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Armington Elasticities and Terms of Trade Effects in Global CGE Models

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X.G. Zhang

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Publications Inquiries:
Media and Publications
Productivity Commission
Locked Bag 2 Collins Street East
Melbourne VIC 8003

Tel: (03) 9653 2244
Fax: (03) 9653 2303
Email: maps@pc.gov.au

General Inquiries:
Tel: (03) 9653 2100 or (02) 6240 3200

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Contents

Preface **V**

Acknowledgements **VI**

Key Points **VIII**

Overview **IX**

1 Introduction **1**

2 Terms of trade effects in non-Armington models **3**

2.1 A two-country two-good non-Armington pure exchange model 4

2.2 Terms of trade effects of a tariff in a non-Armington model 7

3 Terms of trade effects in Armington trade models: one-tier substitution **11**

3.1 One-tier Armington substitution in a two-country pure exchange model 11

3.2 Terms of trade effects of a tariff in a one-tier Armington model 16

4 Terms of trade effects in Armington trade models: two-tier substitution **21**

4.1 Two-tier Armington substitution in a three-country pure exchange model 21

4.2 Terms of trade effects of a uniform tariff in a two-tier Armington model 24

4.3 Terms of trade effects of a discriminatory tariff in a two-tier Armington model 28

5 Extensions of the simple Armington model **31**
5.1 Many goods pure exchange models 31
5.2 Incorporating production with primary factors 31
5.3 Production with primary factors and intermediate inputs 32

6 Applied CGE models with Armington assumptions: the case of GTAP **35**

7 Concluding comments **39**

References **41**

FIGURES

Figure 1 Armington elasticities and terms of trade effects of a 10 per cent rise in US tariff XIII
Figure 2.1 Offer curves in a two-country two-good non-Armington pure exchange model 5
Figure 2.2 Tariff distorted home offer curve in a non-Armington model 9
Figure 3.1 Offer curves in a two-country one-tier pure exchange Armington model 13
Figure 3.2 Home offer curves with different substitution elasticities in an Armington model 15
Figure 3.3 Tariff distorted offer curve in a two-country one-tier pure exchange Armington model 17
Figure 3.4 Substitution elasticity and terms of trade effect of a 10 per cent tariff in a two-country one-tier Armington trade model 19
Figure 4.1 Home offer curves in a three-country two-tier Armington trade model 23
Figure 4.2 Substitution elasticity and terms of trade effect of a 10 per cent tariff in a three-country two-tier Armington trade model 25
Figure 4.3 Combined response of the rest of the world to a home tariff on one import 28
Figure 6.1 Offer curves in GTAP3x3: United States vs Rest of the World 36
Figure 6.2 Armington elasticities and the change in terms of trade from a 10 per cent rise in US tariffs 37

Preface

All policy analysts use some type of model in their work. Most of the conceptual models that underlie thinking in the Australian context are built assuming homogeneous goods, the 'small country' assumption and that countries differ in endowments or technology. The numerical models of global trade that are based on the Armington formulation, however, depart from this set of assumptions, by positing that each country produces its own set of products, which are somewhat differentiated from the products of similar name, produced elsewhere.

Armington elasticities specify the degrees of substitution in demand between similar products produced in different countries. They are critical parameters which, along with model structure, data and other parameters, determine the results of policy experiments. Especially when many tariffs are small, trade liberalisation simulations can produce positive or negative welfare outcomes depending on the values assumed for Armington elasticities.

The Commission developed a research program on the role of Armington elasticities in quantitative models that are commonly used to analyse trade issues. The research program was designed to improve the effectiveness of models used in analysing various options for unilateral, bilateral and multilateral liberalisation.

The purpose of this paper is to illustrate the effects of the Armington assumption on one of the main factors that affects welfare outcomes, namely, the terms of trade.

In publishing its research in this area, the Commission hopes to clarify issues that arise as single-country and global trade models are increasingly used to assess the potential impacts of various types of trade liberalisation.

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OVERVIEW

Key points

- Multi-country computable general equilibrium (CGE) models are important tools for analysing tariff and trade policy changes and most such models incorporate the 'Armington assumption'.
- The Armington assumption differentiates commodities by their country of origin. It takes the products of an industry which come from different countries to be imperfect substitutes for each other. This model structure enables the construction of complex models based on existing world trade statistics.
- The choice of the Armington assumption is an important one as it impacts on the outcomes of policy shocks introduced to CGE models. This is due to both the Armington structure itself and the size of the substitution elasticities, which can have a large effect on the terms of trade (the ratio of export to import prices).
- This paper illustrates the complex relationship between the Armington assumption and the terms of trade. In particular, it demonstrates that:
  (a) the terms of trade effect of a tariff is positively related to the home country's elasticity of substitution between domestic and imported goods;
  (b) the terms of trade effect of a tariff is negatively related to the elasticity of substitution between domestic and imported goods in foreign countries and to all foreign countries' elasticities of substitution between import sources;
  (c) increasing proportionally all elasticities of substitution, starting in the range of typical Global Trade Analysis Project (GTAP) default values, does not reduce terms of trade effects much, because these opposing effects approximately offset each other;
    – however, reducing proportionally all elasticities of substitution below unity increases the terms of trade effect sharply.
- The results on the relationship between Armington elasticities and terms of trade are robust. They are not affected by the size of the tariff-imposing country relative to the rest of the world, nor by the dimension and structure of the model. The results hold for large sophisticated models of global trade, as well as for scaled-down versions.
- The results highlight the importance of understanding how the Armington assumption affects simulation results and the importance of having reliable, model-consistent and empirically sound estimates for Armington elasticities in any model that is used to simulate the effects of changes in trade policies.

Overview

This paper is the first in a series which explores the implications of the 'Armington assumption', in order to assist model users in interpreting results from computable general equilibrium (CGE) models.

When constructing a numerical model of an economy, it is often necessary to introduce assumptions in addition to those made in theoretical models. Most numerical versions of multi-country CGE models include the Armington assumption. This assumption differentiates commodities by their country of origin. This takes the products of an industry which come from different countries to be imperfect substitutes for each other. Furthermore, Armington (1969) assumed that the elasticity of substitution within groups of products was constant. In contrast, standard international trade models, such as the Heckscher-Ohlin model, treat all products of an industry as perfect substitutes for each other, irrespective of their origin.

The Armington assumption is used to accommodate "cross-hauling" in the statistics of international trade. Cross-hauling occurs when a country both exports and imports the products of an "industry". This is a ubiquitous feature of international trade statistics, and is due to aggregation.

Two consequences of introducing the Armington assumption are that:

- every country in a CGE model has market power in every market in which it buys and sells; and
- comparative advantage in production does not exist.

The first consequence means that when one country reduces its tariff rates, the model results tend to display large negative terms of trade effects. The second means that any resource reallocation across industries is small relative to what might occur in a non-Armington model. Both factors reduce the gains from trade liberalisation in simulations that use a CGE model. As a consequence, any benefits from reducing tariffs tend to be small, and occasionally negative. This is especially the case when the initial tariffs are small.

Brown (1987) showed that the relationship between the magnitude of the Armington elasticities and that of the terms of trade effects is complex. In the

current paper, a sequence of simple CGE models is used to explore in more detail than did Brown, the relationships between elasticities and terms of trade effects. It quantifies how the terms of trade vary with different elasticity values in response to a given tariff.

A non-Armington model

To understand better what differences have been brought into global trade models by adopting the Armington assumption, one needs to understand how traditional non-Armington trade models respond to a tariff change. The investigation begins in Section 2 with a conventional non-Armington model of pure exchange between two countries. Each country is endowed with two goods. Consumers in both countries share the same preferences over the two goods. Consumer preferences are described by a constant elasticity of substitution (CES) function. The equilibrium is depicted in terms of the offer curves of the two countries. The terms of trade effect of imposing a tariff is jointly determined by the elasticity of substitution between the two goods and the countries' endowments of the two goods. In this model, the terms of trade effect of a tariff in the home country ranges from 0 to 100 per cent depending on whether foreign preferences are inelastic or elastic.[1] This result is consistent with traditional trade theory.

An Armington model – one tier of substitution

An Armington model differs from a non-Armington model by assuming that imported goods are imperfect substitutes for domestic goods. A typical Armington model assumes a three-stage budgetary allocation procedure. Expenditure is first allocated among goods without regard to their origin. Expenditure on each good is then allocated between a domestic good and a composite imported from different sources. This is modelled through a first tier of Armington substitution between sources. Finally, expenditure on imports is allocated among competing national suppliers. This is the second tier of substitution. This structure can be captured neatly in a set of nested CES functions. The terms of trade effects in Armington models with one and two-tier substitution are discussed separately.

Section 3 looks at the terms of trade effects in a two-country Armington model of pure exchange with a single tier of substitution, that between a domestic and an

1 The terms of trade effect of a tariff is defined as the ratio of the proportional change in the terms of trade, relative to the change in tariff. If introducing a one-per-cent tariff results in a rise in the terms of trade of 1 per cent, the terms of trade effect is 100 per cent.

imported source of the good. Each country is endowed with only one good and these two goods are imperfect substitutes for each other. This is the simplest possible model with the Armington assumption.

Compared with the non-Armington model with the same utility functions, the introduction of the Armington assumption in itself increases the terms of trade effect of a tariff. In a standard non-Armington model of pure exchange, each country has some strictly positive endowments of both goods. In the Armington model, however, each country is endowed with only one good, but consumers demand both goods. The entire endowment of a country becomes tradable; in fact, between the two countries, the entire world endowment becomes tradable. The trade-prohibitive tariff becomes infinite in the Armington model. This implies that, for a given tariff, an Armington model always has a higher terms of trade effect than a similarly defined non-Armington model. Moreover, a substitution elasticity below unity can result in a peculiar offer curve and imply unusually high terms of trade effects.

In this one-tier model, the relationship between the home country's terms of trade effect and the magnitudes of Armington elasticities is given by the following:

1. an increase in the home country's elasticity of substitution increases the terms of trade effects of the home country's tariff; but
2. an increase in the foreign country's elasticity of substitution decreases the terms of trade effect of the home country's tariff; and
3. an increase in both countries' elasticities leaves the terms of trade effect of the home country's tariff largely unchanged, because effects 1 and 2 offset each other.

Moreover, and contrary to expectation, the terms of trade effects of a tariff in this Armington model are not affected by the size of the tariff-imposing country relative to the rest of the world. In fact, if goods are equally preferred by consumers in all countries, smaller countries tend to experience larger terms of trade gains than larger countries. This is because smaller countries' limited endowments drive up the prices of their exports faster than is the case for countries with larger endowments.

An Armington model – two tiers of substitution

Section 4 extends the single-tier model by introducing a third country and a second tier of substitution, between competing foreign sources of imports. Under the Armington assumption, there are now three goods, one from each country. The home country imports from both foreign countries. For this model to be comparable

with the previous models, the third country is assumed to be endowed with an equal quantity of the third good and each country is assumed to spend half its income on its own domestic good and half on imports. However, there are many more substitution elasticities to consider.

First, consider if the home country levies a uniform tariff rate on its imports from the two foreign countries. The results regarding the first-tier elasticities are similar to those obtained with the two-country one-tier model above. However, the second-tier elasticities, especially the foreign ones, have an effect on the terms of trade of a tariff opposite in sign to those of the first-tier elasticities:

1. increasing the home country's second-tier elasticities has no effects on its terms of trade because of the preference separability built into the nested CES functions, which means that if a tariff is levied on imports from all sources, all imports will be equally affected and no substitution between sources occurs.
2. increasing the foreign country's second-tier elasticities *reduces* the terms of trade effect, because the foreign countries react to an increase in the price of the home country's exports by increasing trade among themselves and reducing trade with the home country.
3. increasing all elasticities proportionally means that the opposing effects between increasing the home first-tier elasticities and the foreign first and second-tier elasticities result in little reduction in the terms of trade effects.

However, if the tariff is discriminatory, that is, higher on imports from one country than from the other, the results are different again. For example, if a tariff is imposed on imports from one source only, then increasing the home second-tier elasticity now does reduce the home country's terms of trade. This is because, when a tariff is imposed on imports from one source alone, home consumers switch their demands to imports from the less-taxed source, which results in a small effect on price and terms of trade.

The paper contains a number of other results with respect to variations in other parameters or combinations of parameters.

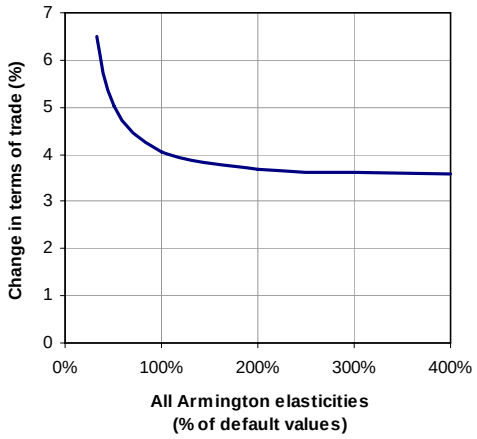
The Armington models can also be extended to many goods and countries, and the fixed endowment assumption can be relaxed by introducing production with both primary and intermediate inputs. These extensions do not alter the relationships between substitution elasticities and the magnitude of the terms of trade effect of a tariff. The results are driven by the implications of the Armington structure rather than the dimensions of the model or other features of the model.

A numerical illustration

An applied trade model, which incorporates the Armington assumption, is used to illustrate the results derived from the simple models. The model used is a simplified three-country version of Global Trade Analysis Project (GTAP): the United States, Europe and the Rest of the World. Three goods are produced in each country: primary, manufacturing and services. The goods produced in different countries are differentiated so that every country's products are exported to the other two countries. Hence, there are nine goods consumed in each country. The tariff rates on imports of the products of the same industry group differ according to the source of the imports.

The effects of a tariff on the terms of trade in the GTAP model are similar to those obtained in the previous simple models. For example, a 10 per cent rise in US import tariffs raises US terms of trade by 4 per cent under the default levels of Armington elasticities. When Armington elasticities are increased from their default levels in all regions of the world, the terms of trade effect for US declines slightly to a constant level at about 3.5 per cent. Conversely, as the elasticities are decreased from their default levels, the terms of trade effects increase (figure 1).

Figure 1. Armington elasticities and terms of trade effects of a 10 per cent rise in US tariff



Data source: Simulation of the simplified GTAP model.

These results are consistent with those from the simple models. The importance of these simulations is that they show that the complex relationships between the magnitude of the terms of trade effect of a tariff and the Armington elasticities apply to the kind of CGE models that are widely used in many countries and in international institutions such as the World Bank to estimate these effects.

These results highlight the importance of having reliable estimates for the Armington substitution elasticities in any model that is used to simulate the effects of changes in tariffs and trade policies. They also reveal that the Armington assumption of differentiation by source has a dramatic effect on model results for all settings of the substitution elasticities, compared with results from the Heckscher-Ohlin model. Improved estimates of the substitution elasticities are required and, in the longer term, it might be possible to modify the Armington model as a basis for global trade modelling. These two aspects of the Armington model are examined in forthcoming work in this research program.

1 Introduction

Many global computable general equilibrium (CGE) trade models adopt an Armington (1969) structure to define demands for domestically produced and imported goods. This structure treats the two types of goods as differentiated and, therefore, as imperfect substitutes. Many models also assume that imports originating from different countries are differentiated from each other.

The Armington structure is introduced to accommodate 'cross hauling', a phenomenon commonly observed in bilateral trade statistics, that is, a country appears simultaneously to export and import the same goods. This phenomenon cannot be explained in traditional trade models with homogeneous goods. Homogeneous goods can either be exported or imported, but not both at the same time. The Armington assumption of product differentiation and imperfect substitution makes the existing trade statistics immediately usable for global trade models. Moreover, the further assumption that the form of the functions for Armington substitution is constant elasticity of substitution (CES) simplifies the task of parameterising multiple-region trade models.

The Armington structure is a convenient choice, which allows the construction of complex models. It also makes the Armington elasticities a critical set of parameters, which strongly influence simulation results. 'Armington models' often produce large terms of trade effects even for relatively small changes in the trade taxes of a 'small country'. In some cases, expected gains in allocative efficiency from a tariff reduction can be wiped out by strong terms of trade losses. This apparently large terms of trade effect is unexpected and difficult to justify on both theoretical and empirical grounds.[1]

Armington substitution elasticities and terms of trade effects of a tariff in CGE models have long been a subject of debate. Brown (1987) was one of the first to evaluate how Armington elasticities relate to terms of trade effects of a tariff. She showed that elasticities at two different levels of a nested Armington structure could have different effects on the terms of trade. However, she did not consider some variations in the elasticity parameters and her investigation of the magnitude of these effects was limited. Francois and Shiells (1994) discuss some of the

[1] Variation in the Armington elasticities also affects the volume of trade and country welfare in interesting ways but these effects are not pursued in this paper.

limitations of Armington structure and alternative specification of demand for traded goods in global CGE models. McDaniel and Balistreri (2001) use an applied global model to demonstrate the welfare sensitivity to Armington specification for a small open economy. However, the Armington structure involves more than the elasticities as the Armington specification of product differentiation changes the nature of demand and production in the model. No one has undertaken a systematic examination of the complex relationship between the Armington structure and terms of trade effects of trade policies. Given the widespread use of the Armington structure in CGE models, this is an important task.

This paper establishes the links between the Armington structure and the terms of trade effects of a tariff by using a sequence of trade models with increasingly sophisticated Armington substitution features. The investigation starts in chapter 2 to analyse how a country's terms of trade change in response to an import tariff with a 2x2 conventional model of pure exchange. This reveals that the Armington assumption that goods are differentiated on a national basis has a profound effect on the terms of trade, irrespective of the values of the Armington elasticities. A series of illustrative Armington models are used in chapters 3 and 4 to quantify the relationship between substitution elasticities and terms of trade effects. This reveals a second structural property of Armington models that affect the terms of trade effects of tariffs. Chapter 5 discusses the possible extension of simple Armington models. The same analytical framework is extended in chapter 6 to the Global Trade Analysis Project (GTAP) model to demonstrate how terms of trade are determined by Armington elasticities in an applied model. Chapter 7 concludes with a summary and comments.

2 Terms of trade effects in non-Armington models

Terms of trade effects reflect the changes in the world prices of traded goods. In a single country model, it can be assumed that the external prices for exports and imports are fixed and hence there will be no terms of trade effect from any policy change. This assumption produces a perfect 'small-country case'.[1] In a global model, however, all countries contribute to the formation of world equilibrium prices. A change in one country's tariff on imports affects world equilibrium prices and changes the terms of trade for all countries. In other words, there is no small country in a global model, and every country has a certain degree of power in the markets they trade in.

In a two-country, two-good world, the most common and useful tool to analyse how the world relative price is affected by individual countries' trade policies is the offer curve. The offer curve shows the desired quantities of the two goods traded between the two countries at various world prices.

If the offer curves are derived for both the home country and the rest of the world, the effects of a tariff on the country's terms of trade can be determined. The problem with the Armington assumption is not whether the terms of trade effect should exist, but rather what is the exact role of the elasticities in determining the magnitude of the terms of trade effects.

To understand what differences have been brought into global trade models by adopting the Armington assumption, one needs to ask first how traditional, non-Armington trade models respond to a tariff change. We begin our investigation with a well known two-country, two-good pure exchange general equilibrium model with perfect substitution between domestic and imported goods.

1 Shoven and Whalley (1992) provide a good discussion on the issues concerning single-country trade model closure (pp. 230–255).

2.1 A two-country two-good non-Armington pure exchange model

Assume that two countries, *1* and *2*, share identical preferences over two homogeneous goods, *X* and *Y*, but each is endowed with different amounts of the two goods. Suppose that country *1* has more of good *X* than good *Y*, while country *2* has more of good *Y* than good *X*. Country *1* exports good *X* to, and imports good *Y* from, country *2*. We assume initially that trade is free.

More formally, using a CES utility function to describe preferences, country *1*'s problem can be defined as choosing X_1 and Y_1 to:

$$\text{maximise} \qquad U_1 = \left(\alpha X_1^{\frac{\sigma-1}{\sigma}} + (1-\alpha)\, Y_1^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$$\text{subject to} \qquad P_x\ \bar{X_1} + P_y\ \bar{Y_1} = P_x X_1 + P_y Y_1 \tag{2}$$

where α is the share parameter for good *X* and σ is the elasticity of substitution between the two goods. $\bar{X_1}$ and $\bar{Y_1}$ are fixed endowments for country *1* and P_x and P_y are the two world prices. Country *2* solves a similar problem.

Graphically, this equilibrium can be expressed as the intersection of the offer curves of the two countries. Each country's offer curve is shown in a box diagram (figure 2.1(a)). The origin for country *1* (the home country) is at the left-bottom corner O_1 while the origin for country *2* (the foreign country) is at the right-top corner O_2. The endowment point for both countries is at A.[2]

The offer curve for country *1* is derived as the solution to the utility maximisation problem for various relative prices. Given the price of good *X* relative to good *Y*, $p = P_x/P_y$, country *1*'s optimal consumption ratio is:

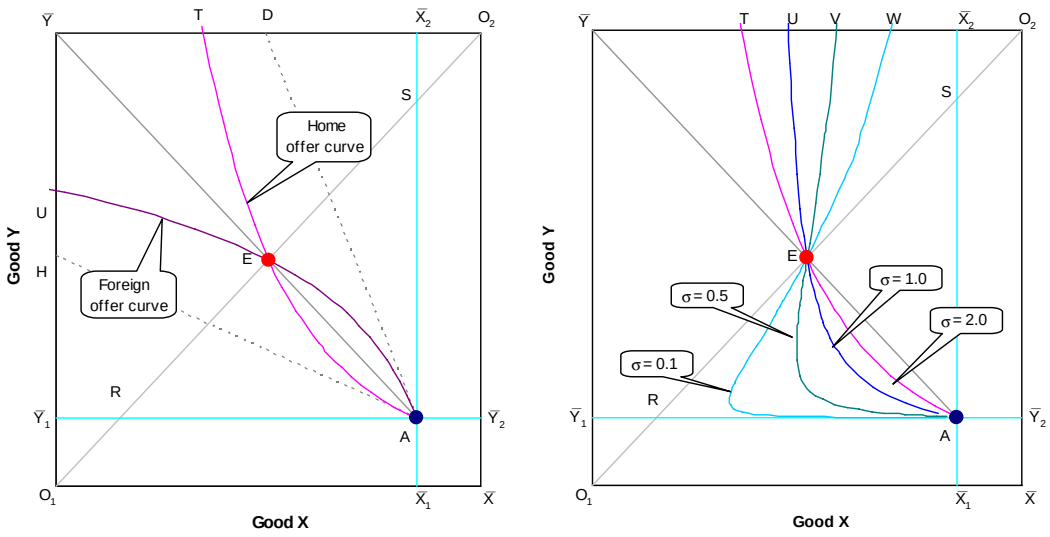
$$\frac{Y_1}{X_1} = \left(\frac{1-\alpha}{\alpha} \right)^{\sigma} p^{\sigma} \tag{3}$$

This would be shown as a ray from the origin O_1 in figure 2.1(a):

$$Y_1 = \left(\frac{1-\alpha}{\alpha} \right)^{\sigma} p^{\sigma} X_1 \tag{4}$$

2 By manipulating the unit of measurement, $\bar{X_1}$ can be made equal to $\bar{Y_2}$ ($O_1\ \bar{X_1} = O_2\ \bar{Y_2}$) and $\bar{Y_1}$ equal to $\bar{X_2}$ ($O_1\ \bar{Y_1} = O_2\ \bar{X_2}$), so that the box diagram is square.

Figure 2.1 **Offer curves in a two-country two-good non-Armington pure exchange model**



(a) Home and foreign offer curves

(b) Home offer curves with different substitution elasticities

The optimal consumption is achieved when the relative price line is tangent to the country's indifference curve (not drawn in the figure). The relative price line is given by the ratio of the amount of good *Y* exchanged for good *X*:

$$p = \frac{Y_1 - \bar{Y_1}}{\bar{X_1} - X_1} \tag{5}$$

This is shown as a downward sloping line through the endowment point A in figure 2.1(a):

$$Y_1 = p\,(\,\bar{X_1} - X_1\,) + \bar{Y_1} \tag{6}$$

The offer curve can be derived by substituting equation (5) into equation (4). This gives:

$$\frac{Y_1}{X_1} = \left(\frac{1-\alpha}{\alpha}\right)^{\sigma}\left(\frac{Y_1 - \bar{Y_1}}{\bar{X_1} - X_1}\right)^{\sigma} \tag{7}$$

Graphically this is the locus of all intersection points of two lines defined by equations (4) and (6). It shows the desired quantities of the two goods that country *1* is willing to buy at various relative price levels.

When $\sigma = 2$ and $\alpha = 0.5$,[3] equation (7) becomes quadratic. The solution is:

$$Y_1 = 1/2 \{ B + \sqrt[2]{B^2 - 4 \ \overline{Y_1}^2} \} \qquad (8)$$

$$\text{where } B = 2 \ \overline{Y_1} + \frac{(\overline{X_1} - X_1)^2}{X_1}.$$

This is country *1*'s offer curve, plotted in figure 2.1(a) as AET. With the same parameter settings, country *2*'s offer curve can be derived accordingly and plotted as AEU in the same figure.

In autarky, the two countries consume at endowment point A, where the domestic relative price of good *X* is lower in country *1* than in country *2*. The two countries' autarkic relative price lines are shown as AH and AD in figure 2.1(a). They are tangent to their respective offer curves at endowment point A. Trade causes the relative price *p* to increase. Consumers in country *1* respond by substituting good *Y* for good *X*, so that the optimal consumption ratio Y_1/X_1 increases. The reverse occurs in country *2*.

The offer curves of two countries start from the autarky equilibrium point A and intersect at point E, which is the free trade equilibrium. At point E, the world relative price is determined with its slope equal to –1. The world markets for both goods clear, that is:

$$\sum_{i=1}^{2} \overline{X_i} = \sum_{i=1}^{2} X_i \qquad (9)$$

$$\sum_{i=1}^{2} \overline{Y_i} = \sum_{i=1}^{2} Y_i \qquad (10)$$

The free trade consumption point is at the centre of the box diagram, E. As expected, country *1* exports good *X* and country *2* exports good *Y*.

The shape of the offer curve varies as σ varies.[4] In figure 2.1(b), four offer curves are drawn with σ equal to 2, 1, 0.5 and 0.1, respectively. As σ increases the offer curve comes closer to the free trade world price line. When σ is low, it comes close to the triangle ARS. However, no matter how low σ is, the offer curve always contains endowment point A.[5] In this two country model, all the possible trade

3 While the assumption that $\alpha = 0.5$ introduces more symmetry into the model, it is also neutral in the sense that the demand in each country is not biased towards or against the good exported by each country.

4 Note that the equilibrium values of X_1 and Y_1 can only be solved algebraically for a few specific settings of σ.

5 It will be shown below that the Armington model's offer curve does not have this feature.

equilibrium points occur in the area enclosed by triangle ARS. This area can be referred to as the *trade possibility triangle*. The size of this triangle is controlled by the endowment point. We will see below that the location of the endowment point separates non-Armington models from Armington models.

2.2 Terms of trade effects of a tariff in a non-Armington model

Now let country *1* impose a tariff on its imported good *Y*. The tariff inserts a wedge between domestic and world prices. For a given world relative price, *p*, the domestic relative price in country *1* becomes p/t_y, where t_y is one plus the *ad valorem* rate of tariff, or the power of the tariff, on imported good *Y*. Assuming the tariff revenue is returned to the consumer, the budget becomes:

$$P_x \ \bar{X_1} + P_y \ \bar{Y_1} + (t_y - 1)\, P_y\, Y_1 = P_x\, X_1 + t_y\, P_y\, Y_1 \qquad (11)$$

The relative price *p* in the optimal consumption in equation (3) and (4) should be replaced by the domestic price p/t_y as:

$$\frac{Y_1}{X_1} = \left(\frac{1-\alpha}{\alpha}\right)^{\sigma} (p/t_y)^{\sigma} \qquad (12)$$

Equation (6) now becomes the world relative price line, while the corresponding domestic price line is:

$$Y_1 = p/t_y \ (\ \bar{X_1} - X_1\ ) + \ \bar{Y_1} \qquad (13)$$

The tariff-distorted offer curve for country *1* is derived from equations (12) and (13). It is:

$$\frac{Y_1}{X_1} = \left(\frac{1-\alpha}{\alpha}\right)^{\sigma} \left(\frac{Y_1 - \bar{Y_1}}{(\ \bar{X_1} - X_1\ )\, t_y}\right)^{\sigma} \qquad (14)$$

With $\sigma = 2$ and $\alpha = 0.5$, the offer curve is still given by equation (8) with variable *B* redefined as:

$$B = 2 \ \bar{Y_1} + \frac{(\ \bar{X_1} - X_1\ )^2\, t_y^{\,2}}{X_1}. \qquad (15)$$

With $t_y > 1$, country *1*'s domestic price of the import rises and its demand for the imported good falls. As both goods are substitutable in consumption, country *1*'s

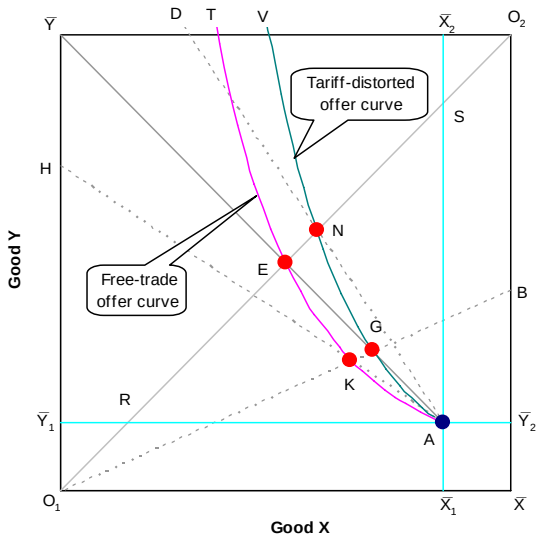
demand shifts toward good *X*, which reduces its exports. To balance trade in both countries, the world price of good *X* must rise relative to that of good *Y*, improving the terms of trade for country *1*. This can be captured by the new offer curve.

This tariff-distorted offer curve for country *1* is plotted in figure 2.2 as AGNV, with the free trade offer curve AET from figure 2.1(a). It will be assumed that country *2* does not impose a tariff on its import. For any given foreign offer curve, it must intersect the home tariff-distorted offer curve on the section between N and G, depending on the foreign substitution elasticity, that is, the shape of the foreign offer curve.

If the foreign country has an infinite elasticity reflecting perfect substitution, the foreign offer curve is a straight line and coincides with the free trade world price line. Hence, it intersects the home offer curve at point G, which is the new trade equilibrium. At this point the world price does not change and, therefore, the terms of trade remains unchanged. However, the domestic price line in country *1* is pushed down by the tariff to AKH. At the new domestic price, the home optimal consumption ratio is lowered to O_1KGB. The movement of the optimal consumption point from E to K measures the *substitution effect* of the tariff. This is because as the domestic price of good *X* increases relative to the price of good *Y*, home consumers substitute good *X* for good *Y*, which lowers the optimal ratio of consumption. On the other hand, the distance between K and G along the optimal consumption line O_1KGB measures the *income effect* of the tariff. Unlike the substitution effect, the income effect does not alter the optimal consumption ratio because an increase in income expands the demand for all goods proportionately when preferences are homothetic. An increase in income shifts the budget line up to be tangent to the highest indifference curve (not drawn) at point G.

If, instead, the foreign country's preference over the two goods is perfectly inelastic, its offer curve intersects the home offer curve at point N. This equilibrium point determines a new world price line AND. The domestic price line now coincides with the free trade world price line AGE $\bar{Y}$. The wedge between the new world price line (AND) and the free trade price line (AGE $\bar{Y}$) is equal to the tariff rate. As the domestic relative price does not change, there is no substitution effect. The distance between E and N on the optimal consumption line measures the income effect of this tariff.

Figure 2.2 **Tariff-distorted home offer curve in a non-Armington model**



If the foreign country's preference is somewhere between these two extremes, its offer curve intersects with the home offer curve within the section NG. The NG section on the home tariff-distorted offer curve is everywhere above the free trade price line. It implies that, except in the limit case of infinite foreign elasticity of substitution, any home tariff will result in a higher world price or a positive terms of trade effect.

Let the *terms of trade effect of a tariff* be defined as how much the world price of exports, relative to the world price of imports (the terms of trade), rises in response to a tariff. If a 1 per cent tariff results in a rise in the terms of trade of 1 per cent, the terms of trade effect is 100 per cent.

The extent to which a country can influence world prices and improve its terms of trade with a tariff depends on the shapes of the two countries' offer curves, which in turn depends on the substitutability of the two goods. As shown in figure 2.2, the terms of trade effect of a home tariff ranges from 0 to 100 per cent depending on whether foreign preferences are perfectly elastic or inelastic. The maximum effect that any tariff may have on the terms of trade in this two-country, two-good non-Armington model is 100 per cent, which is consistent with traditional trade theory.

It should be noted, however, that the terms of trade effect of a tariff is also influenced by a country's endowments of two goods. Other things being equal, if endowment point A is close to consumption point E, the terms of trade effect of a given tariff will be smaller. On the other hand, if the endowment point is further away from consumption point E, the terms of trade effect of a given tariff will be

larger, even if the elasticity of substitution between the two goods remains unchanged. The reason for this lies in the relative prices in autarky.

When the home country imposes a tariff on its imports, the foreign country's relative price in autarky represents the terms of trade that is required for a home tariff to prohibit imports. Any tariff above this level reverses the pattern of trade between the two countries. The tariff that induces this change in the terms of trade is the trade prohibitive tariff. In figure 2.1(a), the lines AD and AH are the foreign and home countries' autarkic relative price lines, respectively. The gap between the two lines measures the import prohibitive tariff rate.

With a given endowment point, the trade prohibitive world relative price varies with the elasticity of substitution. With a given elasticity, on the other hand, the further the endowment point A is from consumption point E (closer to the corner of the box, $\overline{X}$), the steeper the trade prohibitive price line becomes.

In this non-Armington model, the two goods are homogeneous in consumption and endowed in both countries so that the endowment point A is always located within the box. The trade prohibitive tariff rate is therefore finite. It will become clear in the following chapter that it is this feature that distinguishes non-Armington models from Armington models and determines why, for any given tariff, the Armington model always has a higher terms of trade effect than the non-Armington model.

3 Terms of trade effects in Armington trade models: one-tier substitution

A typical Armington model assumes a three-stage budgetary allocation procedure. Expenditure is first allocated among goods without regard to their origin. Expenditure on each good is then allocated between domestic and imported varieties. Finally, expenditure on imports is allocated among competing national suppliers. The whole structure can be neatly captured in a set of nested CES functions.

The first stage allocation does not involve Armington differentiation. It is based on an ordinary utility function with preferences allocated over different goods that are substitutable. The form of this utility function can be exactly the same as the one used in the non-Armington model shown in figure 2.1 or any other function used in consumer theory. The crucial difference in the Armington model is that the 'goods' in this utility function are not actual goods, but composites of domestic and imported goods, which are aggregated from the second stage budgetary allocation.

Only the second and third stage allocations are based on the Armington assumption of product differentiation or imperfect substitution. In the following discussion, these two tiers of substitution are examined separately to determine the effect of each level of substitution on the terms of trade effect of a tariff.

3.1 One-tier Armington substitution in a two-country pure exchange model

The simplest Armington model involves two countries, each of which is endowed with only one good. In this model, the first stage allocation collapses to the second stage: the utility function is now defined over a domestic good and an imported good. With only two countries, there are no competing exporters and the third stage of allocation does not exist. The three stage budgetary allocation collapses to just a single-stage procedure, that is the choice between a domestic good and an import. This is a basic one-tier Armington substitution model. The good each country is endowed with is its 'national' good, differentiated from its substitute, the national good of the other country.

In fact, this is the same model as that used in the previous chapter, but with the added restriction that each country is endowed with only one good. It is assumed that country *1* is endowed with good *X* and country *2* with good *Y*. Graphically, it is equivalent to moving the endowment point from A, inside of the box diagram to the right-bottom corner, as shown in figure 3.1. This simple movement transforms a conventional trade model into an Armington model.

When the world markets for the two goods clear, $\overline{X} = X_1 + X_2$ and $\overline{Y} = Y_1 + Y_2$, and the world equilibrium prices for the two goods are determined. As an example, let $\overline{Y} = \overline{X} = 1$, and $\alpha = 0.5$ and $\sigma = 2$ in both countries again. Figure 3.1 shows the equilibrium for this model. In figure 3.1, the horizontal axis shows country *1*'s endowment of good *X* while the vertical axis measures country *2*'s endowment of good *Y*. The endowment point is located at A. In free trade equilibrium, country *1* exports *X* and imports *Y* while country *2* does the reverse. Both countries maximise utility by consuming at point E.

With the Armington assumption that each country is endowed with only one good, we can derive the explicit equation of the offer curve. For country 1, we set $\overline{Y_1} = 0$ in equation (7), which gives:

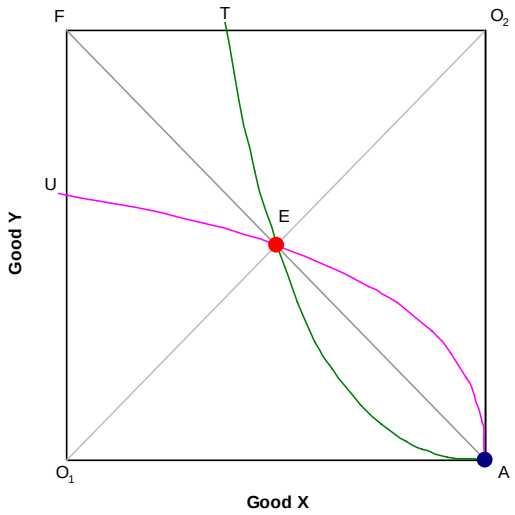
$$Y_1 = \left(\frac{1-\alpha}{\alpha}\right)^{\frac{\sigma}{1-\sigma}} \left(\frac{X_1^{1/\sigma}}{\overline{X} - X_1}\right)^{\frac{\sigma}{1-\sigma}} \qquad (16)$$

With $\overline{X} = 1$, $\alpha = 0.5$ and $\sigma = 2$, equation (16) becomes:

$$Y_1 = \frac{(1 - X_1)^2}{X_1} \qquad (17)$$

This is country *1*'s offer curve as shown by AET in figure 3.1. The same procedure can be used to derive country *2*'s offer curve (AEU).

Figure 3.1 **Offer curves in a two-country one-tier pure exchange Armington model**



As mentioned earlier, the shape of an offer curve is determined by the substitution elasticity. However, when the endowment point moves to the corner, the offer curves, even if derived from the same elasticities, become very different from that in the non-Armington model shown earlier. As was noted, when endowment point A moves away from consumption point E, the trade-prohibitive world relative price line will become steeper. This implies that a larger terms of trade change is required to eliminate trade. When the endowment point is located at the corner of the box diagram, the trade-prohibitive world relative price of good *X* to good *Y* becomes infinite. Geographically, this price line becomes vertical and coincides with the right vertical axis of the box diagram shown in figure 3.1. This implies that the rate of tariff required to prohibit imports is infinite. Moreover, with the same elasticity of substitution, for any given tariff, the Armington model always produces a higher terms of trade effect than the non-Armington model. This can be seen in the following three offer curves, each of which is associated with an extreme value of σ.

1. When the elasticity σ approaches zero, the equation of the offer curve of country *1* becomes:

$$\lim_{\sigma \to 0} Y_1 = X_1 \qquad (18)$$

which is a ray through the origin O_1 with a slope equal to unity. Country *2* has the same curve with the origin at O_2.

2. When σ approaches unity, the CES utility function becomes a Cobb-Douglas function, and the optimal consumption ratio derived from country *1*'s Cobb-Douglas utility function is:

$$\frac{Y_1}{X_1} = \frac{1-\alpha}{\alpha} p \qquad (19)$$

Country *1*'s offer curve is a constant proportion of its endowment:

$$Y_1 = \alpha \bar{X} \qquad (20)$$

This is a vertical line through the free trade equilibrium consumption point E to the horizontal axis. Likewise, country *2*'s offer curve becomes a horizontal line through the free trade consumption point E to the right border line of the box diagram.

3. When the elasticity σ approaches infinity, the offer curve of country *1* becomes:

$$\lim_{\sigma \to \infty} Y_1 = \frac{\alpha}{1-\alpha} (X - X_1) \qquad (21)$$

which is a ray through the endowment point A with a slope equal to $-\alpha/(1-\alpha)$. In figure 3.1, it coincides with the free trade world relative price line (AEF).

The reason Armington offer curves have such unusual shapes can be found in the definition of the substitution elasticity σ itself. By definition, σ is the ratio of the percentage change in the quantity ratio Y_1/X_1 to the percentage change in the relative price P_x/P_y. A value of σ close to unity implies that the percentage change in the relative quantity equals the percentage change in the relative price. Graphically, the optimal consumption line rises proportionately with the relative price line. As a result, they always intersect along a vertical line through equilibrium point E. The offer curve derived from such an elasticity is a vertical line through point E in the middle of the box diagram. When $\sigma > 1$, the relative quantity change is greater than the relative price change, the offer curve must lie on the right hand side of the vertical line through point E. When $\sigma < 1$, the offer curve must lie on the left hand side of the vertical line through point E.

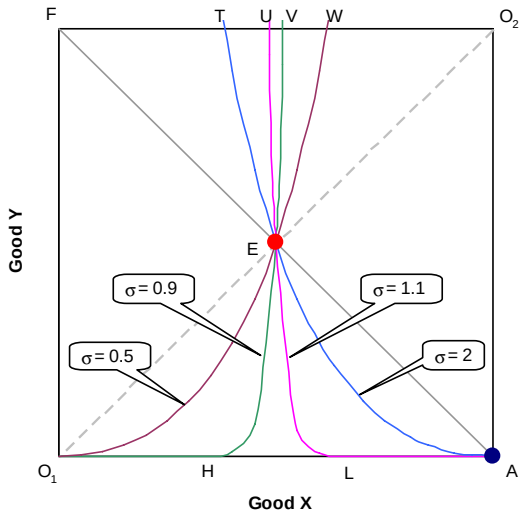
As $\sigma = 1$ is a critical value in the CES function, Armington offer curves can be divided into two groups with distinctive shapes:

1. If $0 < \sigma < 1$, the offer curves have an unusual shape: as σ approaches zero, they tend to move to the origin O_1, rather than the endowment point A.

2. If (and only if) $1 < \sigma < \infty$, that is, the substitution elasticity σ is greater than unity, offer curves exhibit the familiar shape.

Figure 3.2 shows four offer curves for the home country with σ set at 2, 1.1, 0.9 and 0.5. Only with an elasticity setting well above unity, do the offer curves have a familiar shape as seen in a conventional trade model — they run through both the equilibrium consumption point E and the endowment point A. Otherwise, the offer curve moves closer to the horizontal axis and does not come back to the endowment point at all. This is because the origin and the endowment point are on the same horizontal axis. As a result, when the relative price drops to zero, the optimal consumption ratio becomes infinite. Both lines overlap with each other and any point on the horizontal axis becomes optimal. The intersection point of the two lines can be anywhere, not necessarily at endowment point A.[1]

Figure 3.2 **Home offer curves with different substitution elasticities in an Armington model**



The figure reveals some fundamental differences between the offer curves derived from the non-Armington model and those derived from the Armington model. The Armington assumption changes the shape of the offer curve in a trade model and, as

1 With numerical models, Bhattarai, et al. (1999) also found perverse offer curves associated with low Armington elasticities.

a result, it changes the equilibrium world relative price. These differences help explain why the Armington model tends to produce higher terms of trade effects than the conventional trade model. These effects can be seen by imposing a tariff on the imports of one country.

3.2 Terms of trade effects of a tariff in a one-tier Armington model

Let country *1* introduce a tariff on its imported good *Y*. The tariff-distorted offer curve for country *1* is:

$$Y_1 = \left(\frac{1-\alpha}{\alpha}\right)^{\frac{\sigma}{1-\sigma}} \left(\frac{X_1^{1/\sigma}}{(\bar{X} - X_1)\, t_y}\right)^{\frac{\sigma}{1-\sigma}} \tag{22}$$

With $\bar{X} = 1$, $\alpha = 0.5$ and $\sigma = 2$, the offer curve becomes:

$$Y_1 = \frac{(1 - X_1)^2 t_y^2}{X_1} \tag{23}$$

This tariff-distorted offer curve is plotted in figure 3.3 as AGMP along with its free trade counterpart (AJEU), previously shown in figure 3.1. Depending on the elasticity of substitution in the foreign country, the new equilibrium point is located somewhere between points M and G of the home tariff-distorted offer curve. As a result, the effect of this tariff on the world relative price, or the home country's terms of trade, ranges between 0 and 100 per cent.

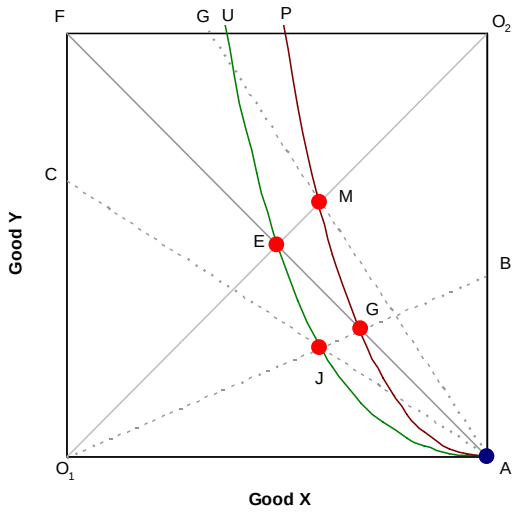
RESULT 1.

Compared with the non-Armington model with the same utility functions, the introduction of the Armington assumption by itself increases the terms of trade effect of a tariff for the importing country.

This can be seen by comparing figures 2.2 and 3.3. Compared with the non-Armington model, the offer curves in the Armington model, derived with the same substitution elasticity ($\sigma = 2$), are further away from the free trade price line, as the endowment point moves to the corner. However, in both models the offer curves intersect the free trade price line at the same points: the free trade offer curves in both models cross the free trade price line at point E, while the tariff-distorted offer curves in both models cross the free trade price line at point G. As a result, point M on the trade-distorted offer curve in the Armington model (figure 3.3) is above point N on the similar offer curve in the non-Armington model (figure 2.2). In fact, the whole section MG of the Armington offer curve is above

the NG section of the non-Armington offer curve. It implies that the tariff-distorted world relative price must be higher in the Armington model than in the non-Armington model. For any given tariff, the terms of trade effect is always higher in the Armington model than in the non-Armington model. This higher terms of trade effect can also be explained by a higher income effect. This is indicated in figure 3.3 by the longer distance between points E and M or between points J and G, in comparison with the similar effect shown in the non-Armington model of figure 2.2.

Figure 3.3 **Tariff distorted offer curve in a two-country one-tier pure exchange Armington model**



Moving the endowment point from somewhere strictly within the box to the corner of the diagram has fundamentally altered the nature of this trade model. In the non-Armington model, trade is used to fill the gap between the consumption pattern and the endowment pattern. Trade occurs therefore only within the trade possibility triangle ARS in figure 2.2. In the Armington model, however, the entire endowment of a country is substitutable and potentially tradable with the imports, which consist of the entire endowment of the foreign country. This means that the entire world endowment is tradable. Trade in the Armington model occurs in the triangle AO_1O_2, covering the entire endowment spectrum for the world. As a tariff increases, the offer curve for country *1* tends to move closer to the horizontal axis, rather than the endowment A as in the non-Armington model. As the entire endowment is tradable, the tariff can be raised to a much higher level than in the non-Armington model without driving trade to zero. The offer curve tends to bow more toward the horizontal axis, implying that a country could potentially gain almost indefinitely from improved terms of trade by increasing its tariffs.

Graphically, when both countries' substitution elasticities are close to unity or below, the intersections of the relative price lines and the optimal consumption lines move close to the horizontal and vertical axes, respectively. Even an extremely high tariff by country *1*, for example, does not reduce trade to zero because the revenue from the high export price (terms of trade improvement) enables country *1* to purchase a large amount of the goods from country *2*. As the substitution elasticity approaches zero, the income from increasing the export price can be high enough to purchase the entire foreign endowment!

In figure 3.3, a continuing rise in the tariff shifts the home offer curve further to the right. The equilibrium world relative price is also changed accordingly. The terms of trade effect varies with the tariff imposed. In the case of identical elasticities, the marginal terms of trade effect is positive if $\sigma < 1$, negative if $\sigma > 1$ and constant if $\sigma = 1$. If the two countries' elasticities are not equal, the marginal terms of trade effect depends on the combination of the two elasticities.

Only with the extreme elasticity settings, can the terms of trade effect of a tariff become a constant, that is, they are no longer affected by the other country's preferences. For example, the terms of trade effect becomes 0 if the home elasticity approaches 0 and becomes 100 per cent if the home elasticity approaches infinity. On the other hand, the terms of trade effect of a home tariff becomes 100 per cent if the foreign elasticity approaches 0, and 0 if the foreign elasticity approaches infinity.

RESULT 2.

In a one-tier Armington mode:

(i) increasing the home country's elasticity of substitution increases the terms of trade effect of the home country's tariff by up to 100 per cent; but

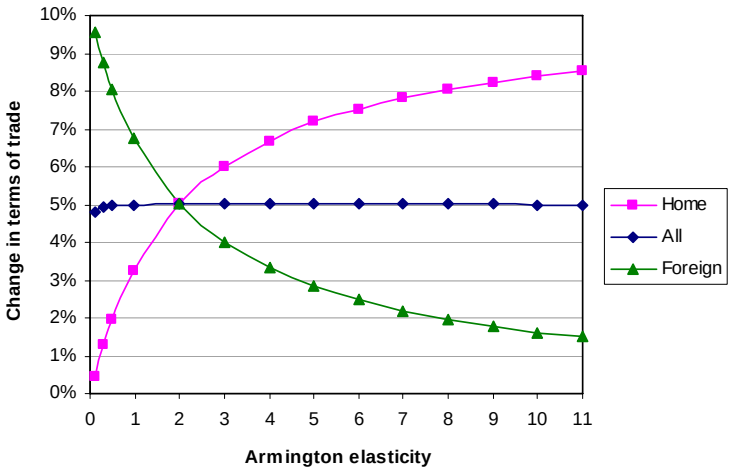
(ii) increasing the foreign country's elasticity of substitution decreases the terms of trade effect of the home country's tariff to 0.

These results can be seen in figure 3.4. Assume an elasticity of 2 for both countries.[2] For a tariff of 10 per cent, as the elasticity of substitution in the home country increases from 0 to infinity and the foreign elasticity is kept constant, the change in the home terms of trade increases from 0 to a maximum of 10 per cent, implying a terms of trade effect of 100 per cent. If the foreign elasticity of substitution is increased from 0 to infinity, the change in the home terms of trade

2 The elasticity of 2 is used here as a benchmark. Changing this elasticity setting would only change the intersection point in figure 3.4 and does not alter the relationship between each elasticity and the terms of trade.

falls from 10 to 0 per cent.[3] If both the home and foreign elasticities are increased, the two opposite effects cancel out. The change in the home terms of trade remains constant at 5 per cent, implying a terms of trade effect of 50 per cent.

Figure 3.4 **Substitution elasticity and terms of trade effect of a 10 per cent tariff in a two-country one-tier Armington trade model**



Before turning to the two-tier Armington models, we need to consider if these results can be affected by variation in the levels of the other parameters of the model. It has been assumed so far that both countries prefer equally domestic and foreign goods in consumption. In the real world, however, there may be a bias toward either home goods or imported goods. It can be shown that, for given home and foreign elasticities, if both countries have similar biases, the share parameters do not affect the terms of trade effect of a tariff.

Moreover, the terms of trade effect of a tariff in Armington trade models does not seem to be affected much by the size of the country relative to the rest of the world either. This can be confirmed by increasing the number of countries in the rest of the world. In this multiple-country model, every country still has market power, which does not diminish very much as the number of countries increases. Even if imports are supplied by nine countries, instead of two, the combined offer curves for the rest of the world, derived from this ten-country trade model, are only slightly more elastic than the one derived from the two-country model. As long as the share of expenditure on all imports remains unchanged, whether these imports are from two countries or nine countries does not seem to change the terms of trade effect of

3 Using an analytical model, Brown (1987) found that the home and foreign elasticities of substitution have opposite effects on the terms of trade.

a home tariff very much. A country's market power is derived largely from its own exportable good.

4 Terms of trade effects in Armington trade models: two-tier substitution

If there is more than one foreign country and if the consumer's preferences over its own domestic and imported goods from more than one country are 'separable', a second-tier Armington substitution can be introduced. To model two tiers of Armington substitution, a minimum of three countries is needed.

4.1 Two-tier Armington substitution in a three-country pure exchange model

Assume that country *3* is endowed with an equal quantity of a third good *Z*. For this model to be comparable with the previous models, it is assumed that each country still spends one half of its income on its own (domestic) good and the other half on all imports. The allocation of the import budget is further guided by another CES utility function, which gives equal shares to the imports from all countries but treats them as imperfect substitutes. This allows the model to start from the same free-trade equilibrium point as that of the previous models.

For country *1*, the consumer's problem can be expressed as choosing X_1, Y_1 and Z_1 to

$$\text{maximise} \qquad U_1 = \left(\alpha X_1^{\frac{\sigma-1}{\sigma}} + (1-\alpha) M_1^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{24}$$

$$\text{where} \qquad M_1 = A_1 \left(\delta Y_1^{\frac{\theta-1}{\theta}} + (1-\delta) Z_1^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{25}$$

$$\text{subject to} \qquad P_x \bar{X} + (t_m - 1)(P_y Y_1 + P_z Z_1) = P_x X_1 + t_m (P_y Y_1 + P_z Z_1) \tag{26}$$

where M_1 is the import composite for country *1* composed of goods *Y* and *Z*; *A* is a scale parameter and δ is the share parameter for imported good *Y*; θ is the elasticity of substitution between two imported goods; t_m is the power of tariff on all imports; P_z is the world price of good *Z*. It is assumed that the tariff rate is uniform on all imports.

Because the two CES functions are separable, the substitution in the second level or tier between competing suppliers of imports is independent of the first level. We can therefore still treat the import composite as a 'good' and define country *1*'s free trade and tariff-distorted offer curves over its own good (X_1) and a composite import (M_1) in the same way as in equations (16) and (22), respectively. The tariff distorted offer curve is:

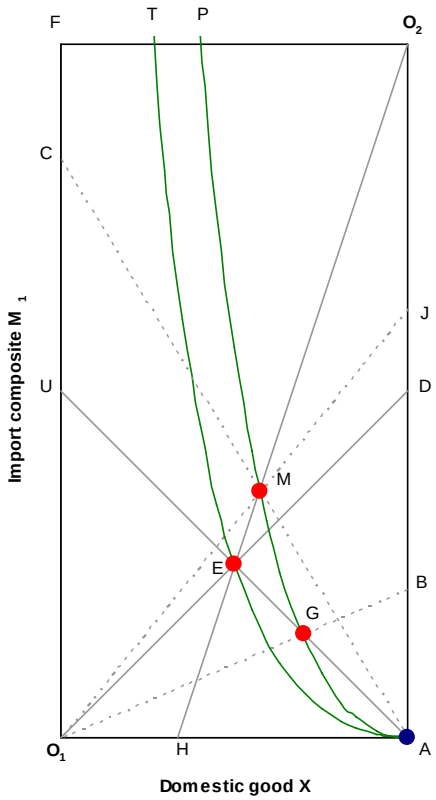
$$M_1 = \left(\frac{1-\alpha}{\alpha}\right)^{\frac{\sigma}{1-\sigma}} \left(\frac{X_1^{\,1/\sigma}}{(\,\bar{X} - X_1\,)\,t_m}\right)^{\frac{\sigma}{1-\sigma}} \qquad (27)$$

Also, with $\sigma = 2$ and $\alpha = 0.5$ in each country, the free trade and tariff-distorted offer curves for country *1* remain the same as defined in equations (17) and (23).

The familiar box diagram framework is still applicable to this model. The box diagram for country *1* is shown in figure 4.1. As the combined endowment of the rest of the world is greater than that of the home country's, the vertical axis of the box diagram is longer than the horizontal axis. The box diagram in this three-country model becomes rectangular. As every country is of equal size, a similar box diagram can be drawn for each of the foreign countries as well.

In this diagram, although the vertical axis is now changed to M_1, a composite of goods *Y* and *Z*, the shape of the home offer curves remains the same as in the two-country one-tier Armington model above. Because the two-tier substitutions are separable, the shape of the home offer curve in this box diagram is determined only by the home's first tier elasticity σ. The offer curve becomes a straight line through the origin (O_1ED) if σ approaches zero and coincides with the free-trade price line (AEU) if σ approaches infinity. These two lines define an area in which all home offer curves are located. When σ approaches unity, the home offer curve is a vertical line through the free trade consumption point E. This line divides the home offer curve into two groups with distinctive shapes.

Figure 4.1 **Home offer curves in a three-country two-tier Armington trade model**



In the three-country box diagram, it is the foreign offer curve that could have shapes very different from that in the two-country model. As each country trades with two foreign countries, the foreign offer curve becomes a combined one. The price of the foreign goods also becomes a composite price, rather than a single good price. In free trade, the composite price is defined as:

$$P_{m1} = \frac{t_m}{A_1}\left[\delta^{\theta} P_y^{1-\theta} + (1-\delta)^{\theta} P_z^{1-\theta}\right]^{\frac{1}{1-\theta}} \qquad (28)$$

The foreign offer curve in the box diagram shows the desired quantities of X and a composite good M_1 that the two foreign countries are willing to consume at any given relative price P_x/P_{m1}. Depending on whether a home tariff is imposed on all imported goods (uniform tariff) or just one imported good (discriminatory tariff), the world relative prices of the three goods vary. In response, the two foreign countries choose different bundles of the three goods to maximise their respective utilities. The foreign countries' decisions not only change their respective trade with the home country but also with each other. Understanding how the two tiers of foreign elasticities affect the shape of the foreign offer curve is crucial to

understanding the effect of a tariff on the world relative price and the terms of trade for the home country.

4.2 Terms of trade effects of a uniform tariff in a two-tier Armington model

Suppose that the home country imposes a uniform tariff on its imports of *Y* and *Z*. The tariff shifts the home offer curve to the right as in the two-country model (figure 4.1). The intersection of this tariff-distorted offer curve and the foreign offer curve determines the new equilibrium. It also determines the effect of this tariff on the world relative price or the home terms of trade. As before, the section between points M and G on the tariff-distorted home offer curve gives all the possible points of intersection with the foreign offer curve.

If all foreign elasticities approach zero (perfectly inelastic), the foreign offer curve becomes a straight line from the foreign origin (the top-right corner) O_2MEH. It intersects the home tariff-distorted offer curve at point M. The new world relative price line is AMC, and the terms of trade effect of this tariff reaches the maximum level. Unlike the two-country case, the maximum terms of trade effect of a tariff with low foreign elasticities could be more than 100 per cent. It means that the world price of the imported goods could decrease so much that the domestic prices of these goods decline.

At the other extreme, if all foreign elasticities approach infinity (perfectly elastic), the foreign offer curve becomes a straight line from the endowment point A (AGEY), which overlaps the free trade price line. The terms of trade effect of a tariff in this case is zero. This result is the same as in the two-country Armington model.

Once again, if all foreign elasticities approach unity, the foreign offer curve is a horizontal line through the free trade equilibrium point E to the vertical border of the box diagram (not drawn in figure 4.1). This line divides the foreign offer curves into two distinct groups as in the two-country model. However, there is a difference between the two sets of offer curves.

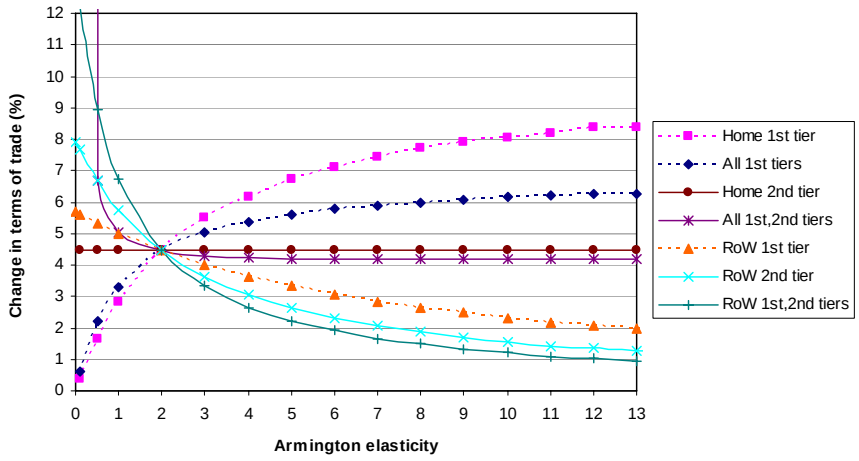
In this three-country model, if all foreign elasticities are equal and above unity, the foreign offer curves are slightly flatter than in a two-country Armington model. That is, they are closer to the free trade world price line than their counterparts in a two-country Armington model. As a result, for a given home tariff, the terms of trade effect is smaller in a three-country model than in a two-country Armington model. This is because trade between the two foreign countries absorbs some of the

pressure that the home tariff may have on world prices. The response of the rest of the world (RoW) to a home tariff is therefore somewhat less than in the two-country Armington model.

If all foreign elasticities are equal and below unity, on the other hand, the foreign offer curve is steeper than in the two-country Armington model. The terms of trade effect of a home tariff in this case is higher than in the two-country model. The rigid mutual demands for each other's goods between two foreign countries reinforce the effect of a tariff on the world relative prices. The terms of trade effect of a home tariff increases as the foreign elasticities become smaller and approaches the maximum when all foreign elasticities are close to zero.

The above discussion is based on the assumption of equal elasticities in the two-tiers of substitution for all countries. For such models, the relationships between various Armington elasticities and the terms of trade effect of a tariff are summarised in figure 4.2.

Figure 4.2 **Substitution elasticity and terms of trade effect of a 10 per cent tariff in a three-country two-tier Armington trade model**



This figure takes a 10 per cent uniform tariff as an example. The effects of this tariff on the terms of trade depend on how elasticities are set. Using a numerical model with all home and foreign elasticities set to 2,[1] a 10 per cent uniform tariff causes the home terms of trade to increase by 4.45 per cent. We then vary one elasticity or a set of elasticities at a time to check how the terms of trade responds to various elasticity settings. Seven results can be derived.

1 The elasticity of 2 is used here as a benchmark level. Changing this elasticity setting would only change the intersection point in the figure and does not alter the relations between each elasticity and the terms of trade.

RESULT 3.

In a two-tier Armington model:

(i) Increasing the home country's first-tier elasticity increases the terms of trade effect. The changes in the terms of trade range between 0 and 10 per cent.

(ii) Increasing all countries' first-tier elasticities only increases the terms of trade to a constant level well below 10 per cent.

(iii) Changing the home second-tier elasticity has no effect on its own terms of trade because of 'preference separability'.

(iv) Increasing the foreign countries' first-tier elasticities reduces the terms of trade effect.

(v) Increasing the foreign countries' second-tier elasticities reduces the terms of trade effect. Although both tiers of foreign elasticities have a similar effect on the terms of trade, the foreign second-tier elasticities have a stronger impact on the terms of trade than the first-tier ones.

(vi) Increasing both first- and second-tier foreign elasticities reduces the terms of trade to zero more quickly. This is because these two separate effects work in the same direction. If both increase, they reinforce each other.

(vii) The effect on the terms of trade of increasing all elasticities for the home and foreign countries depends on how these elasticities are set relatively. If all elasticities are set above their current level of 2, the terms of trade change will be reduced to a constant level of slightly below the current 4.55 per cent. On the other hand, if all elasticities are reduced from 2, the terms of trade effect will increase dramatically and could exceed 100 per cent very quickly; that is, the world relative price of the home export increases more than the tariff rate.

The results regarding the first-tier elasticities — results (i), (ii) and (v) — are similar to those obtained with the two-country model (figure 3.4). However, the second-tier elasticities, especially the foreign ones, have an effect on the terms of trade of a tariff opposite to the first-tier substitution elasticities. This is because foreign second-tier substitution affects the combined foreign offer curve through its impact on the world prices of all three traded goods. If both foreign second-tier substitution elasticities tend to infinity, this is equivalent to increasing all foreign first-tier substitution elasticities to infinity, which results in a linear foreign offer curve through endowment point A.[2] The terms of trade effect of any home tariff is reduced to zero.[3]

2 This result was derived above with a one-tier Armington substitution model.

3 Using a pure exchange model, Brown (1987) derived a similar result concerning the second-tier Armington substitution: '... as imports from different sources become perfect substitutes in all

The results also show that increasing the elasticities does not always reduce the terms of trade effect. In fact, increasing all elasticities beyond $\sigma = 2$ only reduces the terms of trade effect to a minor extent. This is because the opposite effects of individual elasticities on the terms of trade are cancelling each other. When all elasticities are adjusted in the same proportion, the terms of trade may not always respond accordingly.[4]

So far the discussion has been confined to Armington models with equal elasticities in both tiers of substitution for foreign countries. If this restriction is relaxed, the foreign offer curve could take many more complicated shapes. Some foreign offer curves could be very different from what we have seen above. For example, if the foreign first-tier substitution is elastic while the second-tier substitution is inelastic, the foreign offer curve becomes similar to some of those seen in the non-Armington model with low substitution elasticities. The curves first move away from the free trade world price line and then fall back to endowment point A at very high world prices. The terms of trade effect of a tariff in such a model tends to be larger.

On the other hand, if the foreign first-tier substitution is inelastic while the second-tier substitution is elastic, the foreign offer curve becomes flatter and closer to the free trade world price line. In applied CGE models with a two-tier Armington substitution structure (such as the 'SALTER' and 'GTAP' models — see Jomini et al. 1994 and Hertel 1997), it is commonly assumed that the second-tier substitution elasticities are twice that of the first tier substitution elasticities. This so called 'rule of two' has an effect of dampening the terms of trade effects associated with Armington trade models compared with the models with equal first and second tier elasticities.

4.3 Terms of trade effects of a discriminatory tariff in a two-tier Armington model

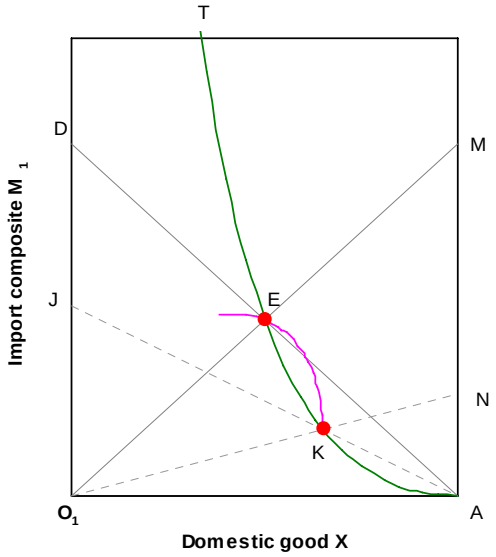
The shape of the foreign offer curve in the box diagram depends also on the type of tariffs imposed by the home country on its imports. As shown above, if the tariff is imposed on both imported goods, changing the home second-tier elasticity has no effect on the home terms of trade. However, if a tariff is imposed on one import alone, changing the home second-tier substitution elasticity does affect the home

countries, then the terms of trade gain by a country from the imposition of a tariff tends to zero. The optimal tariff is zero'. In fact, it is the *foreign* second tier substitution elasticities that cause this result.

4 One should note that a small terms of trade change does not necessarily mean no change in other variables. On the contrary, a small terms of trade change can still have large quantitative consequences in an applied CGE model.

terms of trade. This is because when a tariff is imposed on imports from one source alone, home consumers switch their demand to the import from the other source. In such a case, the combined offer curve for the rest of the world has a unique shape. One such example is shown in figure 4.3.

Figure 4.3 **Combined response of the rest of the world to a home tariff on one import**



In this case, all the parameter settings remain the same as before. All substitution elasticities are set at 2. The home country imposes a tariff on the imports from country *2*. The home offer curve remains unchanged. When the tariff reaches the prohibitive level, the imports from country *2* are reduced to zero. As the home country shifts its demand to the imports from country *3*, the trade between the home country and country *3* increases. As a result, the home demand for composite imports is composed of only good *Z* from country *3*. Once the imports from country *2* becomes zero, the tariff has no effect on the prices or the consumption of the goods. The foreign offer curve reaches point K on the home offer curve. No matter how much the home tariff is increased, the world price and consumption bundle do not change. The home second-tier substitution sets a limit for the discriminatory tariff to affect the terms of trade. Numerically, the maximum effect such a discriminatory tariff can have on the terms of trade in this case is 6.6 per cent.[5]

5 When a discriminatory tariff is introduced, the price for the CES composite of imports is no longer equal to the weighted average price of imports. The latter is used in calculating terms of trade changes. Therefore the price of import composite is no longer indicative of the change in the terms of trade. In figure 4.3, the equilibrium consumption point K is below the free trade price line AED. This does not mean the world relative price line is lower than the free trade

The home country is unlikely to benefit much, by way of terms of trade, from this form of tariff. It can be seen in figure 4.3 that the foreign offer curve lies mostly below the free trade price line. The greater the substitutability between two competing imports, the less the home country can gain from the terms of trade improvement by imposing such a tariff. This is because a higher home second-tier substitution elasticity makes the foreign offer curve flatter and shorter (point K closer to point E). This means a lower prohibitive tariff rate and a lower terms of trade effect.

In this case, only country *3* benefits from such a discriminatory tariff. Both countries *1* and *2* lose. However, country *1* loses more than country *2*. This model is useful for analysing preferential trade agreements (PTAs). As Armington models are often used to analyse the effects of PTAs, insights can be gained if the behaviour from various elasticity settings is clearly understood.

price level. In fact, at K, the world price of good *X* relative to the weighted average price of two imports is 6.6 per cent higher than the free trade price.

5 Extensions of the simple Armington model

The Armington models above can be extended to include many goods and countries. The fixed endowment can be relaxed by introducing production with primary and intermediate inputs. These extensions, however, do not alter the basic properties of the Armington structure and the relationship between substitution elasticities and the terms of trade effect of a tariff.

5.1 Many goods pure exchange models

In a 'one country versus the rest of the world' context, the offer curves can still be drawn for many good models. The offer curve can be defined over an aggregated domestic good and an aggregated composite import good, aggregating from individual countries' domestic outputs and imports. The only difference is that indifference curves can no longer be drawn over the two aggregators in the box diagram because substitution occurs between individual domestic and import varieties, not between aggregates.

In an aggregated domestic and import composite space, the characteristics of the offer curves, derived from one-sector Armington models, remain unchanged. Sector aggregation does not alter the relationship between Armington elasticities and the terms of trade effects of a tariff, derived from the simple models above.

5.2 Incorporating production with primary factors

The fixed-endowment assumption in the above trade models can be relaxed by incorporating production with primary factors. For example, capital and labour can be combined under given technologies to produce goods in different industries. Depending on changes in world relative prices of the goods produced, the total output of domestic production for a country may expand or contract. One would expect that adding production would in general increase domestic supply responsiveness and therefore reduce the terms of trade effect of a tariff. This is correct only for the non-Armington model because a tariff will induce factor

reallocation and increase the outputs of import competing industries. As a result of supply responses, the effect of the tariff on the price of imports relative to exports, or the terms of trade, can be reduced.

For the Armington model, however, the tariff-induced reallocation of factors is much smaller. This is because every industry has two-way trade: it exports and imports simultaneously. Consider a uniform tariff on all imports from all sources. This raises the prices of all domestically produced goods whereas, in the non-Armington model, it raises the price of import-competing goods relative to prices of all export goods. In an Armington model, such a tariff cannot induce such large changes in relative prices between industries. There is a similar result for a tariff on the product(s) of one industry alone. This raises the price of the imported and domestically produced substitutes, which in turn increases production for the home market, but lowers exports of the national product. In a non-Armington model however, this raises the output of the import-competing industry and lowers that of the exports of other industries. As a result, tariff-induced factor reallocations and output changes are much smaller in an Armington model than in a similar model without Armington product differentiation.

RESULT 4.

Compared with a non-Armington model with the same utility and production functions, the Armington assumption dampens the supply response to a tariff and thereby increases the terms of trade effects of a tariff for the importing country.

In fact, the behaviours of the Armington models with and without production are so similar, that adding production does not add any new insight to the findings derived from the pure exchange Armington models shown above.

5.3 Production with primary factors and intermediate inputs

Intermediate inputs can also be introduced into the above Armington trade model with primary factors. Like final consumption goods, intermediate inputs can be supplied by domestic and foreign producers. The domestically produced and imported intermediate inputs are imperfect substitutes, subject to a CES production function, nested under an overall production function for the sectoral output.

The introduction of intermediate inputs adds a production side nesting of Armington substitution. This nesting structure is identical to the consumption side nesting, which contains both tiers of Armington substitutions. This structure can be simplified by assuming that the domestic and imported goods in a sector first form

one CES composite, which is then allocated between the intermediate input users and the final consumption users. In such a model, the fundamental Armington substitution structure remains unchanged so that the above analytical framework remains applicable. A similar box diagram and offer curves can still be constructed in an aggregated domestic good and an aggregated import composite space, no matter how these aggregates are distributed between different domestic users. Therefore, the results derived above on the relationship between Armington elasticities and terms of trade effects remain unchanged.

Hence, the quantitative results obtained in previous chapters for simple pure exchange Armington models hold generally for Armington models with production of many goods using both domestic and imported intermediate inputs. The next chapter will confirm that the similar results can be derived from an applied CGE trade model as well.

6 Applied CGE models with Armington assumptions: the case of GTAP

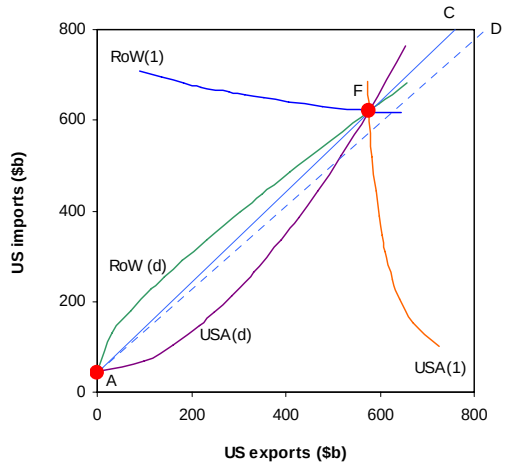
The GTAP model is a multi-good and multi-country global CGE model, which is widely used to analyse trade policies. It adopts a two-tier Armington substitution in a theoretical structure that is much more complex than the models used above. It is chosen here as a case study to illustrate and validate the main findings derived from the previous analytical models about Armington elasticities and terms of trade effects of a tariff.

The GTAP version used in this section has three regions/countries and three sectors/goods.[1] The three regions/countries are the United States (US), the European Union (EU) and the rest of the world (RoW). The United States is referred to in the following as the 'home country' and the European Union and the Rest of the World are treated as the 'foreign country'. The three sectors are 'food', 'manufacturing' and 'services'. The model closure assumes that regional investments are reallocated to equalise a global expected rate of return for capital. The elasticities of substitution between the domestic and import composite (the first-tier substitution) for the three goods in the parameter file are the default ones: 2.4, 2.8 and 1.9, respectively. The elasticities of substitution between import suppliers (the second-tier substitution) are 4.6, 6.1 and 3.9, respectively.

By gradually increasing US import tariff rates uniformly, a series of equilibrium import and export volumes can be obtained. The locus of these equilibrium points gives the offer curve for the 'foreign country'. A similar procedure can be followed for European Union and Rest of the World to increase gradually their tariffs on the US exports and then obtain the consequent equilibrium US export and import volumes. The locus of these equilibrium volumes gives the offer curve for the United States. These offer curves derived from the GTAP model simulations are plotted in figure 6.1.

1 It is available from the GTAP website: www.gtap.agecon.purdue.edu. This aggregate version is chosen purely for saving computation time. Similar results can be obtained from any disaggregated version of the model database.

Figure 6.1 **Offer curves in GTAP3x3: United States vs Rest of the World**



This figure shows only a small portion of the underlying box diagram, used in the previous sections. This is because exports account for only 6 per cent of US total output. The exports to the United States by the rest of the world have an even lower share in its total output. If the entire world output were drawn, the offer curves would be too small to see. The figure therefore shows only the offer curve portion of the box diagram. To do this, the endowment point and the origin point are also switched so that the horizontal axis measures US exports and the vertical axis measures US imports. As a result, the 'home' and 'foreign' offer curves face the directions opposite to those shown in the box diagrams above.

Moreover, this diagram differs from the previous ones in two other aspects. First, US trade is not balanced in the database. There is a trade deficit in the United States, indicating a transfer of income from the rest of the world. As a result, the relative price lines do not start from the origin. The difference between the origin and the intersection (point A) of the world relative price line (AFC) and the vertical axis shows the excess imports paid by the inflow of foreign income.

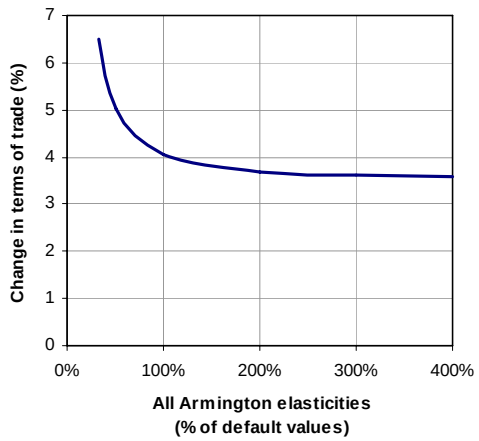
Second, the world initial equilibrium prices are not free trade prices. This is because in the database they embody tariffs imposed by all countries. The United States has an average tariff of 9 per cent on its imports. As a result, the initial price of US domestically produced goods relative to that of goods produced in other regions (shown as line AD) is 9 per cent below the world initial relative price line (AC). As the initial relative prices serve only as a point of reference, these differences do not affect the terms of trade effects resulting from increasing or reducing tariff rates.

The figure shows similarities with that of the simple models. For example, as all regions have identical elasticities in both tiers of substitution, the foreign offer curve (shown as RoW(d) in figure 6.1) should be flatter than the home one. The 'foreign

country' as a whole gains less from imposing a given tariff on its imports from the 'home country'. When all elasticities are reduced to unity, the US offer curve becomes almost a vertical line (shown as USA(1) in figure 6.1) while the 'foreign' offer curve becomes almost horizontal (shown as RoW(1) in figure 6.1), just as the simple Armington model shows.

As figure 6.1 indicated, the offer curves derived from the GTAP model are similar to those from the simple models. It is therefore expected that the effects of a tariff on the terms of trade in the GTAP model should be similar too. This can be seen in figure 6.2, which shows the effect of a 10 per cent rise in US import tariffs on its terms of trade under different elasticity settings. Under the default levels of Armington elasticities, a 10 per cent rise in US uniform tariffs increases the terms of trade by 4 per cent. As Armington elasticities are reduced from the default levels in all regions in the world, the terms of trade effect increases. On the other hand, as all elasticities are raised from the default levels, the terms of trade effect declines slightly to a constant level. This result is consistent with those from the simple models.

Figure 6.2 **Armington elasticities and the change in terms of trade from a 10 per cent rise in US tariffs**



Other disaggregated versions of the model can also be used to produce similar offer curves for any single country or region of interest. As mentioned above, the aggregation or disaggregation of sectors does not alter the properties of Armington models. Therefore, the results derived from the simple analytical models on the terms of trade effects and Armington elasticities hold for applied CGE models with any level of disaggregation of goods, sectors and regions.

7 Concluding comments

The paper develops a box diagram for analysing the terms of trade effects in general equilibrium trade models. This box diagram is a powerful tool in quantifying the links between the Armington structure and the terms of trade effect of any tariff in an applied model with many goods and many countries. The simple framework can be used to specify the range of elasticities that may be used in policy modelling. The paper shows that the Armington structure is remarkably robust. Increasing sophistication of applied trade models does not seem to alter the unique characteristics of the Armington structure.

Compared with the conventional trade models, Armington models tend to give more market power to all trading countries, regardless of size and market share. This is especially so when all Armington elasticities are close to or below unity.

In a two-tier substitution Armington trade model with multiple countries, the substitution elasticities in the two levels affect the terms of trade effect of a tariff differently. Increasing the foreign first-tier elasticities or reducing the home first-tier elasticities lowers the terms of trade effect of a home tariff. Increasing the foreign second-tier elasticities also lowers the terms of trade gain from a home tariff. However, varying the home second-tier elasticities does not change the terms of trade effect of its own tariff.

The effects of an Armington structure go beyond those of the choice of substitution parameters. This paper reveals that adopting an Armington structure changes the terms of trade effects compared to those in a model with a non-Armington structure in two ways. First, on the demand side, Armington differentiation increases the monopoly power of trading countries, for all elasticities of substitution (result 1). Second, it reduces the supply response in the tariff-imposing country (result 4). Both of these aspects increase the terms of trade effect compared to a comparable non-Armington model. They are fundamental to the Armington structure and cannot be removed by changing the elasticities of substitution in any way.

The unique characteristics of the Armington structure revealed in this paper have significant implications for the model users. In Armington models, the demand substitution elasticities play a critical role in determining the simulation results. Consequently, the terms of trade effect becomes an important part of the new equilibrium solution for any trade policy simulation. As substitution elasticities are

parameters determined outside the model's theoretical structure, the Armington structure therefore makes the market power of any country a modeller's choice. As a result, model outcomes can easily be impacted upon by the value of the substitution elasticities.

Brown (1987) and others have raised the serious question of the appropriateness of Armington-type models for policy analysis. The importance of this question is heightened by the results of this paper. There seems to be no easy solution to this question. Alternative demand structures may be tried, but these models are not without their own problems.[1]

If an Armington model is used, this paper offers some insights into how this structure functions, especially how the substitution elasticities affect simulation results. A clear understanding of the Armington structure is vitally important in interpreting the results of a policy simulation using such models. Inadvertent misuse or potential abuse of such models, through selection of parameter values, can be minimised by providing a strong empirical basis for the choice of Armington elasticities and ensuring they are consistent with the model and sector aggregation in which they are used.[2]

1 For a discussion of alternative demand systems used in CGE trade models, see Francois and Shiells (1994).

2 For some recent work on estimating Armington elasticities for the GTAP model, see Hertel et al. (2003) and Zhang and Verikios (2003).

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