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Non-technical summary

In view of increasing international trade relations between the EU-member states and the rest of the world, international trade effects are undoubtedly an essential factor in the economic assessment of EU-wide policy changes. A European CO_2 tax, for instance, that increases production prices will affect the international competitiveness of European firms, and with this, sectoral export and import flows decisively. Losses or gains in the international competitiveness, in turn, determine the policy-induced impacts on economic welfare. Thus, an appropriate quantitative evaluation of environmental policy instruments requires economic models that consider international trade interactions explicitly. However, trade interconnections can be specified in different ways. If a model covers only few countries while the rest of the world is exogenous in large parts, alternative foreign trade rules can be chosen for the model's 'world closure'. Basically, these rules describe the import demand and the export supply behaviour of the rest of the world and are usually completed by a balance-of-payments condition.

In this paper, several world closure systems proposed in the literature are analysed and evaluated with regard to their appropriateness for application in general equilibrium models. The specification of the world closure, i.e. the way of closing the domestic economy model by incorporating the external sector, is a crucial component for those models, in which production and consumption is not specified endogenously for all countries. The closure rule incorporated in the GEM-E3 General Equilibrium Model for the European Union is advantageous in empirical application as it, among other things, avoids complete specialisation in production, allows for modelling of intra-industrial trade and includes non-traded and traded goods. In particular, intra-EU trade activities that account for around 60% of the whole EU trade are modelled realistically as they depend on an endogenous international price system. In this work, two main changes in the foreign trade specification are proposed and tested. The basis is a simulation of an EU-wide ecological tax reform. The first change refers to the rest of the world's export supply function in which a constant finite price elasticity is introduced. The second change concerns the rest of the world's import demand function in which an activity variable is incorporated. In summary, the impact in terms of economic welfare and changes in macroeconomic variables is noteworthy for the former case while no substantial changes could be observed for the latter case.

Future research on the GEM-E3 model will concentrate on a better understanding of production and consumption activities in the rest of the world as a whole and on a further disaggregation in several major trading blocks.

Modelling of Foreign Trade in Applied General Equilibrium Models

Theoretical Approaches and Sensitivity Analysis with the GEM-E3 Model

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Abstract

The specification of the world closure, i.e. the way of closing the domestic economy model by incorporating the external sector, is a crucial component for those models in which production and consumption is not specified endogenously for all countries. This paper looks explicitly at the assumptions concerning the trade behaviour of the rest of the world that can be found in literature and in empirical applications, such as the GEM-E3 General Equilibrium Model for the EU. Starting from a description of the closure rule in the actual GEM-E3 model version, two main changes in the foreign trade specification are proposed and tested using an EU-wide ecological tax reform scenario. The first change refers to the rest of the world's export supply function in which a constant finite price elasticity is introduced. The second change concerns the rest of the world's import demand function in which an activity variable is incorporated. In summary, the impact in terms of economic welfare and changes in macroeconomic variables is noteworthy for the former case while no substantial changes could be observed for the latter case. Additionally, the sensitivity of the GEM-E3 model to variations in key parameter values such as the upper-level Armington elasticity are analysed. Results indicate that the model can be interpreted as quite robust to parameter changes.

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1 Introduction

In open-economy applied general equilibrium models the specification of foreign trade and of the behaviour in the rest of the world (RoW) is an important feature. In the literature a distinction is drawn between multi-country and single-country models[1]. While the former are mainly designed to analyse global issues, the latter takes the perspective of a single country. Multi- and single-country models differ also with regard to the modelling of trade determinants, i.e. in the way of modelling export and import behaviour. In multi-country models, or world models respectively, production and demand are specified for all countries participating in trade. All regions covered by the model are linked together by bilateral world trade matrices or trade pools. Compared with that, in single-country models the behaviour in the RoW is modelled rather roughly. Typically, a ‘closure rule’ for trade with the external sector is incorporated, i.e. a crude specification of the RoW’s import-demand and export-supply functions which is usually completed by a balance-of-payments condition (Shoven and Whalley 1992, p. 81).

As recent studies indicate, the closure rule chosen in a general equilibrium model, and thus in the GEM-E3 model as well, may be of particular importance for simulation results[2].

The GEM-E3 model includes 14 EU countries (EU-15 without Luxembourg) and the RoW covering all other industrialised regions and all developing countries. Each EU-14 country is modelled explicitly as a national applied general equilibrium model. These country models are linked through bilateral trade relations. GEM-E3 is not a global model as the behaviour of the RoW is kept exogenous in large parts. World production and export prices are fixed, i.e. export supply is assumed to be perfectly price elastic. This assumption reflects price-taking behaviour of the EU vis-à-vis RoW. But, as price-taking behaviour is accompanied by product differentiation due to the Armington assumption, the

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[1] Shoven and Whalley (1992) give an overview on recent multi-country and single-country models.

[2] Whalley and Yeung (1984) examine how results from policy simulations depend on the assumptions about international trade, using a simple numerical example. The external sector specifications vary according to the elasticity of the foreign offer curve. They include as extremes the large country assumption and the small, price taking country formulation in which the country has only marginal influence over its terms of trade. Calculating the equilibrium effects of a distorting capital tax Whalley and Yeung yield a substantial sensitivity of results in terms of welfare gains to the external sector specification. Whereas in case of the large country assumption the terms of trade loss offsets the gain from the removal of a distorting tax, in case of the small country assumption the domestic gain is at its highest.

price level in the EU is not completely determined by the world market (and exchange rates). Thus, an exogenous rise in foreign export prices would affect the EU-wide price level only partly.

Another important aspect in the GEM-E3 model is the modelling of interactions between macroeconomic developments in the EU and the foreign sector. Actually, the only feedback is a price elastic foreign demand for EU exports. Optionally, for the long-term analysis, an additional feedback mechanism can be introduced by a balance-of-payments constraint.

Basically, the assumption that the export prices of the RoW remain constant, independent from the amount of imports demanded by the EU, is rather restrictive. It should be taken into consideration that the EU-15's share of the entire world trade volume (measured on merchandise imports and imports of commercial services) is around 40%. Bearing in mind that the share of intra-EU regional trade flows in total merchandise imports is around 64%, the share of extra-EU imports in world merchandise imports is still around 19% (1995 figures, WTO 1996). Thus, it seems reasonable to relax the small-country assumption for the EU and to assume that trade activities of the EU affect world prices.

The objective of this chapter is to clarify the relationship between the foreign sector and the EU economy in the GEM-E3 model. For reasons of simplicity, the analysis is based on the (real) standard version of the GEM-E3 model where money and asset markets are excluded. This has the advantage that any policy-induced change is fully reflected by changes in real variables, and is not absorbed by money market effects.

First of all, Section 2 presents some convenient concepts of world closure as discussed in the literature and applied in some recent CGE (computable general equilibrium) models. Section 3 deals with the specification of the foreign trade system incorporated in the GEM-E3 model. Afterwards, in Section 4, some changes in the foreign trade system are discussed and tested to the sensitivity of results. For reasons of comparability, our sensitivity analysis is fully based on an EU-wide ecological tax reform scenario with an EU-wide 10% reduction of CO_2 emissions; the revenue from the endogenous CO_2 tax is used to reduce the employers' contribution to social security in each EU-country.

2 Theoretical considerations

2.1 Approaches of a world closure in the literature

In recent years the 'world closure issue' has received some attention in literature on CGE trade models. Several external closure rules for single-country models, including the domestic or home country and the external sector (RoW), have been described and assessed according to their appropriateness for empirical work. The first three closures, explained below, are analysed in more detail in Whalley and Yeung (1984), the last one is discussed in de Melo and Robinson (1989).

The first approach presented by Whalley and Yeung is based on a simple two-commodity formulation without national product differentiation and non-traded goods. Foreign import demand and foreign export supply functions are characterised by constant price elasticities.[3]

(1) $IM_{row} = IM_{row,0} \cdot \left(\frac{PEX}{e}\right)^{\varepsilon}, \quad -\infty < \varepsilon < 0$ (foreign import demand)

(2) $EX_{row} = EX_{row,0} \cdot (PEX_{row})^{\gamma}, \quad 0 < \gamma < \infty$ (foreign export supply)

where IM_{row} and EX_{row} are imports demanded and exports supplied by RoW. $IM_{row,0}$ and $EX_{row,0}$ denote base year imports and exports of RoW. PEX (given in domestic currency) is the price received by the domestic country for exports to RoW. Domestic prices are derived from the zero profit conditions and are cost covering prices. As e denotes the exchange rate from domestic into foreign currency, $\frac{PEX}{e}$ is the world price for exports from the domestic country to RoW. PEX_{row} denotes the world price paid by the home country for foreign exports. ε and γ represent the own-price elasticities of foreign import demand and foreign export supply.

Whalley and Yeung introduce a zero trade balance condition in order to close the system.

(3) $(e \cdot PEX_{row}) \cdot EX_{row} = PEX \cdot IM_{row}$ (balance-of-payments condition).

[3] In the following equations, notation has been brought into line with the nomenclature used in the GEM-E3 model. Variables without indices refer to the domestic country.

Thus, in equilibrium the value of RoW's exports equals the value of its imports. This implies equalization of the value of the home country's exports and imports, too.

Whalley and Yeung (1984, p. 130) point to the fact that equation system (1) to (3) 'can be misleading both in creating an appearance of monetary non-neutralities, and in potentially leading to misspecification of intended elasticity values'. They explicitly show that the trade balance constraint for the external sector must be taken into consideration when estimating or selecting foreign export demand and import supply elasticities because this constraint establishes an analytical interrelation between both elasticities. In the consequence, the 'true' elasticities generated by the equation system differ from the parameters ε and γ in (1) and (2).

The second closure rule proposed by Whalley and Yeung (1984, p. 134f.) differs from the first rule mainly in two aspects: Firstly, the assumption of homogeneous goods is given up by introducing product differentiation on the import side following the Armington assumption. According to this, the domestic import demand function is characterised in a simplified version by a constant own price elasticity.[4] Secondly, the domestic economy is faced with fixed world prices for imports (price-taking behaviour for imports)[5].

Whalley and Yeung demonstrate that for this specification the problem of misspecification of trade elasticities may arise in a similar way.

Like in the first rule, foreign import demand is a downward-sloping function with a constant own price elasticity less than infinite. Domestic export prices are given as cost covering prices from zero profit conditions of the model, i.e. export prices are determined domestically and translated into foreign currency by the exchange rate. A zero trade balance equation completes the system. The system is described by the following equations:

(4) $IM_{row} = IM_{row,0} \cdot \left(\frac{PEX}{e}\right)^{\varepsilon}, \quad -\infty < \varepsilon < 0$ (foreign import demand)

(5) $IM = EX_{row}^{S} = IM^{D}$ (equilibrium condition)

(6) $IM^{D} = IM_{0} \cdot (e \cdot PEX_{row})^{\eta}, \quad -\infty < \eta < 0$ (domestic import demand)

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[4] Usually, import demand functions in CGE models do not have a constant price elasticity but are specified, for example, as CES (constant elasticity of substitution) functions.

[5] This implies that RoW supplies any amount of goods demanded by the home country at fixed world prices.

(7) $PEX_{row} = \overline{PEX}_{row}$ (foreign export supply)

(8) $(e \cdot PEX_{row}) \cdot IM = PEX \cdot IM_{row}$ (balance-of-payments condition)

$IM_{row,0}$ and IM_0 are base year imports of RoW and the home country, IM^D denotes the domestic import demand, while EX^S_{row} represents export supply of RoW. PEX_{row}, which is fixed at $\overline{PEX}_{row}$, denotes the price of RoW's exports in foreign currency; $(e \cdot PEX_{row})$ is the domestic price for imports from RoW. $\frac{PEX}{e}$ denotes the price of exports of the home country in foreign currency. ε and η are the foreign and the domestic import demand price elasticities. In equilibrium the balance-of-payments condition is satisfied and the price vectors PEX and PEX_{row} guarantee that excess demands equal zero.

As shown in Whalley and Yeung (1984, p. 132), equation system (4) to (8) leads to the following reduced form elasticities

(9) $$\frac{\partial IM_{row}}{\partial PEX} \cdot \frac{PEX}{IM_{row}} = \frac{\varepsilon \cdot \eta}{(\varepsilon + \eta + 1)}$$

and

(10) $$\frac{\partial IM}{\partial \overline{PEX}_{row}} \cdot \frac{\overline{PEX}_{row}}{IM} = \frac{\varepsilon \cdot \eta}{(\varepsilon + \eta + 1)}.$$

Thus, Whalley and Yeung show that foreign and domestic import demand elasticities are, if the balance-of-payments condition is satisfied, not independent as suggested by equation system (4) to (7), but are a single parameter. They criticise that most of the world closure rules are described as if they allowed to incorporate given foreign and domestic import demand elasticities while simultaneously meeting a trade balance condition. Furthermore, Whalley and Yeung point out that in the two-good case the foreign and the domestic offer curves that are constructed to satisfy external sector equilibrium conditions at any set of prices lie one on top of the other. In exactly the same way, the restrictions given by balanced trade should be considered in econometric estimations. Incidentally, this point is picked up and confirmed by de Melo and Robinson (1989, p. 48).

Basically, in the GEM-E3 model the trade relations between EU-14 and RoW are specified in close analogy to the second rule (see Section 3). The problems outlined above have to be taken seriously, but should be relativised. Whalley and Yeung, in particular, take an econometric point of view. However, the pure econometric problem of identification or misspecification of elasticity parameters is less relevant as the GEM-E3 model is not an econometric model.

Additionally, in an 18 sector model any change in one market will be cushioned by reactions in the remaining 17 markets so as to satisfy the balance-of-payments constraint. Thus, the relation of elasticities is less significant as in a two-good model framework. And finally, the trade balance constraint, and thus the closure rule as well, can be turned off in the GEM-E3 model.

The third closure rule proposed by Whalley and Yeung (1984, p. 134f.) is characterised by the inclusion of non-tradable goods, by price-taking behaviour and by missing product differentiation for tradable goods. Thus, in a two-good case the foreign offer curve is a straight line with a slope given by the world prices of traded goods, while the domestic offer curve incorporates some degree of elasticity. Whalley and Yeung argue that this rule is unpalatable for empirical work on large countries because of the small-country assumption. In addition, its specification of import demand is unable to address the problem of intra-industry trade.

The fourth rule presented here has been applied by de Melo and Robinson. De Melo and Robinson (1989) extend the standard assumption of product differentiation on the import side to the export side. They introduce 'symmetric' product differentiation, using a CES (constant elasticity of substitution) function for domestic aggregate import demand and a CET (constant elasticity of transformation) function for the domestic export transformation function. Furthermore, three assumptions are made: the small-country assumption, i.e. the domestic country can sell or purchase any amount of imports and exports at fixed world prices, the assumption of a fixed aggregate output (full employment) and the assumption of a zero balance of trade.

De Melo and Robinson show that the specification is theoretically well behaved. It implies intersecting offer curves: the balance-of-trade condition defines the foreign offer curve as a straight 45° line (choosing units so that world prices for exports and imports equal one) while the domestic offer curve is well-behaved with an elasticity depending on both elasticity of substitution and transformation. Thus, the problem of identical offer curves arising from the second rule can be avoided. But, similar to the third rule, the small-country assumption restricts the application of this rule to small-country models.

All models described above, introduce a fixed trade balance for the external sector with a flexible exchange rate variable that clears the foreign exchange market. Alternatively, the exchange rate can be fixed while the trade balance is allowed to adjust in order to retain equilibrium on the foreign exchange market. As Francois and Shiells (1994, p. 32) note, ideally, in general equilibrium models the current and capital accounts and the exchange rate would be determined endogenously. However, this more complex approach is not widely used in CGE models. A third alternative, chosen for the (real) standard version of the GEM-E3 model without money market, is a fixed exchange rate system which is combined with a fixed or a variable current account. In the first case, the long-term real interest rate, or national prices respectively, adjust as to satisfy the trade balance equilibrium (see Section 3.4).

2.2 The Armington assumption

CGE trade models differ widely in the specification of import demand. Whereas in some models imports and competing domestic goods are treated as perfect substitutes according to the Heckscher-Ohlin model, in some others the Armington assumption of national or of firm-level product differentiation is employed[6]. Models differ also with respect to the functional forms used. Some apply nested or non-nested CES functional forms, while others employ flexible functional forms such as the almost ideal demand system (AIDS). Armington (1969), and most CGE modelers, have given preference to CES functions as these require relatively less estimation effort and as regularity conditions (global concavity) are satisfied. On the other hand, the AIDS overcomes the restrictiveness imposed by the CES by giving up constancy and pair-wise equality of substitution elasticities (see Francois and Shiells 1994, Shiells and Reinert 1993).

However, the majority of empirically based CGE models have introduced the Armington assumption of national product differentiation, often using CES functions with two levels of nesting[7]: The nested specification includes an upper-level function that specifies a country's demand for the composite of imports (aggregated over all countries) relative to domestic substitutes. The lower-level function defines allocation of imports on competing foreign sources, i.e. countries (Lächler 1985, p. 74, Shiells and Reinert 1993, p. 300).

The upper-level Armington elasticity measures the sensitivity of a country's or industry's competitive position in international trade and controls the degree to which the country's price system is ruled by foreign prices. The higher the

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[6] In the GREEN model, for example, the Armington specification is implemented for all import goods apart from crude oil for which homogeneity across countries of origin is assumed. This is due to relatively low transportation costs, e.g. compared to natural gas or coal (Burniaux et al. 1992).

[7] Some CGE models, for example the Deardorff and Stern model, assume a single level CES function where domestic production competes with an aggregate of imports (Deardorff and Stern 1981). Some other CGE models, for example the models of Cox and Harris (1992), Sobarzo (1992), and Roland-Holst et al. (1992), have adopted the non-nested specification in order to describe national product differentiation. Here, the two-tiered utility function is fitted together into one level by assuming that utility is a function of domestic output and imports from each seperate source (Shiells and Reinert 1993, p. 301,303).

sectoral upper-level elasticity the higher the degree of demand responsiveness to relative prices. Ultimately, the Armington assumption gives small-country models more reality as it provides a degree of autonomy in the domestic price system while preserving all the features of standard neoclassical models (de Melo and Robinson 1989, p. 56).

The wide use of the Armington assumption in practice is motivated by two further advantages. First, it addresses the phenomenon of intra-industry trade flows that is observable to an increasing extent in the international trade data. Instead of increasing specialization according to Heckscher-Ohlin, countries simultaneously increase exports and imports of goods that are classified in the same commodity category, even if an industry is highly disaggregated. This phenomenon of cross-hauling can be explained by qualitative differences between domestic and foreign goods, geography or transportation costs (Shoven and Whalley 1992, p. 187). A second reason for the popularity of the Armington assumption is that difficulties, such as unrealistically extreme specialization effects, due to homogeneous products and linear production possibility frontiers, can be avoided (see Shoven and Whalley 1992, p. 230, de Melo and Robinson 1989, p. 49).

However, among economists and econometricians scepticism against the Armington concept has been arising. Some criticise that the empirical relevance of cross-hauling, and thus the theoretical justification of the Armington concept, mainly depends on the level of data disaggregation. Thus, the question focuses on which aggregation level is appropriate to the concept of an industry (Lächler 1985, p. 75). Besides, some authors describe the Armington approach as a 'simple, restricted and ad hoc (but effective) means of capturing the rigidities apparent in observed trade flows patterns' (Abbott 1988, p. 67). In a similar way Norman argues (1990, p. 726): 'Typically, the Armington approach is used within perfectly competitive models; and must be regarded as a purely ad hoc means of describing intra-industry trade flows and reducing the sensitivity of trade flows to changes in relative prices - essentially, it is an attempt to capture supply-side imperfections through modification of the model demand side'. Norman supports the abandonment of the Armington assumption, instead incorporating imperfect competition based on firm-level product differentiation. In their general equilibrium model Trela and Whalley (1994, p. 263) also refrain from using the Armington assumption, but treat products as homogeneous refering to 'strong and often artificial terms-of-trade effects' the Armington assumption induces in numerical results.

3 Specification of foreign trade in the GEM-E3 standard version

Table 1 illustrates the characteristics of the foreign trade system of the GEM-E3 model[8]. International prices that clear domestic and foreign product markets are not completely determined by the model but are partly exogenous. World import demand depends on international terms of trade only, but does not include any variable measuring RoW's economic performance, e.g. in terms of world income.

Table 1: Import demand and export supply in the GEM-E3 model

	Import demand	Export supply
European Union	=> finite price elastic => depending on international price relations and EU economic performance (e.g. income)	=> finite price elastic => export prices given by cost-covering domestic production prices
Rest of the world	=> finite price elastic => depending on international price relations	=> perfectly price elastic => exogenous

In Section 3.1 and 3.2 the EU countries' and the RoW's export and import supply and demand functions that are incorporated in GEM-E3 are described. Section 3.3 deals with the specification of Armington elasticity parameters. The 'closure' of the external sector system through the balance-of-payments constraint is explained in Section 3.4.

3.1 Foreign trade system: EU countries

Import demand

The specification of import demand of each EU country for tradable commodities is based on the Armington model of national product differentiation combined with the two-stage nested CES specification[9]. It is

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[8] See Capros et al. (1997) for a description of the basic features and characteristics of the GEM-E3 model.

[9] The specification of the import demand for tradable goods takes into account that a fixed share of sectoral imports is non-competitive, i.e. is not determined by relative prices according to the Armington substitution elasticity. In the actual GEM-E3 model version this share is set to 0.5 uniformly for all countries and sectors. Non-competitive imports

assumed that the allocation of expenditure for tradable goods takes place in two stages. At the upper level of substitution, expenditure is allocated between domestic demand of domestically produced goods and an aggregate of imported goods from all sources. At the lower level, the expenditure for the import composite is allocated by origin, i.e. imports are distinguished by place of production (other EU countries and RoW) [10].

At the first level of substitution the aggregate import function for EU country c is derived. The price for domestic supply PY_c in country c is given as an aggregate of the price of competitive imports PIM_c and the price of domestic demand for domestic goods PXD_c

(11) $$PY_c = \left[\delta x_{1,c} \cdot PIM_c^{1-\sigma_x} + \delta x_{2,c} \cdot PXD_c^{1-\sigma_x}\right]^{\frac{1}{1-\sigma_x}} \quad \forall c, \quad c = 1,\ldots,14.$$

Applying Shepard's Lemma to the unit cost function yields the aggregate import demand function of country c

(12) $$IM_c = Y_c \cdot \delta x_{1,c} \cdot \left(\frac{PY_c}{PIM_c}\right)^{\sigma_x} \quad \forall c, \quad c = 1,\ldots,14.$$

IM_c and Y_c are aggregated imports and domestic supply in country c. The parameters $\delta x_{1,c}$ and $\delta x_{2,c}$ are calibrated to the benchmark data. σ_x denotes the elasticity of substitution between comparable domestic and foreign goods (upper-level Armington elasticity). As in the GEM-E3 model elasticity values are identical across countries, the country-specific indices are omitted. Imports and domestic production are complementary for $\sigma_x \to 0$, while they are perfectly substitutable for $\sigma_x \to \infty$. The latter case corresponds to the Heckscher-Ohlin model.

At the second level of substitution, import demand for each good is distinguished by place of production. Hence, the aggregate import demand has to be allocated to the 14 EU-member countries and to RoW. An import unit cost function in the CES functional form is expressed by

reflect these amounts of goods that can not be substituted by domestic production and is therefore price inelastic, but depends on the domestic production level. The import demand for non-tradable goods is specified in close analogy to the demand of non-competitive imports.

[10] In order to keep the notation as simple as possible, the sector-specific indices are not explicitly noted in the following equations.

(13) $$PIM_c = \left[\sum_{k=1}^{14,row} \delta m_{c,k} \cdot \left(PIMP_{c,k} \right)^{1-\sigma_m} \right]^{\frac{1}{1-\sigma_m}} \quad \forall\ c, \quad c = 1,..,14\,,$$

where $PIMP_{c,k}$ is the price of imports in country c for goods produced in country k. As there are import taxes and duties t_{dut}, it is $PIMP_{c,k} = PEX_k \cdot e_{c,k} \cdot (1 + t_{dut})$, whereas PEX_k is the price in currency of country k for exports (no price differentiation between destinations), $e_{c,k}$ denotes the nominal exchange rate in currency of country c per unit currency of country k. As the nominal exchange rates $e_{c,k}$ are fixed, they serve only for converting one currency into each other. $\delta m_{c,k}$ represent share parameters which are specified by calibration. σ_m denotes the lower-level elasticity of substitution between imports from different EU countries and RoW. A cost minimizing composition of the import aggregate with regard to countries of origin is given by the following equation

(14) $$IMP_{c,k} = IM_c \cdot \delta m_{c,k} \cdot \left(\frac{PIM_c}{PIMP_{c,k}} \right)^{\sigma_m} \quad \forall \quad k, \quad k = 1,\ldots,14, row\,,$$

where $IMP_{c,k}$ denotes the import by country c from country k in currency of country c.

The demand function of the EU as a whole for imported goods from RoW is the aggregate over all imports from non-EU countries demanded by EU countries, i.e.

(15) $$IM_{EU,row} = \sum_{c=1}^{14} \frac{IMP_{c,row}}{e_c}\,.$$

As e_c denotes the price of currency of country c in ECU, $IM_{EU,row}$ is expressed in ECU.

Demand for exports

Each EU country k is faced with a downward-sloping export demand curve for all commodities. The demand for exports of country k is the sum of the corresponding import demands across all other EU countries and RoW. Exports enter the product market equilibrium condition.

(16) $$EX_k = \sum_{c=1}^{14,row} IMP_{c,k} \cdot e_{k,c} \quad \forall\ k, \quad k = 1,\ldots,14\,.$$

Export supply

The current version (Version 21) of the GEM-E3 model is characterised by asymmetric product differentiation as product differentiation is introduced for the import side (through the Armington assumption on the first and second level), but not for the export side. Domestically produced goods sold on the domestic market are perfect substitutes for goods that are sold on EU and RoW export markets. This is in contrast to other CGE models and other versions of GEM-E3[11]. The latter and, for example, the model of de Melo and Robinson (1989) specify the transformation possibilities between production for the domestic market and production for the export market by a CET (constant elasticity of transformation) function. Besides, in the current GEM-E3 model no differentiation of exports by export markets is assumed. Exports enter a trade pool and are distributed according to the demands of import countries. Thus, a country's sectoral export price is not differentiated by importing countries. In the GEM-E3 model domestic producers of country c supply exports at price PEX_c

(17) $PEX_c = PX_c \cdot (1 + t_{sub,c}) \quad \forall c, \quad c = 1,\ldots,14$,

where PX_c is the price of domestically produced goods and $t_{sub,c}$ denotes the rate of export subsidies which is calibrated. PX_c is determined for each EU country by the internal costs and the zero profit condition.

3.2 Foreign trade system: RoW

As already mentioned, RoW's production and consumption behaviour are not endogenous. Assuming a fixed price of domestically produced goods, i.e. an infinite domestic supply elasticity, RoW supplies exports at fixed export prices that are not affected by EU-14's demand for goods from RoW. Strictly speaking, with regard to RoW's exports the EU-14 is modelled as a price-taker on world markets that can not affect export prices of RoW by its import demand behaviour.

Import demand

Basically, the RoW's import demand function is modelled in complete analogy to the EU countries. But in contrast to this, all imports (and not only the competitive part of tradables) are specified according to the Armington assumption. i.e. depend on relative prices.

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[11] See e.g. Conrad and Schmidt (1997).

It is assumed that sectoral upper-level elasticities are identical to sectoral lower-level elasticities, i.e. $\sigma_x^{row} = \sigma_m^{row} = \sigma^{row}$. Taking into account that $PIMP_{row,k} = PEX_k \cdot e_{row,k}$, and considering that world prices PXD_{row} and world domestic demand for domestic goods XD_{row} are exogenous, RoW's demand for imports from EU country c can be expressed by

(18) $$IMP_{row,k} = \alpha_k \cdot \left(\frac{PXD_{row}}{PEX_k \cdot e_{row,k}} \right)^{\sigma^{row}} \quad \forall k, \quad k = 1,\ldots,14,$$

where $\alpha_k = \delta m_{row,k} \cdot \frac{\delta x_{1,row}}{\delta x_{2,row}} \cdot XD_{row}$ (calibrated) and PXD_{row} denotes the price for domestically demanded and produced goods in RoW. As PXD_{row} is fixed, RoW's demand for imports from different EU countries depends alone on EU country-specific export prices. The RoW's demand for imports from the EU-14 as a whole is

(19) $$IM_{row} = \sum_{c=1}^{14} IMP_{row,c} \quad .$$

Demand for exports

Like each EU country, RoW is faced with a negative price elastic demand function for its exports

(20) $$EX_{row} = \sum_{c=1}^{14} IMP_{c,row} \cdot e_{row,c} \quad .$$

As RoW's export prices are fixed, demand of EU countries for RoW's exports depends on the price of the import aggregate only.

Export supply

The export supply of RoW is perfectly price elastic. Any amount of goods will be supplied at export prices which are fixed in foreign exchange terms.

(21) $$PEX_{row} = \overline{PEX}_{row} .$$

3.3 Specification of Armington elasticities

Table 2 contains upper- and lower-level Armington elasticity values actually used in the GEM-E3 model in EU and RoW import demand. Elasticities differ among sectors, but values for each sector are identical for all EU countries.

For EU countries upper-level elasticity values are greater than 1 for sectors with a relatively high degree of international competition, such as energy-intensive or consumer goods industry, while values of service sectors or sectors with relatively homogeneous goods (e.g. sector crude oil and oil products) are set below 1. Basically, lower-level elasticity values are set higher than upper-level elasticities. As Shiells and Reinert (1993) - with reference to Brown (1987) - have noted, the two-level nested Armington approach may imply large terms-of-trade effects that are the greater the larger the upper-level elasticities are relative to the lower-level elasticities. Thus, in order to avoid large terms-of-trade effects, lower-level elasticities take often higher values than upper-level elasticities in empirical trade models. However, as empirical studies indicate, this pattern is not absolutely evident. For instance, a comparison of U.S. upper-level elasticities estimated by Reinert and Roland-Holst (1992), with U.S. lower-level elasticities estimated by Shiells and Reinert (1993) shows that for some sectors lower-level elasticities are higher than upper-level elasticities (see Section 4.3.1).[12]

The last column of Table 2 presents values of substitution elasticities used in RoW's import demand. Lower-level elasticity values are set equal to upper-level elasticity values. With regard to relative sectoral degrees of substitutability RoW's elasticities are specified nearly comparable to EU elasticities.

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[12] Whalley (1985, p. 109), for example, in his seven region model uses upper-level elasticity values, that are based on literature values of import-price elasticities. The lower-level elasticity values are set for all sectors and regions on a common value of 1.5, which roughly approximates literature estimates of export price elasticities.

Table 2: Specifications of Armington elasticity values in the standard version of the GEM-E3 model

	EU-14		RoW
	σ_x	σ_m	$\sigma_x^{row} = \sigma_m^{row}$
1 Agriculture	1.2	1.6	1.4
2 Coal	-	-	0.6
3 Crude oil and oil products	0.6	0.8	0.6
4 Natural gas	-	-	0.6
5 Electricity	-	-	0.6
6 Ferrous, non-ferrous ore and metals	1.5	2.4	2.2
7 Chemical products	1.5	2.4	2.2
8 Other energy intensive industries	1.5	2.4	2.2
9 Electrical goods	1.5	2.4	2.2
10 Transport equipment	1.5	2.4	2.2
11 Other equipment goods industries	1.5	2.4	2.2
12 Consumer goods industries	1.7	2.8	2.5
13 Building and construction	-	-	1.4
14 Telecommunication services	0.6	1.6	1.4
15 Transports	1.2	2.4	2.2
16 Credit and insurance	0.6	1.6	1.4
17 Other market services	0.6	1.6	1.4
18 Non-market services	-	-	0.6

3.4 Balance-of-payments equation

The GEM-E3 model can be solved either with a binding or a non-binding balance-of-payments constraint for each of the EU countries, or the EU as a whole respectively. As nominal exchange rates are fixed, the feedback of a surplus or deficit on the EU economy when the constraint is binding is established through the real long-term interest rate.

In the real standard version of the GEM-E3 model without asset markets and international capital flows the balance of payments is reduced to the current account. The current account surplus (deficit) of EU country c for each of the traded or non traded goods is defined as the difference between the value of exports and the value of imports. TS_c in (22) denotes the trade balance of country c to a given level of exchange rates (aggregating TS_c over all countries leads to the current account of EU-14 vis-à-vis RoW).

(22) $$TS_c = \sum_{s=1}^{18} PEX_{s,c} \cdot EX_{s,c} - \sum_{k=1}^{14,row} \sum_{s=1}^{18} PIMP_{s,c,k} \cdot IMP_{s,c,k} \quad \forall\ c = 1,\ldots,14, row;\ s = 1,\ldots,18.$$

In the case of a free variation of the EU current account, the aggregate net EU trade surplus (deficit) is balanced out by a corresponding net currency inflow (outflow). However, these currency flows affect neither EU equilibrium prices nor quantities. The market of foreign currency may be unbalanced. Strictly speaking, the model allows long-lasting external deficits for the EU without considering any feedback on the domestic economy.

In the case of a binding balance-of-payments constraint the EU trade surplus (deficit), in terms of percentage of GDP, is set to a pre-determined value. Now, feedbacks of a surplus or deficit on the EU economy are considered. As exchange rates are fixed in the GEM-E3 model, adjustment mechanisms run through the real long-term interest rate. A current account surplus of the EU, for instance, is balanced out through a decrease of real long-term interest rates in the EU countries. This drop reduces long-term capital costs and savings, but stimulates investment demand and private consumption. Thus, on the demand side of the economy the decrease of the real interest rates pushes up EU domestic prices. On the supply side, the increase in investment raises the stock of real capital. The short-term interest rates that clear markets for real capital fall, provided that the demand effect is no longer sufficient to offset the supply effect. Domestic prices rise just enough to maintain product market equilibrium. Holding foreign prices constant, a rise in EU prices increases EU imports and diminishes EU exports and therefore reduces the surplus.

Note, that in a model that includes a monetary sector, more or less similar adjustment processes are observable. A surplus of the balance of payments would be eliminated by a decrease in the EU interest rate, too. However, effects on the product markets would be smaller as the capital account provides an additional mechanism of adjustment. If EU interest rates decrease, EU citizens will shift their portfolios towards foreign assets. Thus, the equilibrium net capital outflow increases which in turn reduces the balance-of-payments surplus additionally. A model with a flexible exchange rate would offer a third adjustment process, as a growing trade surplus would be cushioned by an revaluation of exchange rates.

Simulations of an ecological tax reform scenario with the GEM-E3 model show that results differ between both cases, a variable and a fixed current account (see Table 3). The ecological tax reform scenario applied prescribes an EU-wide reduction of CO_2 emissions by 10%. In each of the 14 EU-countries an endogenous CO_2 tax is implemented. Tax revenue neutrality is guaranteed as contributions to social security are reduced to keep public deficit constant.

Simulation results of the standard version with a non-binding current account will be analysed in detail in the next section. Therefore, at this point we just refer shortly to the main differences between the constrained and unconstrained specification. In the unconstrained version the ecological tax reform produces a current account surplus. In the constrained model version the feedback mechanism described above leads to comparably higher EU prices and in turn to a greater fall in exports and a lower drop in imports.

Whereas a long-term analysis should consider the feedback mechanism introduced by the balance-of-payments constraint, a flexible current account seems to be more reasonable in the short- or the medium term. Nevertheless, it is worthwhile to notice that the assumption on the flexibility in the current account does not alter the results in principle.

Table 3: EU-wide ecological tax reform

(numbers indicate percent changes from baseline except if defined otherwise)

Macroeconomic aggregates for EU-14

	Standard version of the GEM-E3 model	
	Variable current account	Fixed current account
Gross domestic product	-0.04%	-0.09%
Employment*	780	683
Private investment	-0.18%	-0.16%
Private consumption	0.21%	0.40%
Domestic demand	-0.56%	-0.52%
Exports in volume	-1.02%	-1.81%
Imports in volume	-1.46%	-1.05%
Intra trade in the EU	-1.20%	-1.68%
Energy consumption in volume	-6.21%	-6.22%
Consumers' price index	1.19%	1.71%
GDP deflator in factor prices	-0.74%	-0.16%
Current account as % of GDP***	0.08	-0.01
Equivalent variation of total welfare		
Economic welfare**	0.23%	0.37%

* in thousand employed persons
** as percent of GDP
*** absolute difference from baseline

4 Sensitivity to foreign trade specifications

In this section sensitivity analysis will be conducted with respect to alternative foreign trade specifications. Basically, three approaches will be tested

- An additional price equation for exports from RoW to EU is introduced. Instead of fixed world prices for exports, the EU is faced with a finite price elastic export supply function (Section 4.1).

- The foreign import demand function is changed by introducing a link between the activity level of the domestic (EU) and the foreign (RoW) economy (Section 4.2).
- Variations in the degree of substitution between goods entering the sectoral aggregate import demand functions of both EU countries and RoW are analysed (Section 4.3).

The whole sensitivity analysis will be based on the ecological tax reform scenario described in the previous section. As mainly short- and medium-term aspects are considered, the balance of payments is kept variable. Policy-induced impacts are calculated for all variations in the foreign trade sector suggested above. The sensitivity of results is analysed by comparing the results with those produced by the (unchanged) standard version of the GEM-E3 model. For reasons of clarity, the discussion of results concentrates on selected EU-14 macroeconomic and sectoral aggregates.

4.1 Changes in RoW's export supply

4.1.1 Specification of RoW's export supply

In this section the assumption of a perfectly price elastic export supply function of the RoW is given up. Instead, for each sector a foreign export supply function with a constant own-price elasticity is introduced:

(23) $$EX_{row} = EX_{row,0} \cdot \left(PEX_{row}\right)^{\gamma}, \quad 0 < \gamma < \infty,$$

where $EX_{row,0}$ denotes exports of the base year. γ is the RoW's export supply elasticity, i.e. an increase in the sectoral export price by 1% would increase the supply of exports by γ %. Solving equation (23) for PEX_{row} yields

(24) $$PEX_{row} = \left(\frac{EX_{row}}{EX_{row,0}}\right)^{\frac{1}{\gamma}}, \quad 0 < \gamma < \infty.$$

In the following, equation (24) is introduced as an additional price equation for all sectors in the GEM-E3 standard model version. Now prices of exports from RoW are no longer fixed, but increase with the amount of RoW's exports, or, because of equation (20), with the amount of EU-14 imports, respectively. Obviously, introducing this new specification can lead to substantial changes in simulation results, in particular if the policy induced impacts on EU imports are substantial.

The new specification is tested for three alternative parameter values of γ (see Table 4). For reasons of simplicity, γ is not differentiated among sectors.

Table 4: Values of parameter γ for sensitivity analysis

Sector	Case 0: Standard version of GEM-E3	Case 1: Halved values	Case 2: Central values	Case 3: Doubled values
1 - 18	∞	0.5	1	2

Econometric studies indicate that the own-price elasticity of export supply is below 1. Diewert and Morrison (1989, p. 207), for example, estimated the own price elasticity of export supply for the U.S. economy. They obtained as result that γ is nearly constant between 0.32 and 0.375 over the sample period 1967-1982. Hence, Case 1 with $\gamma = 0.5$ seems to be most close to reality and might be interpreted as an upper limit value.

4.1.2 Simulation results

The following simulations of an ecological tax reform include the case of a perfectly elastic export supply function (reflecting the standard version of GEM-E3) and the case of not perfectly elastic export supply functions as specified in the previous section. Results from these cases are reported in Table 5 in terms of several macroeconomic aggregates and in Table 6 in terms of sectoral extra-EU imports and exports.

The results indicate that, contrary to expectations, the EU-14 as a whole would gain from more flexible export prices in terms of economic welfare. The lower the own-price elasticity of foreign export supply, the higher the economic welfare. While in the standard version of the GEM-E3 model (fixed export prices) the welfare effect of the ecological tax reform is around 0.23%, it rises to 0.32% in Case 3, to 0.42% in Case 2 and, finally, to 0.62% in Case 1.

Overall, gross domestic product, employment, production, private investment, private consumption, extra-EU imports and energy consumption are higher, the lower the own-price elasticity of export supply is. For example, gross domestic product drops in the standard version ($\gamma \to \infty$) by -0.04% and still in Case 3

($\gamma = 2$) by -0.01%, but, however, rises in Case 2 ($\gamma = 1$) by 0.01% and in Case 1 ($\gamma = 0.5$) by 0.05%.

The impacts on exports are opposite to those described above. Exports run parallel to the value of the own-price elasticity of export supply. For instance, the reduction rate of exports is the highest in Case 1 (-2.64%) and the lowest in the standard version (-1.02%). The volume of intra trade in the EU reacts in the same way. Intra-EU trade, defined as intra-EU exports, decreases the most in Case 1 and the least in the standard version.

All in all, the degree of sensitivity of results to a variation of the RoW's export supply elasticity values is considerable. How can this be explained? To do this, we must take a closer look at what happens in the standard version of the GEM-E3 model when the ecological tax reform is implemented.

First of all, the EU-wide introduction of a CO_2 tax leads to an increase in production costs, in particular in energy-intensive sectors which produce above-average CO_2 emissions. Secondly, labour costs are reduced due to the cut of the rate of employer's contributions to social security. Hence, substitution processes from energy-intensive capital and energy to labour will be set off, i.e. demand for labour will increase which in turn forces up wage rates. As Table 8 demonstrates, real wage rates go up in EU countries by 0.29% to 1.48%. Due to increasing real wage rates, households are willing to supply more labour. Finally, EU-wide employment increases by 780.000 persons. On the other hand, substitution processes between inputs and losses in production, are responsible for a drop in energy consumption by -6.21%. The increase in income stimulates consumption demand which in turn pushes up the consumption price index by 1.19%.

However, the EU-wide pressure of costs makes exports to fall by -1.02%. Import demand decreases as well by -1.46%. For the latter, the price-induced, substitution effect from domestic to foreign products is not high enough to compensate the negative effect caused by a reduced production. However, Table 6 shows that sectoral patterns differ. In particular, positive growth rates are obtained for exports of fossil fuels which are exempted from taxation. The decrease in domestic consumption lowers prices and makes these goods more attractive for RoW.

Now, when RoW's export prices are specified as in equation (24), the model's reactions change as follows.

Likewise in the standard version of the GEM-E3 model, the ecological tax reform leads to an increase in production costs. Measured in terms of GDP deflator, the overall price level increases compared to the standard case where world export prices are constant. Obviously, in the standard case European producers are able to evade cost pressures more easily by changing demand patterns and switching to foreign supply. Table 7 shows that RoW's export prices rise for almost all sectors, with exception of the energy sectors 2 - 4 in Case 1 and Case 2 and sectors 5 and 9 in Case 3. Basically, price changes are the higher, the smaller the own-price elasticity of export supply, γ, is. The sectoral price changes are reflected well by the development of sectoral EU-14 imports (see Table 6).

As already mentioned, the new specification leads to a greater fall in EU-14 exports. This is due to an additional increase in EU production costs which is caused by higher prices for RoW's exports. Producers in EU now have less possibilities for cushioning the tax induced EU-wide price increase.

As Table 5 shows, the positive employment effects are stronger in case of flexible RoW's export prices. This can be easily understood taking into account that in particular energy-intensive sectors for which domestic prices rise considerably will be substituted by an increasing extent by imported goods from RoW or by input factors with relatively lower prices, such as labour. As cost-effective possibilities of a switch to foreign products are restricted, the switch to labour is reinforced. As labour demand rises stronger, real wage rates are pushed up to a greater extent as well (see Table 8). Thus, labour supply and employment increase. Rising income stimulates consumption of private households which in turn reduces the negative impact on production.

Imports are higher compared to the standard version and take a positive percentage rate for $\gamma = 0.5$. The rise in import demand is driven by a lower decrease in production (imports of non-tradables and non-competitive imports) and increasing consumption (imports entering the Armington demand function). The positive effect on consumption outweighs the loss in leisure; hence, welfare increases.

Table 5: EU-wide ecological tax reform
Constant price elastic foreign export supply
(numbers indicate percent changes from baseline except if defined otherwise)

Macroeconomic aggregates for EU-14

	Case 0: Standard version of GEM-E3	Case 1: Halved values (γ=0.5)	Case 2: Central values (γ=1)	Case 3: Doubled values (γ=2)
Gross domestic product	-0.04%	0.05%	0.01%	-0.01%
Employment*	780	1108	950	868
Production	-0.57%	-0.50%	-0.54%	-0.56%
Private investment	-0.18%	-0.01%	-0.09%	-0.13%
Private consumption	0.21%	1.03%	0.61%	0.41%
Domestic demand	-0.56%	-0.26%	-0.41%	-0.49%
Exports in volume	-1.02%	-2.64%	-1.81%	-1.41%
Imports in volume	-1.46%	0.04%	-0.74%	-1.11%
Intra trade in the EU	-1.20%	-2.20%	-1.71%	-1.47%
Energy consumption in volume	-6.21%	-5.80%	-6.01%	-6.12%
Consumers' price index	1.19%	6.51%	3.02%	1.92%
GDP deflator in factor prices	-0.74%	4.50%	1.05%	-0.04%
Current account as % of GDP***	0.08	0.20	0.14	0.11
Equivalent variation of total welfare				
Economic welfare**	0.23%	0.62%	0.42%	0.32%

* in thousand employed persons

** as percent of GDP

*** absolute difference from baseline

Table 6: EU-wide ecological tax reform
Constant price elastic foreign export supply
(numbers indicate percent changes from baseline)

	Extra-EU imports (EU-14)				Extra-EU exports (EU-14)			
	Case 0: Standard version of GEM-E3	Case 1: Halved values (γ=0.5)	Case 2: Central values (γ=1)	Case 3: Doubled values (γ=2)	Case 0: Standard version of GEM-E3	Case 1: Halved values (γ=0.5)	Case 2: Central values (γ=1)	Case 3: Doubled values (γ=2)
Agriculture	0.60%	1.81%	1.14%	0.85%	-1.09%	-2.57%	-1.76%	-1.40%
Coal	-25.86%	-20.30%	-22.63%	-24.09%	2.97%	-21.62%	-11.22%	-4.78%
Crude oil and oil products	-4.37%	-2.69%	-3.54%	-3.96%	1.52%	-0.34%	0.58%	1.04%
Natural gas	-4.03%	-2.98%	-3.58%	-3.83%	2.45%	-2.53%	0.06%	1.29%
Electricity	-0.39%	0.83%	0.18%	-0.11%	-2.51%	-4.71%	-3.55%	-3.02%
Ferrous, non-ferrous ore and metals	2.53%	2.52%	2.11%	2.12%	-6.68%	-7.12%	-6.34%	-6.24%
Chemical products	1.49%	2.11%	1.55%	1.40%	-2.72%	-3.30%	-2.67%	-2.53%
Other energy intensive industries	0.79%	2.13%	1.39%	1.06%	-1.48%	-2.85%	-2.10%	-1.76%
Electrical goods	-0.72%	1.44%	0.48%	-0.06%	0.22%	-3.10%	-1.71%	-0.88%
Transport equipment	0.05%	2.15%	1.26%	0.76%	-0.32%	-1.85%	-1.27%	-0.91%
Other equipment goods industries	-0.47%	1.68%	0.77%	0.25%	-0.01%	-2.73%	-1.59%	-0.94%
Consumer goods industries	0.77%	2.09%	1.37%	1.05%	-1.00%	-2.51%	-1.68%	-1.31%
Building and construction	-0.08%	0.98%	0.39%	0.14%	-0.35%	-4.30%	-2.09%	-1.15%
Telecommunication services	0.11%	1.84%	1.00%	0.58%	0.11%	-1.83%	-0.90%	-0.43%
Transports	1.00%	1.97%	1.32%	1.08%	-2.05%	-3.11%	-2.38%	-2.12%
Credit and insurance	-0.58%	1.82%	0.85%	0.27%	0.29%	-1.31%	-0.72%	-0.34%
Other market services	0.53%	2.34%	1.49%	1.06%	-0.47%	-1.87%	-1.23%	-0.89%
Non-market services	0.24%	1.38%	0.73%	0.46%	-0.06%	-1.25%	-0.56%	-0.28%
All sectors	-1.46%	0.04%	-0.74%	-1.11%	-1.02%	-2.64%	-1.81%	-1.41%

Table 7: EU-wide ecological tax reform
Constant price elastic foreign export supply
(numbers indicate percent changes from baseline)

Sectoral export prices of RoW

	Case 0: Standard version of GEM-E3	**Case 1:** Halved values (γ=0.5)	**Case 2:** Central values (γ=1)	**Case 3:** Doubled values (γ=2)
Agriculture	0%	3.64%	1.14%	0.43%
Coal	0%	-36.48%	-22.63%	-12.87%
Crude oil and oil products	0%	-5.30%	-3.54%	-2.00%
Natural gas	0%	-5.87%	-3.58%	-1.93%
Electricity	0%	1.67%	0.18%	-0.05%
Ferrous, non-ferrous ore and metals	0%	5.10%	2.11%	1.05%
Chemical products	0%	4.25%	1.55%	0.70%
Other energy intensive industries	0%	4.31%	1.39%	0.53%
Electrical goods	0%	2.89%	0.48%	-0.03%
Transport equipment	0%	4.36%	1.26%	0.38%
Other equipment goods industries	0%	3.40%	0.77%	0.12%
Consumer goods industries	0%	4.23%	1.37%	0.53%
Building and construction	0%	1.98%	0.39%	0.07%
Telecommunication services	0%	3.72%	1.00%	0.29%
Transports	0%	3.99%	1.32%	0.54%
Credit and insurance	0%	3.66%	0.85%	0.14%
Other market services	0%	4.73%	1.49%	0.53%
Non-market services	0%	2.78%	0.73%	0.23%

Table 8: EU-wide ecological tax reform
Constant price elastic foreign export supply
(numbers indicate percent changes from baseline)

	Real wage rate				**Capital income**			
	Case 0: Standard version of GEM-E3	**Case 1:** Halved values (γ=0.5)	**Case 2:** Central values (γ=1)	**Case 3:** Doubled values (γ=2)	**Case 0:** Standard version of GEM-E3	**Case 1:** Halved values (γ=0.5)	**Case 2:** Central values (γ=1)	**Case 3:** Doubled values (γ=2)
Austria	1.05%	2.73%	1.93%	1.51%	3.06%	12.23%	6.79%	4.77%
Belgium	1.48%	3.32%	2.43%	1.98%	4.21%	13.48%	8.01%	5.96%
Germany	0.99%	2.25%	1.59%	1.28%	3.03%	10.97%	6.03%	4.31%
Denmark	1.15%	2.96%	2.15%	1.69%	4.49%	14.04%	8.52%	6.37%
Finland	0.83%	1.83%	1.30%	1.06%	2.88%	10.79%	5.84%	4.15%
France	0.67%	1.88%	1.29%	0.99%	2.26%	10.18%	5.39%	3.65%
Greece	0.29%	0.94%	0.67%	0.50%	1.47%	7.15%	3.73%	2.49%
Ireland	0.71%	2.36%	1.57%	1.15%	2.88%	11.79%	6.44%	4.48%
Italy	0.52%	1.88%	1.19%	0.85%	1.94%	10.19%	5.15%	3.35%
Netherlands	0.82%	1.94%	1.36%	1.09%	2.22%	9.59%	5.00%	3.43%
Portugal	0.51%	0.99%	0.80%	0.67%	1.65%	7.31%	3.79%	2.58%
Spain	1.17%	2.62%	1.91%	1.55%	3.68%	13.14%	7.56%	5.45%
Sweden	0.99%	2.48%	1.72%	1.35%	3.78%	12.75%	7.28%	5.31%
Un. Kingdom	1.14%	1.94%	1.53%	1.33%	3.76%	10.36%	6.16%	4.76%

4.2 Changes in RoW's import demand

4.2.1 Specification of RoW's import demand

In the standard version of the GEM-E3 model neither production and consumption nor domestic supply in RoW are endogenous. Domestic demand for domestically produced goods which enters RoW's import demand function is given, too. Hence, no linkage to the economy's activity level is incorporated in RoW's import demand specification. Thus, in contrast to the EU import demand specification, import demand of RoW depends alone on relative prices (terms-of-trades).

The idea behind the specification presented below is to introduce an additional endogenous variable in the foreign import demand function which measures the economic performance of RoW. As in the standard version of the GEM-E3 model production of RoW is fixed, RoW's exports are used as 'activity variable' entering import demand. However, as RoW's actual exports are completely determined by import demand of EU-14, RoW's import demand is no longer influenced exclusively by EU country-specific export prices, but also by the amount of imports demanded by EU-14.

The specification represents a rough attempt to provide RoW's import demand function with more flexibility and empirical evidence as economic interactions between the two regions are now taken into account. If in reality, for instance, the economy of EU-14 expands and income rises, EU imports will rise, too, because a part of additional income will be spent for additional imports. This in turn implies a rise in exports of RoW. Up to this point, the interactions are covered by the standard model version. However, in addition to this, in reality an increase in RoW's exports would result in an increase in RoW's income, and thus in an increase in RoW's import demand as well. This feedback mechanism which is ignored in the standard model version has been included in the new specification presented in the following.

The specification of XD_{row} will be changed by relating RoW's production to RoW's exports. First of all, we assume that production in RoW X_{row} is a function of RoW's exports EX_{row}

(25) $X_{row} = \beta \cdot (EX_{row})^{\varphi}$.

φ may be interpreted as elasticity of RoW's production to RoW's exports which measures the degree of linkage between EU and foreign economy. It is assumed that the share of RoW's exports in RoW's production, θ, and thus the share of domestically-sold and domestically-produced goods in domestic production,

$(1-\theta)$, is fixed. With this assumption, substituting (25) in (18) leads to equation (26)

(26) $$IMP_{row,k} = (EX_{row})^{\varphi} \cdot \alpha_k \cdot \left(\frac{PXD_{row}}{PEX_k \cdot e_{row,k}} \right)^{\sigma^{row}} \quad \forall k, \quad k = 1, \ldots, 14,$$

where $\alpha_k = (1-\theta) \cdot \beta \cdot \delta m_{row,k} \cdot \frac{\delta x_{1,row}}{\delta x_{2,row}}$ is calibrated to the observed benchmark data.

In order to specify φ equation (26) is used as an regression equation with RoW's exports as an explanatory (exogenous) and RoW's production as a dependent (endogenous) variable. The regression coefficients β and φ are estimated by the least-squares method. The empirical data base are time-series of RoW's exports and production indices (see Table A-1 in the Appendix). A lack of data occured concerning production data of sector 1 (agriculture), sector 13 (building and construction), sector 14 (telecommunication services), sector 15 (transports), sector 16 (credit and insurance), sector 17 (other market services), and sector 18 (non market services).

The elasticity φ has been estimated for energy intensive goods industries (sector 6, 7, 8) ($\hat{\varphi} = 0.47$), equipment goods industries (sector 9, 10, 11) ($\hat{\varphi} = 0.57$) and consumer goods industries (sector 12) ($\hat{\varphi} = 0.25$). The elasticity values of the remaining sectors were calculated as a linear average over these three estimates ($\overline{\varphi} = 0.43$).

In the following, the sectoral estimates of φ are used as central values with sensitivity analysis around (Case 1, Case 2 and Case 3 in Table 9). Case 0 includes the standard version of the GEM-E3 model, in which φ is set to 0 for all sectors.

Table 9: Sectoral values of parameter φ for sensitivity analysis

Sector	**Case 0:** Standard version of GEM-E3	**Case 1:** Halved values	**Case 2:** Central values	**Case 3:** Doubled values
1 - 5, 13 - 18	0	0.22	0.43	0.86
6 - 8	0	0.24	0.47	0.94
9 - 11	0	0.29	0.57	1.14
12	0	0.13	0.25	0.50

4.2.2 Simulation results

Simulation results of the ecological tax reform scenario are reported in Table 10 for macroeconomic aggregates and in Table 11 for sectoral trade flows. Obviously, the introduction of a linkage between production and exports has just slight impacts on model results. Impacts are the greatest for Case 3 where the feedback parameter φ takes the highest values.

With respect to gross domestic product no changes can be observed. The percentage reduction rate of -0.04% stays the same in all cases. Anyhow, employment, production, private investment, private consumption, domestic demand and exports show some small changes compared to the standard case. In particular, the decreases in imports (-1.24%) and in GDP deflator in factor prices (-0.38%) are cushioned slightly in the third case. EU-wide economic welfare is not much affected by a variation of φ at all. However, economic welfare as percentage of GDP increases in Case 3 by 0.25% compared to the reference scenario. Compared to the standard version, economic welfare rises by 0.02 percentage points, or by 10% respectively.

These differences in results can be explained as follows. As explained in Section 4.1.2, the ecological tax reform brings about a rise in production costs and in consumer prices for domestically produced goods. As a result, domestic demand, and exports as well, are reduced. This reduction is, together with the decline of exports, responsible for a decrease in an overall production level in EU-14. Thus, the quantity of imports demanded, or the quantity of RoW's exports respectively, is reduced as well, as the substitution effect from domestic to foreign goods is not big enough to compensate the negative income effect. According to the new import demand specification, production in RoW decreases if RoW's exports go down, and thus RoW's imports, or EU-14 exports respectively, go down, too. In the end, aggregate exports of EU-14 are forced back stronger if RoW's import demand is modelled dependently on RoW's exports. According to Table 10, in the standard case exports fall by -1.02% only, while in Case 1 to 3 they are reduced by -1.04%, or -1.05% respectively. To summarize, in the changed model version a reduction of EU-14 imports has a negative effect on imports of RoW, assuming other things being equal. This negative effect is growing with φ, i.e. with the link between RoW's exports and imports.

However, in contrast to its impact on aggregate exports, the new specification tones down the fall of aggregate imports. While imports are reduced by -1.46% in the standard case, they show a slightly less decrease when the new specification is applied. In particular, in Case 3 imports fall by -1.24% only. As Table 11 indicates, this pattern is also evident for the development of sectoral imports, apart from few exceptions (e.g. sector coal and oil). The increase in imports (with growing values of φ) can easily be explained by the rise of the consumer price index. While the consumer price index changes by 1.19% in Case 0, it goes up to 1.22% in Case 1, to 1.27% in Case 2 and to 1.55% in Case 3. This increase is explained by the reduction in EU-14 exports due to the setting of φ. As prices of exported goods contain to a certain degree tax payments which have been paid by European producers, the lower the exports, the lower the share of tax burden that can be shifted indirectly to abroad. Consequently, if exports go down, European consumers themselves have to bear a greater part of tax burden. This is reflected in increased consumer prices. Employment rises slightly with increasing values of φ from 780.000 employed persons in Case 0 to 805.000 employed persons in Case 3. As production falls in all cases by nearly the same percentage rate, the increase in employment has to be explained mainly by a higher substitution effect from energy and energy-intensive products to labour. At the sectoral level, a greater shift in the structure of imports can be observed.

All in all, the impact of the changed import demand specification is very low. Certainly, impact will be stronger if higher values for φ are chosen. But the strength of the feedback between EU imports and RoW imports should not be overestimated. While the specification must be interpreted with reservations at all, there is in particular less evidence to support it for higher values of φ.

Table 10: EU-wide ecological tax reform
Changed import demand of RoW

(numbers indicate percent changes from baseline except if defined otherwise)

Macroeconomic aggregates for EU-14

	Case 0: Standard version of GEM-E3	Case 1: Halved values	Case 2: Central values	Case 3: Doubled values
Gross domestic product	-0.04%	-0.04%	-0.04%	-0.04%
Employment*	780	784	789	805
Production	-0.57%	-0.58%	-0.57%	-0.58%
Private investment	-0.18%	-0.17%	-0.17%	-0.15%
Private consumption	0.21%	0.21%	0.21%	0.26%
Domestic demand	-0.56%	-0.56%	-0.55%	-0.54%
Exports in volume	-1.02%	-1.04%	-1.05%	-1.05%
Imports in volume	-1.46%	-1.46%	-1.44%	-1.24%
Intra trade in the EU	-1.20%	-1.23%	-1.27%	-1.36%
Energy consumption in volume	-6.21%	-6.24%	-6.27%	-6.31%
Consumers' price index	1.19%	1.22%	1.27%	1.55%
GDP deflator in factor prices	-0.74%	-0.71%	-0.67%	-0.38%
Current account as % of GDP***	0.08	0.08	0.08	0.08
Equivalent variation of total welfare				
Economic welfare**	0.23%	0.23%	0.23%	0.25%

* in thousand employed persons
** as percent of GDP
*** absolute difference from baseline

Table 11: EU-wide ecological tax reform
Changed import demand of RoW

(numbers indicate percent changes from baseline)

	Extra-EU imports (EU-14)				Extra-EU exports (EU-14)			
	Case 0: Standard version of GEM-E3	Case 1: Halved values	Case 2: Central values	Case 3: Doubled values	Case 0: Standard version of GEM-E3	Case 1: Halved values	Case 2: Central values	Case 3: Doubled values
Agriculture	0.60%	0.62%	0.66%	0.83%	-1.09%	-1.00%	-0.90%	-0.73%
Coal	-25.86%	-25.95%	-26.05%	-26.27%	2.97%	-3.39%	-9.42%	-20.62%
Crude oil and oil products	-4.37%	-4.48%	-4.59%	-4.79%	1.52%	0.67%	-0.21%	-2.10%
Natural gas	-4.03%	-4.03%	-4.03%	-4.01%	2.45%	1.57%	0.69%	-1.12%
Electricity	-0.39%	-0.38%	-0.36%	-0.25%	-2.51%	-2.61%	-2.71%	-2.96%
Ferrous, non-ferrous ore and metals	2.53%	2.65%	2.80%	3.38%	-6.68%	-6.21%	-5.70%	-4.59%
Chemical products	1.49%	1.61%	1.76%	2.40%	-2.72%	-2.44%	-2.13%	-1.35%
Other energy intensive industries	0.79%	0.86%	0.96%	1.53%	-1.48%	-1.35%	-1.21%	-0.86%
Electrical goods	-0.72%	-0.74%	-0.74%	-0.50%	0.22%	-0.01%	-0.26%	-0.84%
Transport equipment	0.05%	0.11%	0.21%	0.88%	-0.32%	-0.34%	-0.35%	-0.10%
Other equipment goods industries	-0.47%	-0.47%	-0.43%	-0.01%	-0.01%	-0.18%	-0.36%	-0.64%
Consumer goods industries	0.77%	0.82%	0.89%	1.28%	-1.00%	-0.96%	-0.94%	-1.06%
Building and construction	-0.08%	-0.07%	-0.06%	0.04%	-0.35%	-0.40%	-0.47%	-0.79%
Telecommunication services	0.11%	0.13%	0.17%	0.47%	0.11%	0.12%	0.12%	0.07%
Transports	1.00%	1.09%	1.22%	1.88%	-2.05%	-1.90%	-1.73%	-1.32%
Credit and insurance	-0.58%	-0.57%	-0.53%	-0.11%	0.29%	0.19%	0.08%	-0.10%
Other market services	0.53%	0.59%	0.67%	1.17%	-0.47%	-0.39%	-0.30%	-0.06%
Non-market services	0.24%	0.24%	0.26%	0.38%	-0.06%	-0.01%	0.04%	0.12%
All sectors	-1.46%	-1.46%	-1.44%	-1.24%	-1.02%	-1.04%	-1.05%	-1.05%

4.3 Variation of Armington elasticity values

Armington elasticities at the lower and upper level of substitution may represent a key parameter in simulation models as, they affect substitution possibilities between imported and domestically produced goods (see de Melo and Robinson 1989, p. 57ff.). In particular, they influence the strength of terms-of-trade effects and, along with production and consumption effects, they determine the total welfare change of any policy measure (see Whalley 1985, p. 110). Thus, a critical issue in CGE modelling is the choice of elasticity values. Whereas in the GEM-E3 model share parameters are calibrated to the base year's observed data set, the values of sector- and country specific substitution elasticities have to be specified from the outside of the model. This is due to an under-identification problem of the calibration procedure as the benchmark data set alone is not enough to determine all parameter values (Fehr et al. 1995, p. 151).

Direct econometric estimates of substitution elasticities are rarely available in the literature, especially at the required sectoral aggregation level. Thus, CGE modelers often have to manage with 'best guess' or 'common values' estimates. Frequently, values are derived indirectly from estimates of import-price elasticities, for which substantial and disaggregated data exist in the empirical trade literature (see Fehr et al. 1995, p. 157, Shoven and Whalley 1984, p. 1042, Deardorff and Stern 1981, Shiells et al. 1986)[13]. Unfortunately, literature offers a wide range of substitution and import price elasticity values, due to different specifications of import demand and varying estimation methods (Kohli 1982, Thursby and Thursby 1988). As they 'all seem justificable from the empirical and theoretical point of view' (Fehr and Wiegard 1996, p. 193), sensitivity analysis on the degree of substitution is a common procedure to get insights into the robustness of results and into the model's reactions to alternative parameter values (Whalley 1985, p. 102, Shiells et al. 1986, p. 516).

Section 4.3.1 provides a short (not complete) literature survey on some recent studies on econometric estimations of Armington elasticities. In Section 4.3.2 and Section 4.3.3, sets of national- and sector-specific Armington elasticity values will be calculated. These values will be compared with the elasticity values actually used in the standard version of the GEM-E3 model. Finally, sensitivity of model results to alternative elasticity values will be tested.

[13] Still widely used is the compendium of estimates of trade elasticities, provided by Stern et al. (1976).

4.3.1 Literature survey on empirical studies

As aforementioned, despite of the popularity of the Armington concept, only few studies on direct econometric estimates of substitution elasticities have been published.

Elasticities of upper-level substitution between imported and domestic goods have been estimated, for example, by Reinert and Roland-Holst (1992), Shiells et al. (1986) and Lächler (1985). Shiells and Reinert (1993) have estimated lower-level elasticities and non-nested elasticities, as well as Sobarzo (1994), and Roland-Holst et al. (1994). Unfortunately, the estimated values from the literature are difficult to compare, as the sectoral aggregation levels differ according to the statistical data base used.

A study for Germany was conducted by Lächler (1985). Lächler estimated disaggregated elasticities of substitution between demand for imports and domestic substitutes in Germany. He found that the primary goods industry, which consists of relatively homogeneous and easily replaceable goods and which is under high pressure in terms of international competitiveness, is the one with the highest elasticity ranking: Apart from two exceptions, elasticity values range from 0.233 to 2.251. In contrast, in the case of the investment goods sector, and particularly in the case of capital goods in the short run, technological rigidities restrict the substitutability; thus, elasticity values are rather low and between the range of -2.283 to 1.209. Finally, the sectors which are classified as belonging to the consumption goods industry differ with respect to the degree of international competitive pressure, reflected by wide differences in measured substitution elasticities (-0.697 to 1.092).

Likewise, Reinert and Roland-Holst (1992) have estimated elasticities of substitution between imported and domestic goods for 163 U.S. mining and manufacturing sectors, based on U.S. trade time series data of both prices of domestic and imported goods, and real values of domestic sales of domestic goods and imports. In about two-thirds of the cases Reinert and Roland-Holst obtained positive and statistically significant estimates ranging from 0.14 to 3.49. Their results allow the conclusion that at the level of aggregation chosen imports and U.S. domestic products are far away from being perfect substitutes.

Furthermore, Shiells et al. (1986) have published estimations on disaggregated own-price elasticities of import demand for 122 3-digit SIC U.S. industries (covering mainly mining and manufacturing sectors) which serve as a basis for inferring upper-level substitution elasticities. The estimations are based on annual data for period 1962-1978. In 48 cases positive and statistically significant elasticities of substitution were obtained, ranging from 0.454 for SIC 208 (beverages) to 32.132 for SIC 373 (yachts).

Shiells and Reinert (1993) estimated both lower-level nested and non-nested elasticities of substitution among U.S. imports from Mexico, Canada, RoW, and competing domestic production, for 22 mining and manufacturing sectors, based on quarterly data for 1980-88. In the non-nested specification, U.S. imports from Mexico, Canada, and RoW as well as domestic substitutes enter a single CES function. The estimates of the non-nested elasticities of substitution range from 0.101 (sector primary lead, zink, and non-ferrous metals, n.e.c.) to 1.49 (sector primary aluminium). The nested specification is composed of an upper-level CES aggregation function for U.S. imports as a whole and a lower-level CES aggregate function for the various import sources, i.e. lower-level substitution elasticities are among U.S. imports from Mexico, Canada, and RoW. Estimates range from 0.04 (sector clay, ceramic, and non-metallic minerals) to 2.97 (sector iron, and ferroalloy ores mining).

A comparison of estimates for non-nested, lower-level and upper-level elasticities for selected sectors taken from Shiells and Reinert (1993) and Reinert and Roland-Holst (1992) show that values differ. While the non-nested estimates lie mainly above the upper-level estimates, they are in half of the cases lower and in half of the cases higher than the lower-level estimates. As already mentioned in Section 3.3, lower-level elasticities are not generally higher than upper-level elasticities, but only in about two thirds of the sectoral cases considered in the table. However, lower-level estimates show that the range of positive values (0.04 - 2.97) is larger, as in the case of the non-nested specification (0.1 - 1.49) and in the case of upper-tier estimates (0.02 - 1.22).

All in all, the sectoral values used in the GEM-E3 model are close to the typical values found in the literature. In most cases the estimates arise from U.S. data whereas for EU countries no estimates are available in the literature. Thus, in Sections 4.3.2.1 and 4.3.3.1 literature-based values are broken down to the country- and sector-specific aggregation scheme used in the GEM-E3 model. This breakdown is based on values presented in Shiells et al. (1986).

4.3.2 Variation of Armington elasticities: RoW

4.3.2.1 Specifications of Armington elasticities

Table 12 considers four variations of upper-level substitution elasticities which are used for subsequent sensitivity analyses. The first column contains the values of the standard version of the GEM-E3 model (Case 0), around which sensitivity analysis is performed. In Case 1, all sectoral elasticity values are halved from those used in the standard model. In Case 2 values are doubled. The fourth and the fifth column depict ‘best guess’ estimates (Case 3) as well as econometric estimates (Case 4), both taken from the Shiells et al. study (1986). As this study is based on the three-digit ISIC classification, the values have been aggregated according to the GEM-E3 18-sector scheme using 1988 RoW's import shares as weights. Ultimately, U.S. literature-based estimates are taken as crude proxy for the RoW's behaviour. Unfortunately, the data base, provided by Shiells et al. is not sufficient to calculate elasticity values for all sectors. As for sectors 1, 3, 4, 13 to 18 no elasticity values are available, the corresponding sectoral values from the standard specification (Case 0) are used.

Table 12: Sectoral values of upper-level Armington elasticities in RoW's import demand

	Case 0: Standard version of GEM-E3	Case 1: Halved values	Case 2: Doubled values	Case 3: U.S. 'best guess' estimates *	Case 4: U.S. econometric estimates **
1 **Agriculture**	1.40	0.70	2.80	1.40	1.40
2 **Coal**	0.60	0.30	1.20	2.36	7.12
3 **Crude oil and oil products**	0.60	0.30	1.20	2.36	-0.34
4 **Natural gas**	0.60	0.30	1.20	0.60	0.60
5 **Electricity**	0.60	0.30	1.20	0.60	0.60
6 **Ferrous, non-ferrous ore and metals**	2.20	1.10	4.40	1.44	2.44
7 **Chemical products**	2.20	1.10	4.40	2.61	9.40
8 **Other energy intensive industries**	2.20	1.10	4.40	2.91	1.78
9 **Electrical goods**	2.20	1.10	4.40	2.11	7.46
10 **Transport equipment**	2.20	1.10	4.40	3.59	2.01
11 **Other equipment goods industries**	2.20	1.10	4.40	1.07	3.20
12 **Consumer goods industries**	2.50	1.25	5.00	2.07	2.65
13 **Building and construction**	1.40	0.70	2.80	1.40	1.40
14 **Telecommunication services**	1.40	0.70	2.80	1.40	1.40
15 **Transports**	2.20	1.10	4.40	2.20	2.20
16 **Credit and insurance**	1.40	0.70	2.80	1.40	1.40
17 **Other market services**	1.40	0.70	2.80	1.40	1.40
18 **Non-market services**	0.60	0.30	1.20	0.60	0.60

*Based upon 'best guess' U.S. estimates constructed by Shiells et al. (1986), weighted by 1988 import shares of RoW.
** Based upon U.S. econometric estimates of sector-specific substitution elasticities provided by Shiells et al. (1986), weighted by 1988 import shares of RoW.

4.3.2.2 Simulation results

In Table 13, simulation results of the ecological tax reform scenario in terms of macroeconomic aggregates are listed for the various cases defined in Table 12. Table 14 depicts results in terms of sectoral imports and exports.

The variations in elasticity values have some impact on results, but, all in all, the percentage change of quantities, related to the standard case, lies within a range of ±0.5 percentage points. The sensitivity of economic welfare to alternative parameter values is not very high as well. Obviously, the EU gains the more from the ecological tax reform policy in terms of economic welfare the less the

Armington elasticity values in foreign import demand are, i.e. the less the foreign sector reacts to increasing production prices in the EU economy.

In the following, the basic mechanisms that are triggered by a variation in the degree of substitution in RoW's import demand are discussed.

In Case 1, where values of the sectoral upper-level Armington elasticities are halved, RoW shows less strong reactions to an increase in EU export prices. While in the standard case exports fall down by -1.02%, they are reduced only by -0.92% in the case of halved elasticity values. This reflects the lower degree of substitutability between domestic and foreign production in RoW's import demand. However, at a sectoral level exports develop in different ways (Table 14). Whereas for some sectors exports are less reduced compared to the standard case, for some other branches (e.g. electrical goods, equipment and consumer goods industries, transports and both service sectors) they show a higher reduction rate, or less growth rates, respectively (fossil fuel sectors). The increase in world demand for EU exports in Case 1 compared to Case 0 is the main reason for a comparatively lower drop in GDP deflator. Prices for domestic production and consumption are higher in Case 1 than in the standard case as domestic and foreign demand are higher as well. The slowing down of the price decrease in EU-14 in Case 1 results in turn in a relatively higher import demand. As exports, investment and consumption settle down (all at a higher level in Case 1 than in Case 0), production and gross domestic product are higher as well (-0.56% reduction of production in Case 1 instead of -0.57% in Case 0, -0.03% reduction of gross domestic product instead of -0.04%). Thus, energy consumption decreases also by a lower rate (-6.18% compared to -6.21%) and employment rises EU-wide by additional 25.000 persons.

Table 13: EU-wide ecological tax reform
Variation of upper-level Armington elasticities in RoW's import demand

(numbers indicate percent changes from baseline except if defined otherwise)

Macroeconomic aggregates for EU-14

	Case 0: Standard version of GEM-E3	Case 1: Halved values	Case 2: Doubled values	Case 3: U.S. 'best guess' estimates	Case 4: U.S. econometric estimates
Gross domestic product	-0.04%	-0.03%	-0.05%	-0.04%	-0.04%
Employment*	780	805	757	769	793
Production	-0.57%	-0.56%	-0.59%	-0.57%	-0.58%
Private investment	-0.18%	-0.15%	-0.20%	-0.18%	-0.19%
Private consumption	0.21%	0.29%	0.15%	0.22%	0.16%
Domestic demand	-0.56%	-0.52%	-0.58%	-0.55%	-0.58%
Exports in volume	-1.02%	-0.92%	-1.08%	-0.98%	-1.12%
Imports in volume	-1.46%	-0.99%	-1.73%	-1.33%	-1.80%
Intra trade in the EU	-1.20%	-1.26%	-1.17%	-1.20%	-1.21%
Energy consumption in volume	-6.21%	-6.18%	-6.23%	-6.21%	-6.26%
Consumers' price index	1.19%	1.65%	0.93%	1.27%	0.95%
GDP deflator in factor prices	-0.74%	-0.27%	-0.98%	-0.63%	-1.01%
Current account as % of GDP***	0.08	0.09	0.08	0.09	0.06
Equivalent variation of total welfare					
Economic welfare**	0.23%	0.27%	0.20%	0.24%	0.19%

* in thousand employed persons

** as percent of GDP

*** absolute difference from baseline

The mechanisms change direction if doubled upper-level elasticity values are introduced (Case 2). The RoW's reactions to an increase in relative prices are now stronger than in the standard case. Consequently, EU exports go down more heavily (by -1.08%). Due to diminished foreign demand, EU prices, expressed by the GDP deflator, go down to a greater extent and imports are reduced more heavily. Overall, gross domestic product and production decrease more.

While, the results in Case 3 lie like Case 0 somewhere between the two extremes, the halved and the doubled-value case, Case 4 causes stronger impacts on exports and imports. The latter is characterised by very high elasticity values for some sectors, e.g. the coal sector, chemical and electrical goods industry. All in all, aggregated exports of the EU drops by the highest percentage rate in this case, compared to all other cases. The relatively high reduction of aggregate demand expressed by a smaller increase in consumption and a greater decrease in investment and exports results in a higher percentage reduction of the GDP deflator. This, in turn, leads to a higher drop in imports.

Table 14: EU-wide ecological tax reform
Variation of upper-level Armington elasticities in RoW's import demand

(numbers indicate percent changes from baseline)

	Extra-EU imports (EU-14)					**Extra-EU exports (EU-14)**				
	Case 0: Standard version of GEM-E3	**Case 1:** Halved values	**Case 2:** Doubled values	**Case 3:** U.S. 'best guess' estimates	**Case 4:** U.S. econometric estimates	**Case 0:** Standard version of GEM-E3	**Case 1:** Halved values	**Case 2:** Doubled values	**Case 3:** U.S. 'best guess' estimates	**Case 4:** U.S. econometric estimates
Agriculture	0.60%	0.91%	0.41%	0.64%	0.51%	-1.09%	-0.77%	-1.61%	-1.15%	-0.92%
Coal	-25.86%	-25.99%	-25.74%	-25.68%	-25.94%	2.97%	1.38%	6.17%	11.17%	38.45%
Crude oil and oil products	-4.37%	-4.34%	-4.33%	-4.20%	-4.75%	1.52%	0.81%	2.52%	3.24%	-1.47%
Natural gas	-4.03%	-3.96%	-4.08%	-3.99%	-4.17%	2.45%	1.11%	5.17%	2.33%	2.76%
Electricity	-0.39%	-0.19%	-0.55%	-0.37%	-0.50%	-2.51%	-1.46%	-4.30%	-2.52%	-2.41%
Ferrous, non-ferrous ore and metals	2.53%	3.63%	1.39%	2.93%	2.27%	-6.68%	-3.96%	-11.18%	-4.60%	-6.99%
Chemical products	1.49%	2.46%	0.70%	1.48%	0.00%	-2.72%	-1.86%	-3.98%	-3.33%	-6.35%
Other energy intensive industries	0.79%	1.69%	0.24%	0.85%	0.42%	-1.48%	-1.23%	-1.74%	-2.08%	-0.87%
Electrical goods	-0.72%	-0.26%	-0.86%	-0.64%	-0.76%	0.22%	-0.26%	1.13%	0.09%	1.58%
Transport equipment	0.05%	1.00%	-0.41%	0.11%	-0.31%	-0.32%	-0.63%	0.36%	-0.69%	0.08%
Other equipment goods industries	-0.47%	0.24%	-0.75%	-0.34%	-0.75%	-0.01%	-0.43%	0.81%	-0.08%	0.51%
Consumer goods industries	0.77%	1.45%	0.38%	0.89%	0.47%	-1.00%	-0.95%	-0.96%	-0.94%	-0.61%
Building and construction	-0.08%	0.08%	-0.17%	-0.04%	-0.18%	-0.35%	-0.49%	0.04%	-0.47%	-0.02%
Telecommunication services	0.11%	0.62%	-0.16%	0.24%	-0.22%	0.11%	-0.28%	0.95%	-0.10%	0.60%
Transports	1.00%	2.06%	0.24%	1.18%	0.56%	-2.05%	-1.56%	-2.72%	-2.27%	-1.51%
Credit and insurance	-0.58%	0.13%	-0.91%	-0.35%	-1.14%	0.29%	-0.17%	1.20%	-0.06%	0.98%
Other market services	0.53%	1.30%	0.11%	0.64%	0.17%	-0.47%	-0.60%	-0.13%	-0.60%	-0.08%
Non-market services	0.24%	0.48%	0.11%	0.33%	0.05%	-0.06%	-0.17%	0.20%	-0.21%	0.23%
All sectors	-1.46%	-0.99%	-1.73%	-1.33%	-1.80%	-1.02%	-0.92%	-1.08%	-0.98%	-1.12%

4.3.3 Variation of Armington elasticities: EU countries

4.3.3.1 Specifications of Armington elasticities

No econometric estimates of sector- and country-specific substitution elasticities for EU countries are available in the literature. Thus, in this section the required set of Armington elasticities for the 14 EU countries is generated following a procedure proposed by Harrison et al. (1991, p. 100). The procedure takes place in three steps:

1. Starting point are sector-specific 'best guess' upper-level Armington elasticities for the U.S. presented in Shiells et al. (1986). Using country-specific import weights (drawn from 1993 data[14]) for each country an *average Armington elasticity of substitution* σ_x^{av} is calculated. The country-specific import weighted elasticities σ_x^{av} are reported in Table 16.

2. The country-specific elasticities σ_x^{av} are then compared with country-specific Armington elasticities ($\sigma_x^{\inf}$) that are inferred from country-specific import price elasticities (ε) and from import shares. Whereas the national import price elasticities are taken from the empirical trade literature (Stern

[14] United Nations (1993).

et al. 1976), the import shares are calculated from the equilibrium benchmark data set.

3. Finally, we re-scale for each country the sector-specific elasticities so that the aggregated, import-weighted elasticity σ_x^{av} is equal to the country-specific elasticity $\sigma_x^{\inf}$ which is derived from the national import price elasticity. The results of the sectorally and nationally disaggregated substitution elasticities are reported in Table 17.

While step 1 and step 3 are more or less self-evident, some comments should be made on the derivation of the national Armington elasticities from literature-based import price elasticities (step 2).

Obviously, the procedure proposed is faced with some problems which arise from the existence of non-tradable sectors and non-competitive imports. Both import demand of non-traded and non-competitive commodities are excluded from the Armington assumption. It is assumed that they are determined not by price relations but by the domestic production level and institutional settings, such as supply contracts. As national import price elasticities, taken from the literature, normally refer to the national aggregate of import demand (aggregating all sectors), they may provide a distorted picture of Armington elasticities. However, this problem is less important here. Fortunately, in the GEM-E3 model the national shares of imports of non-tradable goods in total imports are low and by a majority below 5% (see Table 15). Thus, the literature-based import price elasticity values are reasonable approximates for the price elasticity of import demand of tradable goods in the GEM-E3 model.

Table 15: Import shares of non-tradable commodities in the GEM-E3 model

	Share of imports of non-tradeables goods in all imports (base year)
Austria	4.14%
Belgium	4.02%
Germany	5.70%
Denmark	3.48%
Finland	10.34%
France	5.36%
Greece	0.44%
Ireland	2.29%
Italy	4.87%
Netherlands	1.90%
Portugal	0.41%
Spain	2.92%
Sweden	1.00%
Un. Kingdom	3.26%

More importance should be attached to the problem arising from non-competitive imports. Given the same import price elasticity value, the share of non-competitive imports assumed influences the inferred Armington elasticity values $\sigma_x^{\inf}$ decisively. This can be demonstrated by using equation (27) and equation (28) alternatively for the derivation of the Armington elasticities. As can be shown easily, in the GEM-E3 model the price elasticity of the aggregate import demand ε in terms of upper-level Armington elasticity σ_x and empirically measurable parameters (import shares) is given by

(27) $$\varepsilon^c = \sigma_x \cdot (\omega - 1),$$

when all imports are competitive, and by

(28) $$\varepsilon^{nc} = \sigma_x \cdot \left[\frac{IMC}{IM} \cdot (\omega - 1) + \frac{IMNC}{IM} \cdot \left(\omega - \omega^{nc}\right) \right],$$

when non-competitive imports exist[15]. IM are total imports of tradable goods. IMC represent the competitive and $IMNC$ the non-competitive part. ω denotes

[15] The own-price elasticity of the import aggregate demand is defined as $\varepsilon = (\partial IM/\partial PIM) * (PIM/IM)$, whereas domestic supply Y is kept constant. If all imports of tradable goods are competitive (i.e. $IM=IMC$) the import price elasticity ε^c is derived from equation (12) which expresses the upper-level import demand for tradable goods. If a positive share of total imports of tradable goods is non-competitive (i.e. $IM=IMC+IMNC$) the derivation of ε^{nc} must

the share of expenditure on imports in expenditure on domestically supplied goods and ω^{nc} denotes the ratio of expenditure on non-competitive imports to expenditure on domestically produced and demanded goods, i.e.

$$\omega = \frac{PIM \cdot IM}{PY \cdot Y} \quad \text{and} \quad \omega^{nc} = \frac{PIM \cdot IMNC}{PXD \cdot XD}.$$

If $IMC = IM$ and $IMNC = 0$, then equation (28) is the same as equation (27).

As Table 16 shows, a variation of the share of non-competitive imports in total imports of tradable goods leads to different values of Armington elasticities. In summary, one can say that the higher the share of non-competitive imports, the higher the Armington elasticity which corresponds to a given import price elasticity. In the GEM-E3 model the shares of non-competitive imports are set equal to 0.5 for all countries and all sectors. Thus, the country-specific upper-level Armington elasticities $\sigma_x^{\inf}$ depicted in the fourth column of Table 16 are applied. Keeping in mind that values of own import price elasticities vary widely between alternative import demand specifications (see Kohli 1982), the Armington elasticities derived from the import price elasticities must be interpreted as crude approximations. However, Whalley (1985, p. 103) states that import price elasticity values in the neighbourhood of unity still reflect the current consensus on import price elasticities.

Finally, re-scaling the average Armington elasticity values σ_x^{av} according to step 3 leads to the final values which are reported in Table 17.

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consider that the specification of non-competitive imports in the GEM-E3 model includes two further equations: $PXD=PX+RTNC*PIM$ and $IMNC=XD*RTNC$, where $RTNC$ is calibrated. Thus, the price for domestically produced and demanded goods, PXD, entering the unit cost function of domestic supply (equation (11)), is no longer independent from PIM.

Table 16: Country-specific price and substitution elasticities of import demand for different shares of non-competitive imports

	ε *	σ_x^{av} **	σ_x^{inf} ***		
			(IMNC/IM=0)	*(IMNC/IM=0.5)*	*(IMNC/IM=0.8)*
Austria	-1.32	2.13	1.88	4.57	10.48
Belgium	-0.83	2.13	1.67	5.03	6.53
Germany	-0.88	2.12	1.09	2.90	6.09
Denmark	-1.05	1.99	1.53	2.61	-10.31
Finland	-0.50	2.37	0.62	2.97	3.46
France	-1.08	1.63	1.31	2.36	7.31
Greece	-1.03	2.15	1.04	2.10	5.24
Ireland	-1.37	1.95	1.62	2.65	8.94
Italy	-1.03	2.01	1.77	6.39	8.57
Netherlands	-0.68	2.03	1.20	3.32	5.63
Portugal	-1.03	1.92	1.33	3.05	7.52
Spain	-1.03	2.03	1.21	2.63	6.68
Sweden	-0.79	2.06	0.80	1.38	1.99
Un. Kingdom	-0.65	1.93	0.66	1.17	1.83

* 'Best guess' estimates of uncompensated import price elasticities suggested by Stern et al. (1976, p. 20), constructed as point estimates for several countries according to the three-digit International Standard Industrial Classification (ISIC). As for Greece, Spain and Portugal no data were available, we used Italian data.
** Based on Shiells et al. (1986).
*** Elasticities are inferred from equation (27) for *IMNC/IM=0* and from equation (28) for *IMNC/IM*>0. Import shares ω and ω^{nc} are based on observed data of the benchmark equilibrium.

Table 17: Sector- and country-specific upper-level Armington elasticities for EU-14

	Sector	Austria	Belgium	Germany	Denmark	Finland	France	Greece	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	Un. Kingdom
3	Crude oil and oil products	5.1	5.6	3.2	3.1	3.0	3.4	2.3	3.2	7.5	3.9	3.8	3.1	1.6	1.4
6	Ferrous, non-ferrous ore and metals	3.1	3.4	2.0	1.9	1.8	2.1	1.4	2.0	4.6	2.4	2.3	1.9	1.0	0.9
7	Chemical products	5.6	6.2	3.6	3.4	3.3	3.8	2.5	3.5	8.3	4.3	4.2	3.4	1.7	1.6
8	Other energy intensive industries	6.2	6.5	3.7	3.3	3.5	3.8	2.4	3.5	8.3	4.2	3.8	3.4	1.9	1.5
9	Electrical goods	4.5	5.0	2.9	2.8	2.6	3.1	2.1	2.9	6.7	3.5	3.4	2.7	1.4	1.3
10	Transport equipment	7.7	8.5	4.9	4.7	4.5	5.2	3.5	4.9	11.4	5.9	5.7	4.6	2.4	2.2
11	Other equipment goods industries	2.3	2.5	1.4	1.4	1.6	1.5	1.0	1.4	3.4	1.7	1.7	1.4	0.7	0.6
12	Consumer goods industries	5.2	4.9	3.2	2.6	2.7	2.0	1.9	2.8	5.9	3.4	2.5	2.5	1.5	1.2

Table 18 reports the values of the upper-level Armington elasticity for which sensitivity analysis is performed. As in the previous section, the case of doubled and halved elasticity values are tested. Additionally, the calculated sector- and country-specific values from Table 17 are applied.

Table 18: Sectoral values of upper-level Armington elasticities in RoW's import demand

	Case 0:	Case 1:	Case 2:	Case 3:
	Standard version of GEM-E3	Halved values	Doubled values	U.S. 'best guess' estimates
Agriculture	1.2	0.60	2.40	
Crude oil and oil products	0.6	0.30	1.20	Country- and sector-
Ferrous, non-ferrous ore and metals	1.5	0.75	3.00	specific values
Chemical products	1.5	0.75	3.00	
Other energy intensive industries	1.5	0.75	3.00	(for sectors 3, 7- 10:
Electrical goods	1.5	0.75	3.00	values as calculated from
Transport equipment	1.5	0.75	3.00	'best guess' estimates
Other equipment goods industries	1.5	0.75	3.00	presented in Shiells et al. (1986)
Consumer goods industries	1.7	0.85	3.40	for sectors 1, 6, 11-17:
Telecommunication services	0.6	0.30	1.20	values as in standard version)
Transports	1.2	0.60	2.40	
Credit and insurance	0.6	0.30	1.20	
Other market services	0.6	0.30	1.20	

4.3.3.2 Simulation results

As Table 19 indicates, the four cases of parameter choice differ only slightly with respect to macroeconomic impacts. Differences arise mainly in trade flows and price indices. All other macroeconomic variables show only marginal changes. As consumption and employment, or leisure respectively, remain nearly constant, economic welfare also varies scarcely. Sectoral trade flows between EU-14 and RoW are given in Table 20.

The interpretation of results starts with examining the pure effects of a variation of Armington elasticities.

In Case 1, Armington elasticity values in the aggregate import demand of all EU countries are halved, i.e. substitution possibilities between domestic production and imports are more restricted for all EU countries. For instance, in Case 1 a policy-induced price increase in European domestic supply will induce a lower substitution effect than in the standard version, i.e. import demand for tradable goods will be expanded to a lower extent than in the standard case. This, however, implies that in Case 1 (relatively expensive) domestic production has a relatively bigger share in overall EU domestic supply. The pure substitution effect leads, in Case 1, to relatively higher prices. The latter is expressed by a decrease of the GDP deflator by -0.72% (compared to -0.74% in Case 0).

In Case 2, we have to argue the other way round. Doubling the Armington elasticities increases the substitution effect, i.e. a shift in the price relation of domestic supply and imports results in a comparatively higher demand for imports. Now, domestic production constitutes a lower part in domestic supply compared with both Case 0 and Case 1. This, in turn, results in a decrease in domestic prices. To conclude, the price level is at its highest in Case 1 and at its lowest in Case 2. Case 0 lies in between.

Let us recall the main mechanisms running in the standard version which have already been described in Section 4.1.1. In the standard model, the ecological tax reform policy results in a decrease in exports and imports and in a drop in the GDP deflator (resulting from a decrease in aggregate demand).

As just mentioned, in the case of halved Armington elasticity values (Case 1) the drop in the GDP deflator is less significant, i.e. prices are higher. This exactly reflects the cost effects of a lower degree of substitution of European producers and consumers. Due to comparably higher prices, EU exports are reduced to a greater extent. Whereas exports fall by -1.02% in the standard version, they fall by -1.05% in Case 1. The greater percentage reduction of imports can be explained by reduced substitution possibilities in Case 1, i.e. import demand increases less in response to an increase in domestic production prices.

In the case of doubled Armington elasticities (Case 2) domestic prices are lower. Thus, exports are reduced to a lower extent (by -0.97% compared to -1.02% in Case 0). Imports decrease to a lower extent as well (by -1.42% compared to -1.46% in Case 0) due to the higher substitution possibilities given by doubled elasticity values.

A variation of Armington elasticities according to the calculated set of country- and sector-specific parameter values given in Table 17 (Case 3) show that impacts lie between those of Case 1 and Case 2. Table A-2 and Table A-3 in the Appendix depict the impacts of the ecological tax reform at a national level for the standard case and for Case 3. Obviously, mostly affected in terms of economic welfare are Belgium, Ireland and the United Kingdom.

Table 19: EU-wide ecological tax reform
Variation of upper-level Armington elasticities in import demand of EU countries

(numbers indicate percent changes from baseline except if defined otherwise)

Macroeconomic aggregates for EU-14

	Case 0: Standard version of GEM-E3	**Case 1:** Halved values	**Case 2:** Doubled values	**Case 3:** U.S. 'best guess' estimates
Gross domestic product	-0.04%	-0.04%	-0.04%	-0.04%
Employment*	780	784	774	775
Production	-0.57%	-0.57%	-0.58%	-0.58%
Private investment	-0.18%	-0.17%	-0.18%	-0.18%
Private consumption	0.21%	0.21%	0.20%	0.20%
Domestic demand	-0.56%	-0.55%	-0.56%	-0.56%
Exports in volume	-1.02%	-1.05%	-0.97%	-1.02%
Imports in volume	-1.46%	-1.48%	-1.42%	-1.45%
Intra trade in the EU	-1.20%	-1.25%	-1.11%	-1.14%
Energy consumption in volume	-6.21%	-6.21%	-6.22%	-6.25%
Consumers' price index	1.19%	1.21%	1.16%	1.18%
GDP deflator in factor prices	-0.74%	-0.72%	-0.77%	-0.73%
Current account as % of GDP***	0.08	0.08	0.08	0.08
Equivalent variation of total welfare				
Economic welfare**	0.23%	0.23%	0.22%	0.23%

* in thousand employed persons
** as percent of GDP
*** absolute difference from baseline

Table 20: EU-wide ecological tax reform
Variation of upper-level Armington elasticities in import demand of EU countries

(numbers indicate percent changes from baseline)

	Extra-EU imports (EU-14)				Extra-EU exports (EU-14)			
	Case 0: Standard version of GEM-E3	**Case 1:** Halved values	**Case 2:** Doubled values	**Case 3:** U.S. 'best guess' estimates	**Case 0:** Standard version of GEM-E3	**Case 1:** Halved values	**Case 2:** Doubled values	**Case 3:** U.S. 'best guess' estimates
Agriculture	0.60%	0.50%	0.76%	0.58%	-1.09%	-1.13%	-1.01%	-1.07%
Coal	-25.86%	-25.89%	-25.81%	-25.83%	2.97%	2.96%	3.00%	2.97%
Crude oil and oil products	-4.37%	-4.33%	-4.45%	-4.43%	1.52%	1.59%	1.39%	1.31%
Natural gas	-4.03%	-4.03%	-4.03%	-4.04%	2.45%	2.44%	2.46%	2.47%
Electricity	-0.39%	-0.38%	-0.41%	-0.41%	-2.51%	-2.52%	-2.48%	-2.48%
Ferrous, non-ferrous ore and metals	2.53%	2.30%	2.99%	2.84%	-6.68%	-6.75%	-6.57%	-6.64%
Chemical products	1.49%	1.43%	1.61%	1.67%	-2.72%	-2.76%	-2.65%	-2.69%
Other energy intensive industries	0.79%	0.77%	0.82%	0.82%	-1.48%	-1.52%	-1.40%	-1.45%
Electrical goods	-0.72%	-0.70%	-0.77%	-0.77%	0.22%	0.19%	0.28%	0.23%
Transport equipment	0.05%	0.08%	0.01%	-0.02%	-0.32%	-0.36%	-0.24%	-0.29%
Other equipment goods industries	-0.47%	-0.44%	-0.53%	-0.51%	-0.01%	-0.06%	0.06%	0.01%
Consumer goods industries	0.77%	0.72%	0.85%	0.78%	-1.00%	-1.04%	-0.92%	-0.97%
Building and construction	-0.08%	-0.08%	-0.09%	-0.08%	-0.35%	-0.39%	-0.29%	-0.33%
Telecommunication services	0.11%	0.13%	0.08%	0.12%	0.11%	0.07%	0.18%	0.08%
Transports	1.00%	0.88%	1.23%	1.02%	-2.05%	-2.07%	-2.01%	-2.07%
Credit and insurance	-0.58%	-0.58%	-0.58%	-0.54%	0.29%	0.25%	0.36%	0.19%
Other market services	0.53%	0.55%	0.50%	0.51%	-0.47%	-0.49%	-0.42%	-0.46%
Non-market services	0.24%	0.26%	0.22%	0.26%	-0.06%	-0.08%	-0.03%	-0.10%
All sectors	-1.46%	-1.48%	-1.42%	-1.45%	-1.02%	-1.05%	-0.97%	-1.02%

5 Conclusion

In this paper, several world closure systems proposed in the literature have been analysed and evaluated with regard to their appropriateness for application in general equilibrium models. The specification of the world closure, i.e. the way of closing the domestic economy model by incorporating the external sector, is a crucial component for those models, in which production and consumption is not specified endogenously for all countries. Here, reasonable assumptions concerning the behaviour of the RoW have to be made, often in combination with a balance-of-payments constraint.

The closure rule incorporated in the GEM-E3 model is advantageous in empirical application as it, among other things, avoids complete specialisation in production, allows for modelling of intra-industrial trade and includes non-traded and traded goods. In particular, intra-EU trade activities that account for around 60% of the whole EU trade are modelled realistically as they depend on an endogenous international price system. But even if the GEM-E3 model takes a mainly European perspective, the specification of the foreign sector has a great deal of influence. Relaxing the assumption of fixed prices for exports of the RoW facing the EU as a whole seems to be important. Furthermore, a better link between both economies, the EU economy and the economy of the RoW, should be considered.

In this work, two main changes in the foreign trade specification have been proposed and tested. The basis is a simulation of an EU-wide ecological tax reform. The first change refers to the RoW's export supply function in which a constant finite price elasticity has been introduced. The second change concerns the RoW's import demand function in which a RoW's activity variable was incorporated. In summary, the impact in terms of economic welfare and changes in macroeconomic variables is noteworthy for the former case while no substantial changes could be observed for the latter case.

Additionally, the sensitivity of the GEM-E3 model to variations in key parameter values such as the upper-level Armington elasticity has been analysed. Results indicate that the model can be interpreted as quite robust to parameter changes. Thus, exact econometric estimations of upper-level Armington elasticities are undoubtedly an important issue, but should not be a priority for further research.

To conclude, a comprehensive solution to the problems outlined above will be best tackled by extending the regional scope of the GEM-E3 model towards a global model with an endogenous representation of the behaviour of agents of the RoW. Thus, future research on the GEM-E3 model will concentrate on a better understanding of production and consumption activities in the RoW as a whole and on a further disaggregation in several major trading blocks.

Appendix

Table A-1: Time series of RoW's exports (in Million ECU) and RoW's production indices

Sector in GEM-E3	RoW	1981	1982	1983	1984	1985	1986	1987	1988
2	exports *	3868.08	4495.84	3780.43	5026.61	6832.42	4966.65	3488.00	3583.98
	production index **	102.23	104.32	105.03	115.41	121.44	123.55	125.87	124.65
3	exports	93306.74	98029.52	92467.82	100092.51	113494.63	52879.79	48242.00	37288.92
	production index	93.76	82.27	78.53	81.13	78.50	79.03	80.31	86.13
4	exports	3803.35	5628.27	6182.69	8946.74	10366.69	5284.65	3822.00	3418.23
	production index	102.25	103.88	109.60	116.53	120.40	121.03	126.45	134.88
5	exports	560.01	676.99	766.47	735.16	690.89	689.72	622.00	576.81
	production index	102.25	103.88	109.60	116.53	120.40	121.03	126.45	134.88
6, 7, 8	exports	44220.12	49732.27	55368.53	68174.47	71924.02	67330.66	62690.00	72657.05
	production index	101.08	95.57	101.45	110.72	113.05	115.86	123.30	132.54
9, 10, 11	exports	46253.22	52220.73	61945.58	76218.53	83647.36	84721.98	85592.00	100963.29
	production index	104.43	101.45	107.21	125.61	131.89	135.51	142.86	159.18
12	exports	78223.76	87558.70	96681.84	113522.75	120066.87	111887.58	108606.00	114056.56
	production index	102.18	100.52	106.23	110.17	97.40	115.48	120.61	123.74

* Disaggregated extra-EU imports for 1981-1988 were taken from the OECD Statistic 'External Trade'. These values were set equal to exports of RoW to the EU. RoW's exports were deflated to base year 1987. The values of RoW's exports were deflated using a merchandise export price index (1987=100) created from World Bank data (World Data 1995, World Bank Indicators on CD-ROM).
** Production indices (1980=100). Unfortunately, data of RoW's production in absolute terms are not available on the necessary disaggregation level. Thus, we calculated the weighted sum of the index numbers of industrial production for three main RoW-regions, EFTA, ASIA and North America, with the share of these regions in total industrial production (taken from Industrial Statistics Yearbook 1991). Also, the shares of the three RoW-regions in total production were calculated on the basis of World Bank data.

Table A-2: EU-wide ecological tax reform
Standard version of the GEM-E3 model

(numbers indicate percent changes from baseline except if defined otherwise)

Macroeconomic aggregates for EU-14

	Austria	Belgium	Germany	Denmark	Finland	France	Greece
Gross domestic product	-0.23%	-0.25%	-0.07%	-0.09%	-0.01%	-0.01%	-0.28%
Employment*	12	25	131	10	7	92	20
Private investment	-0.15%	-0.14%	-0.14%	-0.17%	-0.13%	-0.17%	-0.47%
Private consumption	0.46%	0.63%	0.29%	0.45%	0.33%	0.13%	-0.27%
Domestic demand	-0.53%	-0.80%	-0.60%	-0.43%	-0.41%	-0.44%	-0.93%
Exports in volume	-1.35%	-1.57%	-1.14%	-1.56%	-1.27%	-0.96%	-1.36%
Imports in volume	-1.08%	-1.41%	-1.09%	-1.34%	-0.86%	-1.27%	-1.84%
Energy consumption in volume	-5.73%	-6.69%	-6.55%	-7.35%	-6.19%	-5.26%	-7.37%
Consumers' price index	1.12%	1.30%	1.19%	2.11%	1.41%	0.99%	0.94%
GDP deflator in factor prices	-0.18%	-0.39%	-0.71%	-0.06%	-0.03%	-0.60%	-0.85%
Current account as % of GDP***	0.04	0.38	0.06	0.11	-0.03	0.15	0.34
Equivalent variation of total welfare							
Economic welfare**	0.35%	0.41%	0.34%	0.46%	0.23%	0.26%	-0.22%

	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	Un. Kingdom
Gross domestic product	-0.40%	0.03%	0.08%	0.08%	0.01%	-0.13%	-0.02%
Employment*	3	171	29	28	104	9	139
Private investment	-0.36%	-0.16%	-0.09%	-0.44%	-0.29%	-0.14%	-0.22%
Private consumption	0.36%	-0.10%	0.24%	-0.14%	0.25%	0.57%	0.27%
Domestic demand	-0.53%	-0.55%	-0.19%	-0.52%	-0.65%	-0.29%	-0.71%
Exports in volume	-1.44%	-0.56%	-0.39%	0.09%	-1.29%	-1.48%	-0.94%
Imports in volume	-1.13%	-1.72%	-0.62%	-0.85%	-1.78%	-1.08%	-0.89%
Energy consumption in volume	-6.49%	-5.92%	-3.55%	-5.39%	-6.00%	-5.21%	-7.49%
Consumers' price index	1.52%	0.74%	0.51%	0.49%	1.27%	1.96%	1.73%
GDP deflator in factor prices	-0.10%	-0.91%	-0.89%	-1.13%	-0.82%	0.35%	-1.11%
Current account as % of GDP***	0.13	0.26	0.01	0.31	0.21	0.07	-0.13
Equivalent variation of total welfare							
Economic welfare**	0.35%	-0.08%	0.13%	-0.18%	0.17%	0.47%	0.27%

* in thousand employed persons
** as percent of GDP
*** absolute difference from baseline

Table A-3: EU-wide ecological tax reform
'Best guess' Armington elasticity values in import demand of EU countries

(numbers indicate percent changes from baseline except if defined otherwise)

Macroeconomic aggregates for EU-14

	Austria	Belgium	Germany	Denmark	Finland	France	Greece
Gross domestic product	-0.22%	-0.29%	-0.07%	-0.09%	-0.01%	-0.03%	-0.28%
Employment*	12	24	130	10	7	91	20
Private investment	-0.16%	-0.16%	-0.14%	-0.17%	-0.13%	-0.17%	-0.47%
Private consumption	0.41%	0.57%	0.28%	0.43%	0.32%	0.11%	-0.27%
Domestic demand	-0.55%	-0.86%	-0.61%	-0.43%	-0.42%	-0.45%	-0.92%
Exports in volume	-1.15%	-1.46%	-1.06%	-1.54%	-1.20%	-0.90%	-1.30%
Imports in volume	-0.98%	-1.34%	-1.03%	-1.34%	-0.82%	-1.22%	-1.79%
Energy consumption in volume	-5.67%	-6.93%	-6.62%	-7.15%	-6.17%	-5.47%	-7.36%
Consumers' price index	1.04%	1.24%	1.15%	2.10%	1.38%	0.96%	0.92%
GDP deflator in factor prices	-0.31%	-0.45%	-0.75%	-0.09%	-0.06%	-0.62%	-0.86%
Current account as % of GDP***	0.05	0.37	0.06	0.12	-0.04	0.14	0.34
Equivalent variation of total welfare							
Economic welfare**	0.33%	0.38%	0.33%	0.45%	0.23%	0.25%	-0.22%

	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	Un. Kingdom
Gross domestic product	-0.47%	0.04%	0.07%	0.09%	0.01%	-0.13%	-0.02%
Employment*	3	171	30	28	104	9	137
Private investment	-0.40%	-0.17%	-0.08%	-0.41%	-0.29%	-0.14%	-0.21%
Private consumption	0.22%	-0.10%	0.25%	-0.12%	0.24%	0.55%	0.32%
Domestic demand	-0.60%	-0.55%	-0.19%	-0.50%	-0.65%	-0.29%	-0.69%
Exports in volume	-1.34%	-0.51%	-0.41%	-0.03%	-1.23%	-1.48%	-1.14%
Imports in volume	-1.13%	-1.69%	-0.62%	-0.91%	-1.73%	-1.10%	-0.98%
Energy consumption in volume	-6.74%	-5.83%	-3.66%	-5.28%	-6.00%	-5.25%	-7.44%
Consumers' price index	1.44%	0.72%	0.53%	0.55%	1.24%	1.95%	1.84%
GDP deflator in factor prices	-0.22%	-0.93%	-0.84%	-1.05%	-0.84%	0.34%	-0.93%
Current account as % of GDP***	0.11	0.26	0.01	0.31	0.21	0.07	-0.11
Equivalent variation of total welfare							
Economic welfare**	0.28%	-0.08%	0.14%	-0.16%	0.17%	0.46%	0.31%

* in thousand employed persons
** as percent of GDP
*** absolute difference from baseline

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