC Agricultural Policy for the 21st Century, European Economy, Reports and Studies, 4.

European Commission (1995), The Agricultural Situation in the European Union.

European Commission (1998), Agenda 2000 document.

European Commission Directorate General XIX (1998), Budgets Resources Outlook for Financing, Forecasts and Budget Guarantees, 7th October, 1998, annex 8, table 6b.

Feltenstein, A. (1989) Agricultural Policies and the U.S. Federal Budget and U.S. Trade Deficit, in Stoeckel, A.B., Vincent, D. and Cuthbertson, S. (eds) *Macroeconomic Consequences of Farm Support Policies*, Durham, Duke University Press.

Flam, H. and Helpman, E. (1987) Industrial Policy under Monopolistic Competition, Journal of International Economics, 22, pp79-102.

Folmer, C., Keyzer, M.A., Merbis, M.D., Stolwijk, H.J.J. and Veenendaal, P.J.J. (1995) *The Common Agricultural Policy beyond the MacSharry Reform*, Elsevier, Amsterdam, Netherlands.

Francois, J.F., and Panagariya, A. (1995), Import Substitutability and Regional Integration, World Trade Organisation, Mimeo.

Francois, J.F., McDonald, B. and Nordstrom, H. (1995a) Assessing the Uruguay Round, Presented at the World Bank Conference, January 26-27, 1995.

Francois, J.F., McDonald, B. and Nordstrom, H. (1995b) Assessing the Uruguay Round, in, The Uruguay Round and Developing Economies, W. Martin and L.A. Winters (eds), World Bank discussion paper 307.

Francois, J.F. (1998) Scale Economies and Imperfect Competition in the GTAP model, GTAP Technical Paper No.14, GTAP Web site, http://www.agecon.purdue.edu/gtap/

Frandsen, S.E., Jensen, H.G. and Stephensen, P. (1996) European Integration and the Common Agricultural Policy A CGE Multi Regional Analysis, Annual Conference of the Agricultural Economics Society, University of Reading, March 25-27.

Frandsen, S.E., Bach, C.F. and Vanzetti, D.M. (1998) Expanding 'Fortress Europe' Implications of European Enlargement for Non-Member Regions, First Annual Conference on Global Economic Analysis, Purdue University, USA.

Gehlhar, M.J., Gray, D., Hertel, T.W., Huff, K., Ianchovichina, E, McDonald, B.J., Mcdougall, R., Tsigas, M.E. and Wigle, R. (1996) Overview of the GTAP Data Base, Ch. 3 in, Hertel, T.W. (ed.), *Global Trade Analysis: Modelling and Applications*, Cambridge, Cambridge University Press.

Gohin, A., Guyomard, H., Herrard, N., Le Roux, Y. and Trochet, T. (1996) Modelling Agricultural Policy Instruments in a Single-Country, Multi-sector General Equilibrium Framework: Application to France, discussion paper, INRA-ESR.

Green, H.A.J. (1971) *Consumer Theory*, MacMillan.

Greenaway, D. (ed.) (1985) *Current Issues in International Trade* : Theory and Policy, MacMillan.

Greenaway, D., Leybourne, S.J., Reed, G.V. and Whalley, J. (1993) Applied General Equilibrium Modelling: Applications, Limitations and Future Development, HMSO Report, London.

Gros, D. (1987) A Note on the Optimal Tariff, Retaliation and the Welfare Loss from Tariff Wars in a Framework of Intra-Industry Trade, Journal of International Economics, 23, pp357-367.

Hamilton,R. and Whalley, J. (1985). Geographically Discriminatory Trade Arrangements, Review of Economics and Statistics, 67, pp446-455.

Harberger, C. (1959) The Corporation Income Tax: An Empirical Appraisal, *Tax Revision Compendium I* (House Committee on Ways and Means, 86th Congress, First Session), pp231-240.

Harberger, C. (1962) The Incidence of the Corporation Income Tax, Journal of Political Economy, 70, pp215-240.

Harris, R.G. (1984) Applied General Equilibrium Analysis of Small Open Economies with Scale Economies and Imperfect Competition, American Economic Review, 74, pp1016-1032.

Harrison, G.W., Rutherford, T. and Wooton, I. (1989) The Economic Impact of the European Community, American Economic Review, 79, pp288-294.

Harrison, G.W., Rutherford, T.F. and Tarr, D.G. (1994) Product Standards, Imperfect Competition, and Completion of the Market in the European Union, World Bank working paper, 1293.

Harrison, G.W., Rutherford, T.F. and Tarr, D.G. (1995a) Quantifying the Uruguay Round, Presented at the World Bank Conference, Jan 26-27, 1995.

Harrison, G.W., Rutherford, T.F. and Tarr, D.G. (1995b) Quantifying the Uruguay Round, in, The Uruguay Round and Developing Economies, W. Martin and L.A. Winters (eds), World Bank discussion paper 307.

Harrison, G.W., Rutherford, T.F. and Wooton, I. (1995) Liberalising Agriculture in the European Union, Journal of Policy Modelling, v17, (3), pp223-255.

Harrison, J. and Pearson, K. (1994) GEMPACK User Documents, Release 5.1, KPSOFT and IMPACT Project, Monash University, Australia.

Harvey, D.R. and Thomson, K.J. (1981) Costs, Benefits and the Future of the Common Agricultural Policy, Journal of Common Market Studies, v24, pp1-20.

Harvey, D.R. (1989) The Economics of the Farmland Market, Paper to Agricultural Economics Society, one day conference, December.

Heckscher, E. (1949) The Effect of Foreign Trade on the Distribution of Income, in H.S. Ellis and L.A. Metzler (eds), *Readings in the Theory of International Trade*, Homewood, IL:Irwin.

Helpman, E. (1981) International Trade in the Presence of Product Differentiation, Economies of Scale and Monopolistic Competition : A Chamberlin-Heckscher-Ohlin Approach, Journal of International Economics, 11, pp305-340.

Helpman, E. and Krugman, P. (1989), *Trade Policy and Market Structure*, Cambridge, MA:MIT Press.

Henderson, D.R. and Handy, C.R. (1993). “Globalisation in the Food Industry”, in *Food and Agricultural Marketing Issues for the 21st Century*, Parlberg, D.I (ed), University College Station.

Herok, C.A. and Lotze, H. (1998) Implications of an EU Eastern Enlargement under a New Common Agricultural Policy, First Annual Conference on Global Economic Analysis, Purdue University, USA.

Hertel, T.W., Thompson, R.L. and Tsigas, M.E. (1989) Economywide Effects of Unilateral Trade and Policy Liberalisation in U.S. Agriculture, in Stoeckel, A.B., Vincent, D. and Cuthbertson, S., *Macroeconomic Consequences of Farm Support Policies,* Durham, Duke University Press.

Hertel, T.W., Horridge, J.M. and Pearson, K.R. (1992). Mending the Family Tree : A Reconciliation of the Linearization and Levels Schools of AGE Modelling. Economic Modelling, Oct 92, pp385-407.

Hertel, T.W. (1992) Partial vs General Equilibrium Analysis of Trade Policy Reform, Journal Agricultural Economics Research, 44, pp3-15

Hertel, T.W. and Tsigas, M.E. (1993) Structure of the Standard GTAP Model, Staff Paper #93-23, Department of Agricultural Economics, Purdue University.

Hertel, T.W. (1994) The 'Procompetitive' Effects of Trade Policy Reform in a Small Open Economy, Journal of International Economics, 36, pp391-411.

Hertel, T.W. (ed) (1997) *Global Trade Analysis: Modelling and Applications*, Cambridge University Press.

Horn, S. (1984) Product Diversity, Trade and Welfare, Ch. 4 in Kierzkowski, H. (ed), *Monopolistic Competition and International Trade*, Oxford, Clarendon Press.

Horridge, J.M., Parmenter, B.R. and Pearson, K.R. (1993) ORANI-F: A General Equilibrium Model of the Australian Economy, Economic and Financial Computing, pp71-140.

Hotelling, H. (1929) Stability in Competition, Economic Journal, 39, pp41-57.

Howard, D.G. (1989) Understanding How American Consumers Formulate Their Attitudes About Foreign Products, Journal of International Consumer Marketing, 2(3), 77, pp56-70.

Hubbard, L.J. (1995a) General Equilibrium Analysis of the CAP using the GTAP Model, Oxford Agrarian Studies, v23, (2), pp163-176.

Hubbard, L.J. (1995b) CGE Modelling of the CAP: Trade Elasticities, Structural Effects and Welfare, Discussion paper 4/95, Department of AEFM, University of Newcastle upon Tyne.

Hubbard, L.J. (1998) United Kingdom Input Output Table, Chapter 14 in *Global Trade, Assistance and Protection: The GTAP 4 Database*, McDougall, R.A., Elbehri, A. and Truong, P. (eds), Center for Global Trade Analysis, Purdue University.

Huff, K. and Hertel, T.W. (1996) Decomposing Welfare Changes in GTAP, GTAP Technical Paper Series No. 5., GTAP Web site, http://www.agecon.purdue.edu/gtap/

James, M. and McDougall, R. (1993) FIT: An Input-Output Update Facility for SALTER, SALTER working paper no.17, Australian Industry Commission, Canberra.

Jensen, H.G., Frandsen, S.E. and Bach, C.F. (1998) Agricultural and Economic-Wide Effects of European Enlargement: Modelling the Common Agricultural Policy, Working Paper no. 11/1998, Danish Institute of Agricultural and Fisheries Economics.

Johansen, L. (1960). *A Multi-Sectoral Model of Economic Growth,* Amsterdam, North-Holland. (Second edition (1975))

Jomini, P., Zeitsch, J.F., McDougall, R., Welsh, A., Brown, S., Hambley, J., and Kelly, J. (1991) SALTER: A General Equilibrium Model of the World Economy, Vol. 1, Model Structure, Data base and Parameters. Canberra, Australia:Industry Commission.

Jorgensen, D.W. Lau, L.J. and Stoker, T.M. (1982) The Transcendental Logarithmic Model of Aggregate Consumer Behaviour, in R.L. Basmann and G. Rhodes (eds.), *Advances in Econometrics*, Greenwich, JAI Press, pp97-238.

Jorgensen, D.W. (1984) Econometric Methods for Applied General Equilibrium Analysis, in *Applied General Equilibrium Analysis*, Chapter 4, H.E Scarf and J. Shoven (eds.), New York, Cambridge University Press.

Juric, B., Worsley, T. and Garret, T. (1996) "Country of Origin Related Food Product Images", in Proceedings of the 25th EAAE Conference, Budapest University of Economic Sciences, 14th-17th May.

Kaynak, E. and Cavusgil, S.T. (1983) Consumer Attitudes Towards Products of Foreign Origin: Do They Vary Across Product Classes?, International Journal of Advertising, pp147-157, April/June.

King, M. (1981). What is a SAM? A Layman's Guide to Social Accounting Matrices, World Bank Staff, Working Paper no.463.

Koutsoyiannis, A. (1979) *Modern Microeconomics*, MacMillan.

Krugman, P. (1979) Increasing Returns, Monopolistic Competition and International Trade, *Journal of International Economics*, 9, pp469-479.

Lancaster, K.J. (1979) *Variety, Equity and Efficiency*, New York, Columbia University Press.

Lancaster, K.J. (1980) Intra-Industry Trade under Perfect Monopolistic Competition, Journal of International Economics, 10, pp151-175.

Lancaster, K.J. (1984) Protection and Product Differentiation, Ch. 9 in Kierzkowski, H. (ed), *Monopolistic Competition and International Trade*, Oxford, Clarendon Press.

Lancaster, K.J. (1991) The 'Product Variety' Case for Protection, Journal of International Economics, 31, pp1-26.

Lawrence, C. and Spiller, P.T. (1986) Product Diversity, Economies of Scale and International Trade, Quarterly Journal of Economics, 98, pp63-83

Lloyd, T.A. (1989) A Reconsideration of an Agricultural Land Price Model for the UK, Discussion no. 69, Dept. of Economics, University of Nottingham.

Loo, T. and Tower, E. (1989) Agricultural Protectionism and the Less Developed Countries: The Relationship between Agricultural Prices, Debt Servicing Capacities, and the need for Development Aid, in, *Macroeconomic Consequences of Farm Support Policies*, Stoeckel, A.B., Vincent, D. and Cuthbertson, S., Duke University Press, Durham.

Malcolm, G. (1998) Adjusting Tax Rates in the GTAP Database, GTAP Technical Paper No.12, September 1998.

McDougall, R.A., Elbehri, A. and Truong, P. (eds) (1998) *Global Trade, Assistance and Protection: The GTAP 4 Database*, Center for Global Trade Analysis, Purdue University.

Mercenier, J. (1992) Completing the European Internal Market: A General Equilibrium Evaluation Under Alternative Market Structure Assumptions, Working Paper 0892, CRDE, University of Montreal.

Merrill, O.H. (1972) *Applications and Extensions of an Algorithm that Computes Fixed Points of Certain Upper Semi-Continuous Point-to-Set Mappings*, unpublished Ph.D dissertation, Department of Industrial Engineering, University of Michigan.

Miller, M.H. and Spencer, J.E. (1977). The Static Economic Effects of the UK Joining the EEC: A General Equilibrium Approach, Review of Economic Studies, 44, pp71-93

Morkre, M.E. and Tarr, D.G. (1993). Reforming Hungarian Agricultural Trade Policy - A Quantitative Evaluation, Discussion paper, World Bank, Sept '93, WPS 1185.

Morris, C.N. (1980) The Common Agricultural Policy, Fiscal Studies, v1, 2, pp15-35.

Morris, L.J. and Hallaq, J.H. (1990) The Changing South Korean Marketplace: Product Perception of Consumer Goods, Journal of International Consumer Marketing, 2(3), 77, pp89-97.

Nguyen, T, Perroni, C. and Wigle, R. (1991). The Value of a Uruguay Round Success, The World Economy, 15, pp359-374.

Ohlin, B. (1933) Interregional and International Trade, Cambridge, Harvard University Press.

Ozanne, A. (1992) *Peverse Supply Response in Agriculture*, Avebury Publishing.

Pearson, K.R. (1991) Solving Nonlinear Economic Models Accurately via a Linearised Representation, Impact Project Preliminary Working paper, No IP-55, July 1991.

Peerlings, J. (1993) *An applied general equilibrium model for Dutch agribusiness policy analysis*, PhD thesis, University of Wageningen.

Renwick, A. and Hubbard, L.J. (1994) Distributional Aspects of the UK Costs of the CAP, Food Policy, v19, pp459-468.

Ritson, C. and Swinbank, A. (1997) Europe's Green Money, ch. 6 in, *The Common Agricultural Policy*, (2nd edition), Ritson, C. and Harvey, D.R. (eds), CAB International.

Roberts, D. (1992) UK Agriculture in the Wider Economy : An Analysis Using a Social Accounting Matrix, unpublished Ph.D. thesis, University of Manchester.

Roberts, I. (1985) Agricultural Policies in the European Community, Policy Monograph No.2, Bureau of Agricultural Economics, Canberra.

Robinson, S., Kilkenny, M and Adelman, I. (1989) The Effect of Agricultural Trade Liberalisation on the US Economy: Projections to 1991, in Stoeckel, A.B., Vincent, D. and Cuthbertson, S., *Macroeconomic Consequences of Farm support policies, Durham*, Duke University Press.

Scarf, H.E. (1967a) On the Computation of Equilibrium Prices, in *Ten Economics Studies in the Tradition of Irving Fisher* (W.J. Fellner ed), New York, Wiley.

Scarf, H.E. (1967b) The Approximation of Fixed Points of a Continuous Mapping, Journal of Applied Mathematics, 15, pp1328-1343.

Shoven, J.B. and Whalley,J. (1992). *Applying General Equilibrium*, Cambridge, Cambridge University Press.Ch 2, 4 and5.

Sodersten, B. and Reed, G. (1994) *International Economics*, 3rd edition, Macmillan

Spence, A.M. (1976) Product Selection, Fixed Costs and Monopolistic Competition, Review of Economic Studies, 43, pp217-235

Spencer, J. (1985) The European Economic Community: General Equilibrium Computations and the Economic Implications of Membership, in, *New Developments in Applied General Equilibrium Analysis,* Piggot, J. and Whalley, J. (eds), Cambridge Umiversity Press, Cambridge.

Stern, R., Francis, J . and Schumacher, B. (1976). *Price Elasticities in International Trade, An Annotated Bibliography*, Macmillan, London.

Stoeckel, A.B. and Breckling, J. (1989) Some Economywide Effects of Agricultural Policies in the European Community: A General Equilibrium Study, in, *Macroeconomic Consequences of Farm Support Policies*, Stoeckel, A.B., Vincent, D. and Cuthbertson, S., Duke University Press, Durham.

Strotz, R.H. (1957) The Empirical Implications of a Utility Tree, Econometrica, 25(2), pp.269-280.

Swaminathan, P. and Hertel, T.W. (1996) Introducing Monopolistic Competition into the GTAP, GTAP Technical Paper Series No. 6., GTAP Web site, http://www.agecon.purdue.edu/gtap/

Taylor, L. (1975) Theoretical foundations and Technical Implications pp33-109 in Blitzer, C., Clark, P. and Taylor, L. (eds) *Economy-wide Models and Development Planning*, Oxford University Press for the World Bank, New York.

Tyers, R. (1985) International Impacts of Protection: Model Structure and Results for EC Agricultural Policy, Journal of Policy Modelling, 7, 2, pp219-252.

Tyers, R. and Anderson, K. (1987) Liberalising OECD Agricultural Policies in the Uruguay Round: Effects on Trade and Welfare, Working paper on Trade and Development No 87/10, Canberra: Australian National University.

van der Laan, G. and Talman, A.J. (1979) A Restart Algorithm for Computing Fixed Points without an Extra Dimension, Mathematical Programming, 17, pp74-83.

Varian, H.L. (1990) *Intermediate Microeconomics: A Modern Approach*, 2nd edition, W.W.Norton and Co.

Venables, A.J. (1984) Multiple Equilibria in the Theory of International Trade with Monoplistically Competitive Commodities, Journal of International Economics, 16, pp103-122

Verdoorn, P.J. (1960) The Intra-Bloc Trade of Benelux, in Robinson, E.A.G. (ed), *Economic Consequences of the Size of Nations: Proceedings of a conference held by the International Economics Association.,* London, MacMillan.

Vousden, N. (1990) *The Economics of Trade Protection,* Cambridge University Press.

Weyerbrock, S. (1998) Reform of the European Union's Agricultural Policy: How to reach GATT-compatability ?, European Economic Review, 42, pp375-411.

Whalley, J. (1982). An Evaluation of the Tokyo Round Trade Agreement Using General Equilibrium Computational Methods, Journal of Policy Modelling, 4,(3), pp341-361.

Whalley, J. (1985) *Trade Liberalisation Among Major World Trading Areas*, Cambridge, Mass., MIT Press.

White, P.D., (1979) Attitudes of US Purchasing Managers Toward Industrial Products Manufactured in Selected European Nations, Journal of International Business Studies, Spring/Summer, 1979, pp81-90.

Wigle, R.M. (1988) A General Equilibrium Evaluation of Canada-US Trade Liberalisation in a Global Context, Canadian Journal of Economics, 21, pp539-564.

Winters, L.A. (1984) Separability and the Specification of Foreign Trade Functions, Journal of International Economics, 17, pp239-263.

Winters, L.A. (1987) The Economic Consequences of Agricultural Support: A Survey, OECD Economic Studies, 9, pp7-54.

Winters, L.A. (1991) *International Economics*, (4th ed.), Routledge.

Glossary of Terms in the Standard GTAP Database and Model

(Source: Hertel (ed), 1997)

A. Base Data

1. Value Flows

(i) Value Flows Evaluated at *Agents'* Prices

SAVE(r) — Value of net savings, in region r
SAVE(r) =*PSAVE* **QSAVE(r)* ∀ *rϵ REG*

VDEP(r) — *Value of capital depreciation expenditure in region r* ∀ *rϵ REG*
VDEP(r) = *PCGDS(r)* **KB(r)*

(ii) Value Flows Evaluated at *Market* Prices

VFM(i,j,r) — value of purchases of endowment commodity *i* by firms in sector *j* of region *r* evaluated at market prices ∀ *iϵ ENDW_COMM* ∀ *jϵ PROD_COMM* ∀ *rϵ REG*

VFM (i,j,r) =*PM(i,r)* **QFE(i,j,r)* ∀ *iϵ ENDWM_COMM* ∀ *iϵ ENDWS_COMM*

VDFM(i,j,r) — value of purchases of domestic tradable commodity *i* by firms in sector *j* of region *r* evaluated at market prices ∀ *iϵ TRAD_COMM* ∀ *jϵ PROD_COMM* ∀ *rϵ REG*
VDM(i.j,r) =*PM(i,r)* **QPD(i,r)*

VIFM(i,j,r) — value of purchases imported tradable commodity *i* by firms in sector *j* of region *r* evaluated at market prices ∀ *iϵ TRAD_COMM* ∀ *jϵ PROD_COMM* ∀ *rϵ REG*
VIFM(i,j,r) =*PIM(i,r)* **QFM(i,r)*

VDPM(i,r) — value of expenditure on domestic tradable commodity *i* by private household in region *r* evaluated at market prices ∀ *iϵ TRAD_COMM* ∀ *rϵ REG*
VDPM(i,r) =*PM(i,r)* **QFM(i,r)*

VDGM(i,r) — value of expenditure on domestic tradable commodity *i* by government household in region *r* evaluated at market prices ∀ *iϵ TRAD_COMM* ∀ *rϵ REG*
VDGM(i,r) =*PM(i,r)* **QGD(i,r)*

VIGM(i,r) — value of expenditure on imported tradable commodity *i* by government household in region *r* evaluated at market prices ∀ *iϵ TRAD_COMM* ∀ *rϵ REG*
VIGM(i,r) =*PIM(i,r)* **QGM(i,r)*

VXMD(i,r,s) — value of exports of tradable commodity *i* from source *r* to destination *s* evaluated at (exporter's) market prices ∀ *iϵ TRAD_COMM* ∀ *rϵ REG* ∀ *sϵ REG*
VXMD(i,r,s) =*PM(i,r)* **QXS(i,r,s)*

VIMS(i,r,s)	value of imports tradable commodity *i* from source *r* to destination *s* evaluated at (importer's) market prices *VIMS(i,r,s) =PMS(i,r,s) *QXS(i,r,s)*	∀ *iϵ TRAD_COMM* ∀ *rϵ REG* ∀ *sϵ REG*
VST(i,r)	value of sales tradable commodity *i* to the international transport sector in region *r* evaluated at market prices *VST(i,r,) =PM (i,r,) *QST(i,r,)*	∀ *iϵ TRAD_COMM* ∀ *rϵ REG*

(iii) Value Flows Evaluated at *World* Prices

VXWD(i,r,s)	value of exports of tradable commodity *i* from source *r* to destination *s* evaluated at world (*fob*) prices *VXWD(i,r,s) =PFOB(i,r,s) *QXS(i,r,s)*	∀ *iϵ TRAD_COMM* ∀ *rϵ REG* ∀ *sϵ REG*
VIWS(i,r,s)	value of imports of tradable commodity *i* from source *r* to destination *s* evaluated at world (*cif*) prices	∀ *iϵ TRAD_COMM* ∀ *rϵ REG* ∀ *sϵ REG*

B. Derivatives of the Base data

1. Value Flows

VOA(i,r) value of non-savings commodity *i* output or supplied in region *r* evaluated at agents' prices ∀ *iϵ NSAV_COMM* ∀ *rϵ REG*

$$VOA(i,r) = EVOA(i,r) \quad \forall i \epsilon ENDW\_COMM$$

$$VOA(i,r) = \sum_{j \epsilon DEMD\_COMM} VFA(j,i,r) \quad \forall i \epsilon PROD\_COMM$$

VFA(i,j,r) value of purchases of demanded commodity *i* by firms in sector *j* of region *r* evaluated at agent's prices ∀ *iϵ DEMD_COMM* ∀ *jϵ PROD_COMM* ∀ *rϵ REG*

$$VFA(i,j,r) = EVFA(i,j,r) \quad \forall i \epsilon ENDW\_COMM$$

$$VFA(i,j,r) = VDFA(i,j,r) + VIFA(i,j,r) \quad \forall i \epsilon TRAD\_COMM$$

VOM(i,r) value of non-savings commodity *i* output or supplied in Region *r* evaluated at market prices ∀ *iϵ NSAV_COMM* ∀ *rϵ REG*

$$VOM(i,r) = \sum_{j \epsilon PROD\_COMM} VFM(i,j,r) \quad \forall i \epsilon ENDW\_COMM$$

$$VOM(i,r) + \sum_{s \epsilon REG} VXMD(i,r,s) + VST(i,r) \quad \forall i \epsilon TRAD\_COMM$$

$$VOM(i,r) = VOA(i,r) \quad \forall i \epsilon CGDS\_COMM$$

VIM(i,r) value of aggregate imports of tradable commodity *i* ∀ *iϵ TRAD_COMM* in region *r* evaluated at market prices ∀ *rє REG*

VPA(i,r) value of private household expenditure on tradable commodity *i* in region *r* evaluated at agent's prices ∀ *iє TRAD_COMM* ∀ *rє REG*

$$VPA(i,r) = VDPA(i,r) + VIPA(i,r)$$

PRIVEXP(r) private household expenditure in region *r* evaluated at agent's prices ∀ *rє REG*

$$PRIVEXP(r) = \sum_{i \in TRAD\_COMM} VPA(i,r)$$

VGA(i,r) value of government household expenditure on tradable commodity *i* in region *r* evaluated at agent's prices ∀ *iє TRAD_COMM* ∀ *rє REG*

$$VGA(i,r) = VDGA(i,r) + VIGA(i,r)$$

GOVEXP(r) government household expenditure in region *r* evaluated at agent's prices ∀ *rє REG*

$$GOVEXP(r) = \sum_{i \in TRAD\_COMM} VGA(i,r)$$

INCOME(r) expenditure in region *r* which equals net income (net of capital depreciation) ∀ *rє REG*

$$INCOME(r) = PRIVEXP(r) + GOVEXP(r) + SAVE(r)$$

INC(r) initial value of income (expenditure) in the base data in region *r* stored as a parameter, used in calculating *EV(r)* ∀ *rє REG*

$$INC(r) = INCOME(r)$$

GLOBINV global net investment

$$GLOBINV = \sum_{r \in REG} NETINV(r) = \sum_{r \in REG} SAVE(r)$$

VTWR(i,r,s) value of transportation services associated with the shipment of tradable commodity *i* from source *r* to destination *s* (*fob – cif margin*) ∀ *iє TRAD_COMM* ∀ *rє REG* ∀ *sє REG*

$$VTWR(i,r,s) = VIWS(i,r,s) – VXWD(i,r,s)$$

VT value of total international transportation services

(sum of *fob – cif* margins across all commodities and all routes)

$$VT = \sum_{i \in TRAD\_COMM} \sum_{r \in REG} \sum_{s \in REG} VTWR(i,r,s)$$

2. Shares

SHRDFM(i,j,r) share of domestic sales of tradable commodity *i* used by firms in sector *j* of region *r* evaluated at market prices $\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

$$SHRDFM(i,j,r) = \frac{VDFM(i,j,r)}{VDM(i,r)}$$

FMSHR(i,j,r) share of imports in the composite for tradable commodity *i* used by firms in sector *j* of region *r* evaluated at agent's prices $\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

$$FMSHR(i,j,r) = \frac{VIFA(i,j,r)}{VFA(i,j,r)}$$

PMSHR(i,r) share of imports in the composite for tradable commodity *i* used by private household in region *r* evaluated at agent's prices $\forall i \in TRAD\_COMM$ $\forall r \in REG$

$$PMSHR(i,r) = \frac{VIPA(i,r)}{VGA(i,r)}$$

GMSHR(i,r) share of imports in the composite for tradable commodity *i* used by government in region *r* evaluated at agent's prices $\forall i \in TRAD\_COMM$ $\forall r \in REG$

$$GMSHR(i,r) = \frac{VIGA(i,r)}{VGA(i,r)}$$

MSHRS(i,r,s) market share of source *r* in the aggregate imports of tradable commodity *i* in region *s* evaluated at market prices $\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

$$MSHRS(i,r,s) = \frac{VIMS(i,r,s)}{\sum_{r \in REG} VIMS(i,r,s)}$$

SVA(i,j,r) share of endowment commodity *i* in value-added of firms in sector *j* of region *r* evaluated at agent's prices $\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$

∀ *r*є *REG*

REVSHR(i,j,r) share of endowment commodity *i* used by firms in sector *j* of region *r* evaluated at market prices — ∀ *i*є *ENDW_COMM*, ∀ *j*є *PROD_COMM*, ∀ *r*є *REG*

C. Variables

1. Quantity Variables

QO(i,r) quantity of non-saving commodity *i* output or supplied in region *r* — ∀ *i*є *NSAV_COMM*, ∀ *r*є *REG*

QOES(i,j,r) quantity of sluggish endowment commodity *i* supplied to firms in sector *j* of region *r* — ∀ *i*є *ENDWS_COMM*, ∀ *j*є *PROD_COMM*, ∀ *r*є *REG*

QXS(i,r,s) quantity of exports of tradable commodity *i* from source *r* to destination *s* — ∀ *i*є *TRAD_COMM*, ∀ *r*є *REG*, ∀ *s*є *REG*

QST(i,r) quantity of sales tradable commodity *i* to the international transport sector in region *r* — ∀ *i*є *TRAD_COMM*, ∀ *r*є *REG*

QFE(i,j,r) quantity of endowment commodity *i* demanded by firms in sector *j* of region *r* — ∀ *i*є *ENDW_COMM*, ∀ *j*є *PROD_COMM*, ∀ *r*є *REG*

QVA(j,r) quantity index of value-added (land labour composite) in firms of sector *j* in region *r* — ∀ *j*є *PROD_COMM*, ∀ *r*є *REG*

QF(i,j,r) quantity of composite tradable commodity *i* demanded by firms in sector *j* of region *r* — ∀ *i*є *TRAD_COMM*, ∀ *j*є *PROD_COMM*, ∀ *r*є *REG*

QFD(i,j,r) quantity of domestic tradable commodity *i* demanded by firms in sector *j* of region *r* — ∀ *i*є *TRAD_COMM*, ∀ *j*є *PROD_COMM*, ∀ *r*є *REG*

QFM(i,j,r) quantity of imported tradable commodity *i* demanded by firms in sector *j* of region *r* — ∀ *i*є *TRAD_COMM*, ∀ *j*є *PROD_COMM*, ∀ *r*є *REG*

QP(i,r) quantity of composite tradable commodity *i* demanded by private household in region *r* — ∀ *i*є *TRAD_COMM*, ∀ *r*є *REG*

QPD(i,r) quantity of domestic tradable commodity *i* demanded by private household in region *r* — ∀ *i*є *TRAD_COMM*, ∀ *r*є *REG*

*QPM(*i,r) quantity of imported tradable commodity *i* demanded by — ∀ *i*є *TRAD_COMM*

	private household in region *r*	∀ *rє REG*
QG(i,r)	quantity of composite tradable commodity *i* demanded by government household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
QGD(i,r)	quantity of domestic tradable commodity *i* demanded by government household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
QGM(i,r)	quantity of imported tradable commodity *i* demanded by government household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
QIM(i,r)	quantity of aggregate imports of tradable commodity *i* demanded by region *r* using market prices as weights	∀ *iє TRAD_COMM* ∀ *rє REG*
QT	quantity of global transport services supplied	
QSAVE(r)	quantity of savings demanded in region *r*	∀ *rє REG*
QGDP(r)	quantity index for GDP in region *r*	∀ *rє REG*
WALRAS_DEM	quantity demanded in the omitted market (equals global demand for savings)	∀ *rє REG*
WALRAS_SUP	quantity supplied in the omitted market (equals global supply of new capital goods composite)	

2. Price Variables

PS(i,r)	supply price of non-savings commodity *i* in region *r*	∀ *iє NSAV_COMM* ∀ *rє REG*
PM(i,r)	market price of non-savings commodity *i* in region *r*	∀ *iє NSAV_COMM* ∀ *rє REG*
PMES(i,j,r)	market price of sluggish endowment commodity *i* supplied to firms in sector *j* of region *r*	∀ *iє ENDWS_COMM* ∀ *jє PROD_COMM* ∀ *rє REG*
PFE(i,j,r)	demand price of endowment commodity *i* for firms in sector *j* of region *r*	∀ *iє ENDW_COMM* ∀ *jє PROD_COMM* ∀ *rє REG*
PVA(j,r)	price of value-added sector *j* of region *r*	∀ *jє PROD_COMM* ∀ *rє REG*
PF(i,j,r)	demand price of composite tradable commodity *i* for firms in sector *j* of region *r*	∀ *iє TRAD_COMM* ∀ *jє PROD_COMM* ∀ *rє REG*
PFD(i,j,r)	demand price of domestic tradable commodity *i* for	∀ *iє TRAD_COMM*

	firms in sector *j* of region *r*	∀ *jє PROD_COMM* ∀ *rє REG*
PFM(i,j,r)	demand price of imported tradable commodity *i* for firms in sector *j* of region *r*	∀ *iє TRAD_COMM* ∀ *jє PROD_COMM* ∀ *rє REG*
PP(i,r)	demand price of composite tradable commodity *i* for private household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
PPD(i,r)	demand price of domestic tradable commodity *i* for private household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
PPM(i,r)	demand price of imported tradable commodity *i* for private household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
PG(i,r)	demand price of composite tradable commodity *i* for government household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
PGD(i,r)	demand price of domestic tradable commodity *i* for government household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
PGM(i,r)	demand price of imported tradable commodity *i* for government household in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
PPRIV(i,r)	price index for private household expenditure in region *r*	∀ *rє REG*
PGOV(r)	price index for government household expenditure in region *r*	∀ *rє REG*
PFOB(i,r,s)	world (*fob*) price of tradable commodity *i* exported from source *r* to destination *s* (prior to including transport margin)	∀ *iє TRAD_COMM* ∀ *rє REG* ∀ *sє REG*
PCIF(i,r,s)	world (*cif*) price of tradable commodity *i* exported from source *r* to destination *s* (prior to including transport margin)	∀ *iє TRAD_COMM* ∀ *rє REG* ∀ *sє REG*
PMS(i,r,s)	market price by source of tradable commodity *i* imported from source *r* to destination *s*	∀ *iє TRAD_COMM* ∀ *rє REG* ∀ *sє REG*
PIM(i,r)	market price of aggregate imports of tradable commodity *i* in region *r*	∀ *iє TRAD_COMM* ∀ *rє REG*
PSW(r)	price index received for tradables produced in region *r* including sales of net investment to the global bank	∀ *rє REG*
PDW(r)	price index paid for tradables used in region *r* including purchases of net investment to the global bank	∀ *rє REG*
TOT(r)	terms of trade for region *r* *TOT(r) = [PSW(r) / PDW(r)]*	∀ *rє REG*

PT	price of global transport services supplied	
PCGDS(r)	price of investment goods in region *r* (equals *PS*("capital"*(r)*)	∀ *rє REG*
PSAVE	price of composite capital good supplied to savers by global bank	
PGDP(r)	price index for GDP in region *r*	∀ *rє REG*

WALRASLACK

Slack variable in the WALRAS equation (this is exogenous as long as price of savings, PSAVE, is endogenous as is the case in a *standard GE closure.* When any one of the GE links is broken, this is swapped with *PSAVE*, the numeraire price, thereby forcing global savings to equal global investment)

VGDP(r)	percentage change in value of GDP in region *r* (is identical to the linearised form of *GDP(r)*)	∀ *rє REG*
Y(r)	percentage change in regional household income in region *r* (is identical to the linearised form of *INCOME(r)*)	∀ *rє REG*
U(r)	per capita utility from aggregate household expenditure in region *r*	∀ *rє REG*
UP(r)	per capita utility from private household expenditure in region *r*	∀ *rє REG*
UG(r)	aggregate utility from government household expenditure in region *(r)*	∀ *rє REG*

3. Welfare Variables

EV(r)	equivalent variation in region *r*, in $ US million (positive figure indicates welfare improvement)	∀ *rє REG*
WEV	equivalent variation for the world, in $ US million (positive figure indicates welfare improvement)	