Implicit Trade Costs and European Single Market Enlargement.

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Abstract

A major current issue in the economics of trade blocs is where the bloc is not just a customs union, but also incorporates substantial regulatory harmonisation or mutual recognition elements. The derivation of the costs of non-membership of such a bloc is not straightforward. In this paper I build on the assumption that observed trade patterns can be taken to reveal trading costs, and develop a model-consistent Dixit-Stiglitz general equilibrium-based calibration technique as an alternative to gravity methods previously used. I use the model to investigate numerically the likely trade effects of the recent widening of the European Single Market to incorporate several Central and Eastern European Countries.

Keywords: Protection, General Equilibrium, European Union.

JEL Classifications: F12, F15, F17.

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1   Introduction.

In this paper, I develop a general equilibrium methodology for exploring the impact of widening trade blocs, when the trade bloc is not just a customs union, but also incorporates substantial regulatory harmonisation or mutual recognition elements[1]. In particular, I use the model to investigate numerically the likely trade effects of the recent widening of the European Single Market to incorporate several Central and Eastern European Countries.

Standard analysis of trade protection focuses upon the effects of tariffs and non-tariff barriers. Increasingly, however, trade debates have focused upon the perceived effects of different regulatory regimes - the setting of standards for product conformity, safety, labelling and such like, and the associated application of testing and border checks. The effects of such regulatory barriers are complicated, and difficult to model (see Maskus and Wilson's World Bank initiated study, 2000, and Edwards, 2003). In this paper, I follow the approach of inferring such costs by comparing actual observed trade patterns with those predicted from country size and transport costs. The novel aspect is the use of a fully model-consistent procedure for identifying such costs, by calibrating a multi-country Dixit-Stiglitz general equilibrium model directly upon observed trade flows. While the conclusions broadly support those of previous studies, the implied potential gains to new EU members from joining the Single Market are, if anything, somewhat more optimistic, while existing member states do not lose.

The layout of the paper is as follows. Section 2 contains a discussion of the issue of derivation of border costs. Section 3 outlines the calibration and general equilibrium

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[1]In this context, harmonisation means that countries agree on centrally-set product specifications, while mutual recognition is an agreement under which, if goods are deemed acceptable by regulators in one country, then other countries with a mutual recognition agreement will also accept them.

methodology, especially the novel model-consistent calibration methodology. In section 4, I present results and compare them with previous studies of European enlargement. Section 5 concludes. summarises the modelling approach and data used in this paper: in particular the novel model-consistent calibration procedure to estimate country bias effects.

2   The inference of Trade Costs and the Gains from the Single Market

Traditional studies of European trade integration (eg Brown *et al*'s early study of East-wards European enlargement, 1995) concentrated on the removal of tariffs and formal non-tariff barriers (NTBs). Such barriers are relatively straightforward to identify, although the precise nature of the model (usually computable general equilibrium) used to simulate integration will affect estimates of potential gains and losses.

However, the relevance of such an approach to European enlargement is arguably rather limited, since, except in agriculture, most formal barriers between the EU and the CECs were removed in the mid 1990s by the Europe Agreements. The issue has then moved to the effects of the CECs' joining the EU's Single Market, with its associated mix of regulatory harmonisation and mutual recognition agreements (see Brenton *et al*, 2001). The Single Market is intended to remove supposed regulatory barriers to trade - some intentional ('regulatory protection'), others unintentional - which have supposedly hobbled the development of European industry compared to the more integrated market of the United States. The effects of regulatory barriers are much harder to quantify, since many current national regulatory regimes impose costs which are a mixture of technical costs of changing standards, retooling and redesigning goods for different markets, as well as

administrative costs (labelling etc) and border delays and testing costs.[2]

There are essentially two approaches to estimating such costs. The first approach is to focus upon 'bottom-up' estimates of costs, surveying firms for technical data, finding estimates of border queues, costs of labelling and testing according to different specifications and the like. This is by no means an easy task, although some studies (e.g. Harrison et al, 1996) do make attempts at such measurement.

2.1 Top-down approaches to deriving trade costs: Inference from trade patterns.

An alternative approach is to derive costs directly from observed behaviour[3]. If a pair of countries is seen to trade much less than might normally be expected, then we might well infer that there is some cost obstructing that trade. This may be something easily identifiable (like tariffs or high transport costs), but it may also be costs of different product standards and border regulations, currency conversion costs or even the informational costs of finding trade partners where trade has been difficult in the past (see Rauch, 1999, Edwards 2005).

The key phrase in the preceding paragraph is 'than might normally be expected'. In order to identify whether trade is abnormally low, we require some view of an underlying pattern or model to which trade, other things equal, would be expected to conform. The most commonly-used approach in this case (related to, though with some differences from

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[2] The articles in Maskus and Wilson (2000) are a good survey of the limited research carried out so far on the economics of technical barriers to trade. Baldwin's article summarises the view that these barriers comprise 'regulatory protection'. Edwards (2005) gives a more cautionary view on this.

[3] One could perhaps deem this a 'revealed trade cost' approach, with some parallels to the revealed comparative advantage literature.

that which I outline below) to identifying trade biases is to use gravity equations for trade

in good g between exporting country c and importing country cc of the form:

$$X_{g,c,cc} = \alpha_g + \beta_g d_{c,cc} + \gamma_{1g} Y_c + \gamma_{3s} Y_{cc} + \epsilon_{s,c,cc} \tag{1}$$

where all variables (except the dummies) are in logs. $X_{g,c,cc}$ is exports from country c to cc

in industry g, and Y is GDP, d is distance between capitals of the countries c and cc. The

usual expectation of gravity modellers is that the coefficients on Y_c and Y_{cc} should be close

to 1 and that that on distance should be near minus 1, so that trade is roughly proportional

to the product of country sizes and inversely proportional to distance.

Such a basic gravity equation is usually held to fit well for trade between large subsets

of countries (hence the widespread view that gravity 'works' as an explanation of trade),

particularly when correction is also made for the presence of tariffs and formal NTBs.

However, there is a clear misfit in the case of the national borders of the importing coun-

try. Quite simply, trade within almost any country is substantially greater than that with

neighbouring countries, even after taking account of distance. This 'missing trade' (to use

Trefler's (1995) terminology) can be very substantial: McCallum's well-known (1995) study

of Canadian-US trade found Canadian provinces trade over 22 times more with each other

than with neighbouring US states, after correcting for size and distance. The extent to

which the causes of this effect can be identified is controversial[4].

Despite its intentions, the EU Single Market and introduction of the Single Currency are

far from eliminating home bias across EU member states[5]. Nevertheless, there is evidence

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[4]Obstfeld and Rogoff (2000) argue that a combination of border regulatory costs, currency conversion costs, informational costs and under-measurement of transport costs explains much of the difference.

[5]See Brenton *et al* (2001).

of more limited regional bias effects linked to the presence of regional trade blocs. These are potentially particularly important when we come to analyse the impact of EU Single Market enlargement. It should also be added that there are some noticeable effects, too, in gravity models from income per capita[6]. A fuller gravity model could therefore be written as:

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\begin{aligned}
X_{g,c,cc} &= \alpha_g + \beta_{1g}D_{EU}^{ijs} + \beta_{2g}d_{c,cc} + \gamma_{1s}Y_c + \gamma_{2s}y_c + \gamma_{3s}Y_{cc} + \gamma_{4s}y_{cc} + \quad (2)\\
&\quad \sum_d \delta_d Dd_{g,c,cc} + \upsilon_{1s}TM_{g,c,cc} + \upsilon_{2s}TE_{g,c,cc} + \epsilon_{s,c,cc}
\end{aligned}
$$

where all variables (except the dummies) are in logs. $X_{g,c,cc}$ is exports from country c to cc in industry g, Y is GDP and y is GDP per capita, d is distance between capitals of the countries c and cc. Dd is a set of dummies for border effects, with D^{EU} set to 1 if both c and cc are EU members, otherwise set to zero. $TM_{g,c,cc}$ is the import tariff on imports of s from country c to country cc. $TE_{g,c,cc}$ is the export tariff levied by country c on country cc. In the LeJour *et al* study this estimated trade between EU members in the late 1990s was between 0-250 % higher than that between EU members and the CECs.

2.2   Inference of Cost-Equivalence of Implicit Trade Barriers

In addition to the assumption that a gravity model is a good basic model of trade in the absence of barriers, if we wish to derive cost estimates, it is also necessary to make assumptions about underlying demand and supply elasticities, in order to relate changes in trade volumes to particular levels of trade costs. Ideally, we should also ensure that these

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[6]Countries with high income per capita tend to trade more with one another, perhaps because they tend to produce higher-quality and more differentiated goods.

demand and supply elasticities are consistent with the estimated effects of tariffs and formal NTBs. In addition, it is crucially necessary to assume the nature of the costs imposed on trade when two countries are not members of the EU's Single Market - for example, are these costs fixed or variable with the volumes of trade? The standard answer to this is to assume they are 'iceberg' costs, which effectively eat up a fixed proportion $\phi_{g,c,cc}$ of the value of exports from c to cc.

Assuming an own-price elasticity of demand of 2 for demand within an EU statefor a CEC's exports, and if the gravity 'EU membership' dummy implies a 100% boost to trade in a particular good if both states are members of the EU, then the implied iceberg cost on trade, $\phi_{g,c,cc}$ is 41.4 per cent. By contrast, with an elasticity of substitution of 1, there would be a 100% iceberg cost, and with an elasticity of substitution of 4 the iceberg cost would be just 19 per cent. Clearly, therefore, specification of the underlying trade model, including elasticities, is an important step in determining the costs of non-membership of the Single Market.

The precise nature of the the costs of non-membership is also critical to the economic assessment of Single Market enlargement. Baldwin et al (1997) and LeJour et al (2001) assume this is a real resource cost, in the form of an iceberg cost borne (in the first instance) by the importer. This could be consistent with border bureaucratic or testing costs in the limited case where a fixed proportion of goods imported have to be tested, or with pure horizontal regulatory barriers (in the sense that different countries' rules specify different technical specifications, but which have no tangible difference in terms of the quality of the good or service experienced by consumers).[7] Unlike a tariff, an iceberg border cost yields no revenue: consequently its abolition gives a much greater boost to overall incomes.

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[7] See, again, Maskus and Wilson (2001) or Edwards (2005a) for more detail.

Even though one would expect such costs to be greater - and so the appeal to importing countries of this type of barrier to be far less - than that of a tariff, there may be some limited circumstances, when tariffs are ruled out, where a horizontal regulatory barrier might appeal to the importing country for profit-shifting reasons (see Wallner, 1998, though this finding is highly qualified by Edwards, 2003). In general, one would expect the abolition of such barriers to benefit most countries, and some quite substantially.

It is worth noting that the above resource cost specification is open to challenge. Firstly, many trading costs may be lump-sum costs upon individual importing companies (for example the redesign of a good, or testing a variety just once to meet a different country's standards). The economic analysis of this type of cost is more complicated than that of an iceberg cost. If all producers in a country are identical, then there will be a threshold level of lump-sum cost of entry into a new market, above which exports will cease. The resource cost of this may be greater or less than that of an iceberg cost, depending upon elasticities and the scale of reduction in observed trade volumes, but numerical analysis suggests that, if market entry is deterred, the cost of a lump-sum barrier must be high.[8]

An additional point is that the assumption that regulatory differences are of the 'pure horizontal' variety is open to criticism (see Edwards, 2003). Different regulatory standards may be better suited to the different tastes of different importing countries. Higher standards may raise consumer welfare, though at the expense of producers.

In this paper, I continue with the iceberg cost specification.

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[8]The threshold lump-sum cost at which foreign firms withdraw from the market rises towards infinity as the demand elasticity falls to 1. The author's calculations indicate that, for a demand elasticity of 4, the threshold lump-sum entry cost imposes a higher welfare loss than the iceberg trade cost consistent with a halving of trade volumes.

2.3 Specification of the simulation model

Having derived trade costs, either by the bottom-up or top-down inference method, a simulation model is then required in order to estimate the costs, benefits and other effects (such as on trade volumes) of entry into the Single Market. This is because the order of magnitude of the effects - certainly upon the CEC accession states - is so great, and so many sectors of the economy are affected, that there will be a significant feedback into labour and other factor markets, and domestic goods markets. Consequently, the most appropriate tool is probably a multi-country computable general equilibrium model, encompassing a number of key sectors (especially those, such as agriculture and food processing, on which there was some residual protection on trade with the CECs prior to accession), and several regions, both among the accession states and existing EU members (plus the Rest of the World).

As to formulation of the general equilibrium model, the neoclassical Heckscher-Ohlin framework is probably not well-suited to policy modelling in a multi-country framework, since it only allows for trade in one direction between countries. The major alternatives to this are the Armington formulation - a somewhat ad hoc model specification where producers within a country are perfectly competitive, but different countries' goods are imperfectly competitive and so countries face downward-sloping demand curves for their products - and the Dixit-Stiglitz formulation, which is explicitly derived from a 'love-of-variety' model of consumer demand, and usually assumes Chamberlinian monopolistic competition between producers of differentiated varieties. In practice, under many circumstances, both the Armington and the Dixit-Stiglitz models share many behavioural properties (downward-sloping demand curves, improvements in consumer utility from being able to spread demand across a variety of sources), although the latter also incorporates price mark-up effects (trade makes markets more competitive) and potential gains from rationalisation of excess ca-

pacity if firm numbers are allowed to change when there is an increase in trade openness (see Krugman, 1979, Baldwin and Venables, 1995). The Dixit-Stiglitz formulation may also, under circumstances where inputs have a variety effect and where transport costs are high, result in agglomeration economies, which may make the model more prone to multiple equilibria.

Of previous studies of Eastward EU enlargement, LeJour *et al* (2001) used fitted cost coefficients based upon a gravity model of European trade and a multi-country Armington general equilibrium model for simulations. There was no guarantee of theoretical consistency between the fitted gravity equations and the simulation model. Baldwin *et al* (1997) utilised a Dixit-Stiglitz general equilibrium model, but simply assumed that trade between EU members and non-members carried a (fairly arbitrary) 10% iceberg cost. There have also been some single-country studies of accession, such as Zahariadis' (2001) work on possible Turkish accession, which utilised more conservative bottom-up estimates of border costs.

3   Methodology of this study

This paper proceeds upon the assumption that residual border effects do indeed reflect residual trade costs. Nevertheless, the approach here differs somewhat from previous work. First of all, in this paper, rather than estimating a gravity model, I derive residual border effects by direct calibration of a theoretical Dixit-Stiglitz model (see below), which is then used for simulation. Unlike previous studies the calibration and simulation models are fully consistent.

Secondly, the calibration exercise calibrates residual border effects for imports and exports between each pair of countries (though averages are then constructed for inter-EU trade using model-consistent CES functions for aggregation). Since gravity studies typi-

cally use a much more parsimonious set of dummies (eg just a home dummy and a second dummy if both countries are EU members) they are effectively constraining many residual border effects to be equal - yet just by comparing two different calibrations we show that the choices of which prior restrictions to make on border effects has a potentially very large effect on the putative impact of EU membership on countries' trade patterns. This is perhaps a topic not sufficiently explored in the gravity literature.

The third difference from standard gravity approaches is that more specific account is taken of the importance of relative output prices. While we do not know exactly what the relative costs of production in different countries are (particularly when quality is corrected for) we can calibrate for revealed comparative costs once a certain set of restrictive assumptions has been made about border effects. However, the interrelationship between calibrated residual border effects and revealed comparative advantage is a close one, and different restrictions on border effects will greatly affect our picture of the underlying competitiveness of the CEECs in different industries.

3.1 Derivation of border and comparative production costs.

In principle it is possible to estimate border effects directly by calibration of a general equilibrium model, rather than relying on indirect methods such as estimation of a gravity model. This is most clearly seen in the case of a Dixit-Stiglitz (D-S) model.

The theoretical relationship between a D-S model, with monopolistic competition between differentiated goods g, each produced in one country c only, is well-established since Bergstrand (1989).

Since the calibration method is novel, I outline in detail its derivation. For simplicity, consider a D-S model where goods are consumed in countries $c = \in 1...C$ yielding consumer

utility. Consumption of good g in country cc is $Q_{g,cc}$. Total consumer utility in country cc is assumed to reflect the function:

$$U_{cc} = \left[\sum_c \sum_{g \in c} \beta((1 - \phi_{c,cc}) Q_{g,cc})^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}, \tag{3}$$

where σ is the elasticity of substitution between goods varieties, and $\phi_{c,cc}$ is an iceberg cost reducing by a fixed proportion the usable value of all goods from country c consumed in cc.

I differentiate (3) and set the marginal utility of consumption of g equal to its relative price. Rearranging then yields

$$Q_{g,cc} = U_{cc} \left[\beta(1 - \phi_{c,cc})^{(\sigma-1)/\sigma} (\pi_{cc}/P_c(1 + \tau_{c,cc})(1 + t_{c,cc}) \right]^{\sigma}, \tag{4}$$

where $\tau_{c,cc}$ is the proportionate transport cost between country c and cc, and $t_{c,cc}$ is the net contribution of import and export tariffs, subsidies and the tariff equivalents of NTBs. P_c is the selling price of goods from country c at the point of export (ie prior to trade costs and tariff). π_{cc} is an aggregate consumer price index for country cc.

The next step is to rewrite the equation in terms of observable variables. The nominal value of exports from c to cc, $E_{c,cc}$ is the number of goods varieties produced in country c, n_c, times the volume of sales per good, $Q_{g,cc}(g \in c)$, (upscaled by $(1 + \tau_{c,cc})$ to take account of the assumed iceberg transport cost) times the export price P_c. We can also replace U_{cc} with total expenditure in country cc, Y_{cc} divided by the aggregate price index π_{cc}, and replace n_c with the value of output in country c, X_c, divided by the size of turnover of a

'representative' firm T_c.

$$E_{c,cc} = \beta(1 - \phi_{c,cc})^{(\sigma-1)}.X_c Y_{cc} T_c^{-1} P_c^{1-\sigma}.\pi_{cc}^{-1}(1 + \tau_{c,cc})^{1-\sigma} \qquad (5)$$

$$(1 + t_{c,cc})^{-\sigma}$$

It should be clear by taking logs that this is a very similar functional form to the equations estimated by gravity modellers, but with various parameter restrictions imposed in order to achieve consistency with the general equilibrium Dixit-Stiglitz framework. This is even clearer if we choose to model transport costs as a function of distance $d_{c,cc}$:

$$\ln(1 + \tau_{c,cc}) = a + b \ln d_{c,cc} \qquad (6)$$

Substituting from (6) into (5), we essentially have a gravity model, but unlike the econometrically estimated gravity models the coefficients on industry output in country c and on demand in country cc are constrained to equal 1, while production prices are introduced as exogenous data (rather than being proxied by per capita income, as in many gravity studies), and it is worth noting that the tariff term is $\ln(1 + t_{c,cc})$ not $\ln(t_{c,cc})$ as in many gravity models. The number of fitted residual border cost coefficients, $\phi_{c,cc}$, is far greater than the number of dummies estimated in a gravity model. Effectively the gravity modeller is rewriting these as $\phi_{c,cc} = DUM_{c,cc} + \phi(\epsilon_{c,cc})$, where $DUM_{c,cc}$ is whatever combination of country dummies happens to apply to trade between countries c and cc, and $\epsilon_{c,cc}\epsilon_{c,cc}$ is the estimated equation residual. Because there are more coefficients to estimate in our version, there are fewer degrees of freedom, making calibration more appropriate than econometric estimation.

To eliminate the consumer price indices, the easiest way is to say that for $cc = c$ we can

replace $E_{c,cc}$ with H_{cc} (home use). For H_{cc} $\tau_{cc,cc} = t_{cc,cc} = 0$. This means that, rearranging (4), and dividing by the version for H_{cc} gives us:

$$E_{c,cc}/H_{cc} \;=\; (1 - \phi_{c,cc})/(1 - \phi_{cc,cc}))^{(\sigma-1)}(X_c/X_{cc})(T_{cc}/T_c) \tag{7}$$

$$(P_c/P_{cc})^{1-\sigma}(+\tau_{c,cc})^{1-\sigma}(1 + t_{c,cc})^{-\sigma}$$

We can rearrange this to put $(1 - \phi_{c,cc})$ on the left hand side, and if we assume $\phi_{c,cc} = 0$ for $c = cc$ we can simplify somewhat:

$$(1 - \phi_{c,cc}) \;=\; \{(E_{c,cc}/H_{cc})(X_c/X_{cc})(T_{cc}/T_c)(P_c/P_{cc})^{1-\sigma} \tag{8}$$

$$(1 + \tau_{c,cc})^{1-\sigma}(1 + t_{c,cc})^{-\sigma}\}^{1/(1-\sigma)}$$

An interesting result is found if we multiply together these expressions for trade in both directions between a pair of countries, c and cc, since a lot of terms can then be eliminated:

$$(1 - \phi_{c,cc})(1 - \phi_{cc,c}) = \langle\sqrt{\tilde{E}_{c,cc}\tilde{E}_{cc,c}}|\sqrt{H_c H_{cc}}\rangle^{2/(1-\sigma)} \tag{9}$$

where the tild represents exports adjusted for the effects of tariffs, NTBs and transport costs. Effectively, if the geometric average volume of trade between two countries, once tariffs and transport costs have been corrected for, is significantly smaller than the geometric mean of home-based consumption in the two countries, then the model implies there must be residual border costs present.

Once an estimated value for the elasticity of substitution, σ has been chosen, all the other terms on the right hand side of (9) are given. This means that for given observed output, consumption and trade and an assumed elasticity of substitution, the higher the

value of the trade cost for imports from c to cc, $\phi_{c,cc}$, the lower will be the implicit trade cost in the other direction, $\phi_{cc,c}$. Based upon these assumptions, it is therefore possible to use data on observed trade flows a) between existing EU member states and b) between existing and future member states (as well as that between pairs of future member states) to infer the cost-equivalence of assumed regulatory barriers to trade. The next stage is to derive simulations of what would happen to trade, production and factor incomes if entry of the new member states leads to the Single Market means that their firms are now competing on a level playing field with those in existing EU member states.

3.2   The Model for simulations

Simulations are carried out using a multi-country static computable general equilibrium (CGE) model, as outlined in Appendix 2. Goods are produced using a Cobb-Douglas aggregate of intermediate inputs and 4 primary factors: unskilled labour, skilled labour, capital and land. Land is fixed sectorally. Both types of labour are mobile between sectors, but not between countries. For capital, I investigate two variants, one where it is fixed in total within a country, and one where it is internationally mobile.

Intermediate inputs and final consumption goods are CES aggregates of home production and imports from various sources. The elasticity of substitution between different sources of a good is set at 4 in all sectors. There are also transport costs (modelled as iceberg costs), iceberg unspecified trade costs (see above) and tariffs, as well as taxes/subsidies on output and use of a commodity.

Firms both at home and abroad are imperfectly competitive (competing with a Dixit-Stiglitz symmetrical CES function), and charge profit markups dependent on their market shares.

Treatment of the number of firms within an industry and country is an issue here. Many Dixit-Stiglitz models utilise the assumption that the number of firms is endogenous, adjusting to return profits to normal, just covering fixed costs. In practice, when there is trade liberalisation, this usually leads to a general shakeout of capacity (see Krugman, 1979). The closure of firms leads to a small loss of consumer variety (but overall ariety is still improved due to easier access to foreign varieties), but there is a larger offsetting gain from allowing firms to reap economies of scale (see Baldwin and Venables, 1995, for discussion on this).

However, endogenised firm numbers may be suitable as a long-run assumption only. In particular, fixed costs may not be avoidable in the short- or medium-run, so firms may well not shut, and the scale economy/rationalisation gains may well not be achieved. For this reason, I retain a 'medium-run' formulation, with a fixed number of firms in each country/industry.

The top level of the consumption function, where different industries' products are aggregated, uses a Cobb-Douglas structure.

3.3 Data.

I use the GTAP version 5 database. This database has harmonised trade and input-output data for regions across the world in 1997. GTAP potentially has a large number of goods

and regions, so for practical purposes I aggregate data into 8 goods[9] and 10 regions[10], chosen

for their relevance to the issue of enlargement[11].

For **trade and protection** I use 4 principal data series from GTAP for these countries

and regions:[12]

exports at market (ie domestic) prices (VXMD), exports at world prices (VXWD),

imports at world prices (VIWS) and imports at market prices (ie sales prices in the importing

country before indirect tax) (VIMS). Trade volumes, transport costs and tariffs are derived

from these series[13].

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[9]**Goods**
AG agriculture, forestry and fishing
OP other primary
FP food processing
IS iron and steel
TX textiles
MH heavy manufacturing
ML light manufacturing
SV services

[10]**Regions***
PLD Poland
HUN Hungary
OCEC Other CECs (Cz Rep, Slovakia, Slovenia, Romania, Bulgaria)
UK United Kingdom
GER Germany
OEUN Other EU Northern
OEUS Other EU Southern (Italy, Spain, Portugal, Greece)
FSU Former Soviet Union
ODX Other OECD excluding EU and CECs
LDC rest of the world (mostly less developed countries)
*note GTAP version 5 has only 3 CEC regions.

[11]Due to data limitations, I am unable to carry out simulations on the precise accession list of 2004. The other CEC region comprises the Czech Republic, Slovakia, Slovenia, Romania and Bulgaria. The latter two are not on the 2004 EU accession list, whereas the 3 Baltic States, as well as Cyprus and Malta, are.

[12]In the latter case, capital rents are equated across the world at RBW. A country will then pay rent at this rate to foreigners if it imports capital. This assumption, which follows Fehr *et al.* avoids some of the problems Rodrik notes in the Baldwin *et al.* model's treatment of changing capital stocks.

[13]The difference between *VXWD* and *VIWS* is taken to be the transport cost margin.
VXWD - VXMD is a value for net export tax/subsidy, and the GTAP estimates of the tariff equivalent of some quantitative trade restrictions whose revenue accrues to the exporting country.
VIMS - VIWS is the value for net import tax/subsidy and the tariff equivalent of remaining NTBs.
Correction is made for some data errors in the GTAP Version 5. In particular, I have removed tariffs on

4 Results

4.1 Results of the calibrations for border costs.

According to the GTAP database, there were only formal trade barriers (tariffs and tariff equivalent of NTBs) in existence between the EU and CECs in 1997 for agriculture and food processing. As can be seen, imports from the CECs into the EU faced sizeable barriers in agriculture and food processing, but barriers elsewhere had been removed by 1997 under the Europe Agreements. CES weighted averages of the barriers facing CEC trade across the various EU component regions (UK, GER and OEU) varied between 10 and 31 per cent for agriculture, while for food processing they were higher, between 25 and 54 per cent. However, even when country size, transport costs and these formal trade barriers are taken into account, there is still a considerable shortfall in imports compared to domestic produce in all cases: our model attributes this home bias to an iceberg cost of trade, $\phi_{g,c,cc}$.

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trade between the EU and CECs other than in agriculture and food processing, as these had been abolished under the Europe Agreements.

Table 1   *Calibrated relative production prices and iceberg cost of home/country bias*

POLAND Industry	Relative Price	Inter-EU Home Bias	EU v Poland	Poland v EU
AG	-0.41	0.68	0.08	0.08
OP	-0.21	0.50	0.20	0.20
FP	-0.35	0.68	-0.05	-0.05
TEX	-0.30	0.55	0.09	0.09
IS	-0.01	0.56	0.16	0.16
MH	-0.40	0.59	0.14	0.14
ML	-0.41	0.53	0.17	0.17
SV	-0.38	0.82	0.06	0.06

HUNGARY Industry	Relative Price	Inter-EU Home Bias	Hungary v CEC	Hungary v EU
AG	-0.35	0.68	0.10	0.10
OP	-0.50	0.50	0.33	0.33
FP	-0.41	0.68	0.05	0.05
TEX	-0.35	0.55	0.06	0.06
IS	-0.14	0.56	0.19	0.19
MH	-0.45	0.59	0.14	0.14
ML	-0.39	0.53	0.09	0.09
SV	-0.45	0.82	0.06	0.06

OTHER CECs Industry	Relative price	Inter-EU Home bias	EU v OCEC	OCEC v EU
AG	-0.36	0.68	0.09	0.09
OP	-0.16	0.50	0.30	0.30
FP	-0.41	0.68	0.06	0.06
TEX	-0.20	0.55	0.08	0.08
IS	0.24	0.56	0.13	0.13
MH	-0.31	0.59	0.11	0.11
ML	-0.34	0.53	0.13	0.13
SV	-0.36	0.82	0.04	0.04

Table 1, above, shows the calibrated comparative costs and country bias (measured as an iceberg trade cost equivalent) based on the calibration assumptions in this paper. In this case, average 'excess' EU bias against CEC goods has been set the same as average CEC bias against EU goods. The first column shows calibrated production costs in each accession region relative to the EU. This calibration suggests the CECs are low-cost producers

compared to the EU in almost all industries, especially services[14], agriculture, and light and heavy manufactures. Hungary is low-cost in textiles, while the OCEC region is high-cost in iron and steel. The second column is an average figure for calibrated home bias within the EU (meaning the implied iceberg cost on goods from one EU state entering another). This shows that the Single Market has a long way to go to eliminate home bias within the EU and create a fully unified market.

The remaining two columns are the most important from our point-of-view: they show average calibrated iceberg costs of trade in both directions on trade between the EU and CECs. These costs vary from slightly negative (for Polish food processing only) to around 15% for Polish manufactures, 10-13% for other CEC manufactures and 9-14 per cent for Hungarian manufactures. For agriculture they are around 7-10%. The key assumption for modelling entry into the Single Market is that the costs in these two columns can be removed by entry.

5   Enlargement simulations

The simulation runs are carried out on the CGE model, assuming the number of firms per sector in each country does not vary. The welfare effects are probably smaller than would be expected in a fully long-run model where scale and variety effects of altering firm numbers were included.

Table 2 (below) shows the effects on consumer welfare in each region resulting from (1) customs union (the removal of the remaining tariffs on agriculture and foodstuffs between

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[14]Comparative costs in services would, of course, be expected to be lower in poorer countries (see Balassa, 1964). However, it seems that, at least for Poland, the low relative costs apply to all sectors. Only for the Other CEC region does there seem to be clear evidence supporting the Balassa-Samuelson relationship.

the EU and CEC regions and harmonisation of the CEC's external tariffs with those of the EU) and (2) assumed abolition of iceberg unspecified trading costs ϕ_I when countries join the EU single market. These simulations are carried out for cases where capital is immobile between countries and where it is assumed to be mobile.

Customs union has only small simulated welfare effects, though these generally benefit the accession states by $0\text{-}2\frac{1}{2}\%$ while having no significant effect on existing EU members. The former effect is not surprising given the fact that most tariffs have already been abolished, while the latter reflects the small size of the CEC economies relative to the existing EU.

Under (2) the CEC trade shares with the EU, and the EU trade shares with the CEC are increased to reflect the supposed removal of trade costs when the CEC countries join the single market. Since it is assumed these costs are real resource costs, it is possible in this case for all countries to gain, and this does indeed seem to be the case. The biggest beneficiaries are the CEC countries, where welfare rises by 10-20% compared to 1997 base. Gains to the existing EU members are small, typically around $\frac{1}{2}\%$. While Germany gains most, even the poorer EU countries in the South experience gains of 0.4%, so that the benefits of expansion of trade outweigh the cheap-wage competition effects even for these countries. The Former Soviet Union and LDCs also see small welfare gains, so that trade diversion effects are outweighed for them by the effects of the overall expansion of the EU and CEC economies.

Table 2   *Summary of results - change on 1997 base,*
             calculated consumer utility

	1.EU-CEC customs union		2. CEC trade shares shift in line with intra-EU trade	
	a) National capital stocks fixed %	b) Capital mobile internationally %	a) National captal stocks fixed %	b) Capital mobile internationally %
Poland	1.9	2.4	15.3	19.4
Hungary	0.2	0.2	14.6	17.6
Other CEC	1.0	1.2	11.5	13.3
UK	-0.0	0.0	0.2	0.1
Germany	0.0	0.0	0.6	0.7
Other EU North	0.0	0.0	0.4	0.4
Other EU South	0.0	0.0	0.4	0.4
EU total	0.0	0.0	0.4	0.4
Europe total	0.1	0.1	0.9	1.1
Former Soviet Union	0.1	0.1	0.0	0.1
Other OECD	0.0	0.0	0.0	0.0
LDCs	0.0	-0.0	0.0	0.0
Global total	0.0	0.0	0.3	0.3

Table 3 shows the change in trade volumes: these are typically of the order 50-100%

between the EU countries and CECs on accession.

Table 3   *Changes in trade volumes with trade share*
             shifts and mobile capital assumed

Total trade volumes	Before	After	% change
Poland to EU	4.98	9.12	+ 83%
Hungary to EU	2.62	4.34	+ 65%
Other CEC to EU	6.05	9.81	+ 62%
EU to Poland	1.88	3.77	+100%
EU to Hungary	1.45	2.20	+ 51%
EU to Other CEC	3.56	5.50	+ 55%

To summarise some further model simulation results[15] :

1. Gains in output are spread widely across all industries in the CEC region, though

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[15]Full details and tables are available in Edwards (2004).

the biggest gains are to agriculture, food products and manufactures. Within the EU there appear to be few losers, though agriculture and heavy manufactures decline marginally in the UK.

2. Output prices in the EU generally fall as a result of the saving in costs of inputs (the unskilled wage in Germany is set to 1 in this model, to act as a numeraire). However in Poland output prices generally rise (and the same is true to a lesser degree of some sectors in other parts of the CEC region) as prices rise towards Western European levels.

3. Relative skilled/unskilled wages do not change greatly in any country, though there are sizeable gains to both types of labour in Poland in particular. The lack of distributional changes between types of labour may partly be because of the Cobb-Douglas production function structure, and partly because the presence of a fixed factor (land) in two sectors absorbs much of the effects of changes in output prices.

6 Comparison with other studies

6.1 Gravity Effects

The calibration exercise in this paper effectively involves the fitting of an implicit gravity model - though with certain constraints (such as constraining country scale parameters to unity for both the importing and exporting countries), plus the use of direct estimates (from GTAP) of transport costs rather than a distance parameter, and with a rather larger set of country and regional dummies. It is possible to convert the iceberg trade costs $\phi_{c.cc}$

directly into equivalent gravity dummies $(\sigma - 1)\ln(1 - \phi_{c.cc})$ - see Appendix 1 Table 1a. The dummies for trade between the EU and CEC are broadly of a similar order of magnitude to those found by LeJour *et al.*'s (2001) gravity model study, summarised in Appendix 1 Table 1b, which estimated an EU trade dummy of 1.25 for much of agriculture and around 0.7

for most industrial sectors. The sectoral breakdown differs, and there are certain sectoral discrepancies (notably in other primary products), but general orders of magnitude of the dummies seem consistent. I suggest that the Dixit-Stiglitz calibration approach seems to work satisfactorily as an alternative to the usual gravity model estimation.

6.2 Border costs

A second possible comparison is of the border costs of entry of goods into the single market, and how our implied estimates compare with bottom-up studies. The residual border costs implied by the model here (which correspond to EU membership dummies in more traditional gravity models) vary between 7 and 15 per cent of total cost of goods traded - which suggest they are roughly twice as large as implied by 'bottom-up' estimates such as Harrison et al (1996) or Zahariadis, 2002. I suggest this represents a general discrepancy between the findings of gravity models and attempts to quantify the effects of observable barriers[16]. Possible reasons are that different regulatory regimes imply a greater degree of both inconvenience and uncertainty to trading firms than simple cost estimates imply, or that there may be fixed costs involved which have not properly been modelled, or alternatively that trade costs are magnified by the presence of informational barriers (see Edwards, 2005).

6.3 Enlargement simulation results

The methodology implied in this study differs from the two main previous studies of the enlargement in a number of ways. Baldwin et al's work (1997) used a relatively sophisticated Dixit-Stiglitz general equilibrium formulation, and also incorporated estimates of

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[16] This finding is in line with Trefler's 'missing trade' claims, and tends to cast doubt on, say, Obstfeld and Rogoff (2000) that the relatively small levels of observed international trade can be easily accounted for.

the impact of the Common Agricultural Policy and of structural and regional assistance, as well as capital mobility. However, their estimate of trade barriers was crude: simply an assumed 10% across-the-board iceberg cost (which exceeds bottom-up estimates, but is smaller than the implicit cost barriers found for many sectors in this study), attributed to an unspecified 'risk premium'. The LeJour et al study (2001) applies a detailed (but not strictly model-consistent) gravity model estimation to a more conventional Armington multi-country general equilibrium model.

The model used here is a Dixit-Stiglitz general equilibrium model, but with fixed firm numbers (unlike the Baldwin approach): I argue that the sunken nature of capital costs mean a shake-out of capacity may well not happen in the medium run, but that the competitive effects on pricing (which are missed by an Armington approach) are realistic.

The two previous studies both found significant welfare and trade gains from EU enlargement. Baldwin *et al*'s (1997) simulation results, based on an assumed 10% iceberg cost on trade between the EU and CECs, are shown in Table 4 (below).

Table 4: *Comparison with other studies. Real income per cent change*

	Baldwin et al 1997		LeJour et al 2001	
	Conservative	Less conservative	Custom union	Single market entry
CEC7	2.5	18.8	1.3	5.3
EU15	0.2	0.2	0.0	0.1
EFTA 3	0.1	0.1	N/A	N/A
Other OECD	N/A	N/A	0.0	0.0
Former Sov Union	0.3	0.6	0.0	0.0

Le Jour *et al* (2001) also find substantial benefits for the accession countries, particularly Poland, though not as sizeable as in Baldwin *et al* (1997). This is not surprising since LeJour *et al* use an Armington model, which does not model all of the benefits (particularly those linked to increased competition) which a Dixit-Stiglitz model captures. Both studies are agreed that enlargement involves few costs for existing EU members, though LeJour *et al* imply France may have lost slightly from the 1997 tariff changes.

The study in this paper finds GDP gains to Poland of around 20% of GDP, to Hungary of nearly 18% and just over 13% for the other CEC countries, with small gains for the existing EU countries. These estimates are therefore greater than those found by LeJour et al, but roughly in line with Baldwin et al's earlier figures. The difference may largely reflect the greater gains from trade in a Dixit-Stiglitz compared to an Armington framework, with significant pro-competitive and variety gains to utility.

7 Conclusions

This paper addresses the potential benefits of membership of the EU's Single Market, based upon the assumption that different regulatory regimes pose a significant barrier to trade. A method is developed for inferring the size of such potential barriers, based upon comparing the trade volumes between countries which are already members of the Single Market and trade with those which (prior to 2004) were not members. This method involves assumptions about the nature and specification of the barriers imposed by different regulatory regimes, as well as about the underlying structure of the economy.

I proceed on the assumptions that regulatory barriers impose an 'iceberg'-type cost upon trade (lump-sum market entry costs might well imply larger gains from abolition) and that they are of a pure horizontal type (i.e. entering the EU's regulatory regime does not noticeably affect the quality of goods consumed). With these assumptions, and using a Dixit-Stiglitz type general equilibrium structure, it is possible to directly calibrate for implicit trade costs - so avoiding the questions of model consistency which apply to previous work.

The estimated GDP gains for the EU's new members from Central and Eastern Europe, based upon this approach, are of the order of 13-20 per cent from entry into the Single Mar-

ket and abolition of remaining tariff barriers. I do not look at the effects of agricultural or regional subsidies. These cost estimates are somewhat larger than those from a large recent Armington-based study, which included fewer competitive and variety gains to consumer utility.

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Appendix 1: Gravity dummy equivalence of fitted border effects, and comparison with previous estimates by LeJour *et al* (2001).

Appendix 1 Table 1a	*Gravity dummy equivalents of calibrated residual border effects*					

INDUSTRY	OCEC into EU	EU into OCEC	HUN into EU	EU into HUN	PLD into EU	EU into PLD
AG	1.04	1.04	1.11	1.11	0.82	0.82
OP	2.81	2.81	3.31	3.30	1.54	1.54
FP	0.67	0.67	0.52	0.52	0.05	-0.05
TEX	0.60	0.60	0.40	0.40	0.69	0.69
IS	0.99	0.99	1.62	1.62	1.32	1.32
MH	0.93	0.93	1.24	1.24	1.20	1.20
ML	0.92	0.92	0.65	0.65	1.30	1.30
SV	0.71	0.71	1.28	1.28	1.26	1.26

Appendix 1 Table 1b *EU dummies in gravity equations (LeJour et al, 2001)*

Sector	EU dummy	Trade increase%
Agriculture	2.25[*]	249
Raw materials	-0.10	94
Food processing	0.66[*]	
Textiles & leather	0.85[*]	134
Non-metallic minerals	0.73[*]	107
Energy-intensive products	0.13	
Other manufacturing	0.08	
Metals	-0.10	
Fabricated metal products	0.44[*]	56
Machinery & equipment	0.31[*]	37
Electronic equipment	0.58[*]	79
Transport equipment	0.66[*]	94
Trade services	0.76[*]	113
Transport & communication	0.03	
Financial services	-0.14	
Other services	0.27[*]	31

Appendix 2: General equilibrium model (GEMEE).
Notes on the structure of the model:

The model is based on an imperfectly competitive structure, using a Dixit-Stiglitz framework. In this framework, an industry i contains g goods produced by closely competing firms in the various regions. Each good g is produced in one country c only.

In this paper I have used the simpler version of the model, where the number of goods, g, is fixed. However, unlike many Armington models, it does allow for monopolistic markups. The full Dixit-Stiglitz variant allows the number of goods/firms to vary endogenously.

Another variant is to allow capital to flow between countries rather than be fixed within each country.

Production of goods.

The production function of each firm combines labour and capital using a Cobb-Douglas function to form a Value Added input: ie

$$VA_g = \theta_{ci} LU_g^{\beta uci} LS_g^{\beta sci} K_g^{\beta ci} \tag{A2.1}$$

Where VA is value added (quantity), Lu and Ls are unskilled and skilled labour, K is capital, D is land which is sectorally fixed, g denotes the good, i denotes industry and c denotes the country of production. θ is a scale parameter and β is a set of share parameters.

To obtain an equation for the whole industry in country I, we assume all firms gi are identical. We also choose units so that $\theta=1$. This gives us:

$$VA_{ci} = D_{ci}\beta d_{ci} U_{ci}^{\beta U_{ci}(1-\beta k_{ci}-\beta d_{ci})} K_{ci}^{\beta kci}, \tag{A2.2}$$

where βk and βd are shares of capital and land in total value added, and βu is the share of unskilled βs is the share of skilled and unskilled labour income in an industry/country, and sum to 1.

Differentiating (A2.2) with respect to K, U, S and D and setting value of marginal products equal to the wage rate and price of capital gives:

$$
\begin{align}
U_{ci} &= VA_{ci} PV_{ci} \beta u_{ci}(1-\beta k_c - \beta d_{ci})/WU_c \tag{A2.3a}\\
S_{ci} &= VA_{ci} PV_{ci} \beta s_{ci}(1-\beta k_c - \beta d_{ci})/WS_c \tag{3.A2.3b}\\
K_{ci} &= VA_{ci} PV_{ci} \beta k_{ic}/R_{ci} \tag{3.A2.3c}\\
D_{ci} &= VA_{ci} PV_{ci} \beta d_{ic}/LDP_{ci}, \tag{3.A2.3d}
\end{align}
$$

where WU and WS denote the wage rates for unskilled and skilled labour, R denotes return on capital and LDP the sectoral return on capital. Both types of labour are assumed to be mobile between sectors, but not between countries.

At present the model has been set up with capital mobile between sectors but not between countries. However, we have written R_{ci} in order to give the possibility of fixing capital sectorally later on in sensitivities if desired.

Hence at present we fix R within a country:

$$R_{ci} = RB_c. \tag{A2.4}$$

The price of value added is given by

$$PV_{ci} = (WU_c U_{ci} + WS_c S_{ci} + R_{ci} K_{ci} + LDP_{ci} D_{ci})/VA_{ci}. \tag{A2.5}$$

Higher level of production function.

The output of good i is produced by a combination of other goods ii and value added, VA. This is done again using a Cobb-Douglas production function

$$Y_{ci} = \Omega_{ci} VA_{ci}^{\alpha v_{ci}} \prod_{ii} II_{c,ii,i}^{\alpha I_{ci}}. \tag{A2.6}$$

Where Y is output, II is the input of good ii into good i and the α coefficients are input shares which sum to 1.

Assuming cost-minimisation, this gives inputs:

$$II_{c,ii,i} = \alpha v_{ci} Y_{ci} PY_{ci}/PU_{c,ii,i}, \tag{A2.7}$$

where PY is the output unit variable price and PU is the unit price of inputs, and

$$VA_{ci} = \alpha v_{ci} Y_{ci} PY_{ci}/PV_{ci}. \tag{A2.8}$$

The marginal cost of producing of output is easily calculated from inputs

$$PPY_{c,ii} = (VA_{c,ii} PV_{c,ii} + \sum_{i} II_{c,i,ii} PU_{c,i})/Y_{c,ii}. \tag{A2.9}$$

This cost is then adjusted to take account of output taxes and subsidies:

$$PY_{c,ii} = PPY_{c,ii}(1 + OUTTAX_{c,ii}) - SUBSIDY_{c,ii}/Y_{c,ii}. \tag{A2.10}$$

Trade and the aggregation of goods.

The total demand in country C for produce of industry i is taken to be TU_{ci}. This is an aggregate bundle of all the goods g which belong to industry i, using a Dixit-Stiglitz demand function:

$$TU_{ci} = \left(\sum_{g} \gamma_{gc} U_{gc}^{\rho i} \right)^{1/\rho_i}, \tag{A2.11}$$

where U_{gc} is use of good g in country c and γ is a parameter reflecting qualitative factors (eg compatibility of standards) and home bias in consumption. ρ is a substitution parameter, where $\rho_i = -1/(1-\eta_i)$, where η_i is the elasticity of substitution between goods g in industry i (assumed to be the same in all countries).

If we assume there are n_{icc} firms in country cc making good i, and that the γ preference parameter depends only on country of origin, cc, country of use, c, and industry, i, then we can rewrite (A2.11) as:

$$TU_{ci} = \left(\sum_{g} \gamma_{gc} U_{gc}^{\rho i} \right)^{1/\rho_i}. \tag{A2.12}$$

Total expenditure in country cc on goods in industry i (by final consumers and intermediate users) is calculated by summing price times volume for all goods g in industry i.

$$VU_{cc,i} = \sum_{c} QU_{i,c,cc} PUU_{i,c,cc}. \tag{A2.13}$$

This is then used to calculate the price of PU of the aggregate bundle TU:

$$PU_{cc,i} = VU_{cc,i}/TU_{cc,i}. \tag{A2.14}$$

Competition and pricing.

In a Dixit-Stiglitz model, firms are imperfect competitors. In basic versions of the model, each firm produces one good, and the goods are symmetrically competitive, with a constant elasticity of substitution between all goods in an industry consumed in one country.

The own-price elasticity of demand facing a firm is derived as follows:

1) If the own price elasticity for the aggregate produce of an industry i is φ_i, and if competitors do not change their prices in response to firm g changing its price (Bertrand Nash equilibrium), then the own-price elasticity facing company g would be $\eta_i(1-S_g)+S_g\varphi_i$ where η_i is the elasticity of substitution between goods g, and S_g is the value share of firm g in demand for industry i. If S_g is small (ie n is large) the own price elasticity would be approximately equal to η_i.

2) Within export markets, it is assumed that a firm has a very small market share and so its own-price elasticity is η_i.

3) By contrast, in the home market country c, the firm's market share S_{gc} is assumed to be significant. It is calculated as $S_{gc} = (1/n_c)(1 - SM_c)$, where SM_c is the share of imports. Since the top level of the consumption function (where different industries' products are aggregated) is a Cobb-Douglas function in our model, the own price elasticity for the aggregate product of industry i, $\varphi_i = 1$. Consequently, the firm's own price elasticity in the home market:

$$\eta h_{ci} = \eta_i(HU/Y_{ci})(1/n_{ci})\varphi_i, \tag{A2.15}$$

where

$$SM_{ci} = 1 - HU_{ci}Pt_{i,c,cc}/VU_{c,i} \tag{A2.16}$$

4) The overall own price elasticity for a firm's sales is taken as a weighted average (by sales) of its own-price elasticity in the home and export markets.

$$\eta o_{ci} = \eta h_{ci}(HU/Y_{ci}) + \eta_{ci}(Y_{ci} - HU_{ci}/Y_{ci}). \tag{A2.17}$$

5) In the model variant where the number of firms is fixed, we fix the value of ηo_{ci}.

Monopolistic competition markups: it is assumed that the firm marks up its production costs by a proportion MM_{ci}, where

$$MM_{ci} = 1/(1 - (1/\eta o_i)) - 1. \tag{A2.18}$$

The price of good g including monopoly markups is therefore:

$$PM_{ci} = PY_{ci}(1 + MM_{ci}). \tag{A2.19}$$

It is assumed that no monopoly margin is charged on import tariffs (the justification being that importers can buy the good in another country if the manufacturer starts price discrimination between markets).

Transport costs

Transport costs are assumed to be proportional to value.

$$PT_{ci} = PM_{ci}(1 + Tmarginc_{c,c}). \tag{A2.20}$$

Transport costs are treated in the model as being in terms of depreciation in the value

of the goods transported. Hence, if $X_{i,c,cc}$ is the quantity of i leaving country c for country cc, the amount which arrives in country c is:

$$M_{i,c,cc} = X_{i,c,cc}/(1 + Tmargin_{c,cc}). \tag{A2.21}$$

This form of treatment means that there is no need for an explicit transport industry, nor for dealing with transport specifically in the trade accounts.

Tariffs.

The model allows for tariffs applied to prices including transport. Tariffs are expressed as a percentage rate.

$$PT_{i,c,cc} = PTR_{i,c,cc}(1 + tariff_{i,c,cc}/100). \tag{A2.22}$$

The price of produce of industry i from country c consumed in country cc, $PUU_{i,c,cc}$, also included a use tax on i in cc:

$$PUU_{i,c,cc} = PT_{i,c,cc}(1 + USETAX_{cc,i}). \tag{A2.23}$$

Exports.

We define quantity used,

$$QU_{i,c,cc} = \{EX_{i,c,cc}/(1 + Tmargin_{i,c,cc}) \text{ if } cc \neq c \text{ or } HU_{i,c} \text{if } cc = c\} \tag{A2.24}$$

Total use.

The total value of use of i in country cc, $TU_{cc,i}$, is calculated as a CES aggregate of $QU_{i,c,cc}$ across the various countries of origin, c:

$$TU_{cc,i} = \left(\sum_c n_{ci}\gamma_{i,c,cc} \left(QU_{i,c,cc}/n_{c,i}\right)^{\rho_i} \right)^{1/(1-\rho_i)}, \tag{A2.25}$$

where g is a CES share parameter, and ρ is an elasticity-related parameter, related to the elasticity of substitution σ by the formula:

$$\rho = (\sigma - 1)/\sigma. \tag{A2.26}$$

Sales shares.

We then differentiate (A2.25) setting price equal to marginal utility, to calculate $QU_{i,c,cc}$ as a function of total use of products of industry i in country cc, $TU_{cc,i}$ and the relative price of input of i from country cc, $PUU_{i,c,cc}$ compared to that of aggregate use of i in country cc, $PU_{cc,i}$.

$$QU_{i,c,cc} = TU_{cc,i}n_{c,i}(\gamma_{i,c,cc}PUU_{cc,i}/PUU_{i,c,cc})^{1/(1-\rho_i)}. \tag{A2.27}$$

Aggregate consumer price.

The total value of expenditure on good i in country c is given by

$$VU_{cc,i} = \sum_c QU_{i,c,cc}PUU_{i,c,cc}. \tag{A2.28}$$

The aggregate consumer price of i in cc,

$$PU_{cc,i} = VU_{cc,i}/TU_{cc,i}. \tag{A2.29}$$

Consumption.

Consumers' income is divided between the various industries, i, in order to maximise a Cobb-Douglas utility function

$$UT_c = \prod_i CN_{i,c}^{\beta c_{i,c}}, \tag{A2.30}$$

where UT is utility and CN is consumption of produce of industry i in country c. The beta coefficients are expenditure shares, and sum to 1.

Consumers' expenditure on each industry, i, CN_{ic} can be calculated relatively simply from the Cobb-Douglas property that β_{ic} is the share of expenditure on i in total consumers' expenditure in country c, CE_c. Hence:

$$CN_{ic} = \beta_{ic} CE_c / PU_{ci}. \tag{A2.31}$$

Factor markets

Both types of labour are immobile between countries, but mobile between industries. The wage is assumed to clear each labour market, so that total skilled and unskilled labour use by all industries equals the skilled and unskilled labour endowment of country c

$$\overline{LU} = \sum_i LUi_{ci} \tag{A2.32}$$

$$\overline{LS} = \sum_i L\,\mathrm{Si}_{ci}. \tag{3.A2.32}$$

For capital, we again assume it is totally mobile between industries. There are two variants - one where total capital within a country is fixed (net capital imported from abroad $KM_c = 0$) and one where it is allowed to vary.

$$\overline{K}_c + KM_c = \sum_i Ki_{ci}. \tag{A2.33}$$

Where KM_c is allowed to be non-zero (so that there are international transfers of capital) the global total of KM is set to zero.

$$\sum_c KM_c = 0. \tag{A2.34}$$

The rate of return on capital in each industry is equated to the national rate of return, RB_c.

$$R_{ci} = RB_c. \tag{A2.35}$$

Where capital is allowed to move internationally, we also set national rates of return equal to the return in the 'Other OECD' region:

$$RB_c = RB_{ODX}. \tag{A2.36}$$

Land is only used in two sectors: agriculture and other primary. Its rent varies according to sector.

$$LD_{ci} = \overline{LD}_{ci}. \tag{A2.37}$$

Variety of goods

The model assumes all goods within an industry are produced by separate firms. Each firm within a country is of identical size, though the average company size may vary between countries.

For sensitivities, the fixed firm numbers version of the model assumes the total number of firms in each country is fixed

$$n_{ci} = \overline{n}_{ci}. \tag{A2.38}$$

National accounts

Home use of goods from industry i in country c, HU_{ci}, is defined as total production in country c less exports.

$$HU_{ci} = Y_{ci} - \sum_{cc} EX_{i,cc}. \tag{A2.39}$$

Imports of i from country cc to country c are equal to exports from cc to c deflated by the share of transport costs.

Total use of good i in country c produced in country cc equals home use where $c = cc$ (ie the variable $IDEN_{c,cc}$ equals 1) and imports from cc to c otherwise (when $IDEN_{c,cc}$ equals 0).

As well as tariffs, there are two types of taxes:

Use tax: Use tax revenue is given by

$$TUY_c = \left(\sum_i HU_{ci} PT_{i,cc} + \left(\sum_{cc} PT_{i,cc,c} EX_{i,cc,c}/(1 + tm \arg in_{i,cc,c}) \right) \right) (1 + u \, setax_{c,i}). \tag{A2.40}$$

Output tax: tax per unit value of output of an industry.

Total consumer expenditure in country c is taken as equalling

Value added from all industries in C +monopoly profits from all industries in country C +total tariff revenue in country C +output tax revenue +use tax revenue -total subsidies - the trade balance of country C (assumed to be constant and exogenous) - interest on net capital imports paid at the world rate.

$$
\begin{aligned}
CE_c \;=\; & \sum_i VA_{ci} PV_{ci} + \sum_i Y_{ci} PY_{ci} MM_{ci} \tag{A2.41}\\
& + \sum cc \sum_i (EX_{i,cc,c} PM_{cc,i} TR_{i,cc,c})/100) \\
& + \sum_i OT_{ci} \left(VA_{ci} PW_{ci} + \sum_{ii} II_{c,ii,i} PU_{c,ii} \right) \\
& + TUY_c - TSUBY_c - BOT_c - KM_c RB_c. \tag{3.A2.41}
\end{aligned}
$$

The Balance of Trade (including long-term net capital payments) is assumed to be fixed.

$$BOT_c = \sum_i \sum_{cc} EX_{i,c,cc} PMc, i - \sum_{cc} EX_{i,cc,c} PMcc, i - KM_c RB_c. \tag{A2.42}$$