Decomposing General Equilibrium Effects of Policy Intervention in Multi-Regional Trade Models

Method and Sample Application

by

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Abstract

Policy interventions in large open economies do not only affect the allocation of domestic resources but change international market prices. The change in international prices implies an indirect *secondary* burden or benefit for *all* trading countries. This secondary terms of trade effect may have important welfare implications: Countries without change in domestic policies may nevertheless gain or suffer from the action of other countries; in turn, the primary welfare effect of countries interfering domestically may be substantially enhanced or weakened due to international spill-overs. Obviously, policy makers of economies that are integrated into international markets have an essential interest to gain insights about the different sources of welfare changes associated with domestic policy changes. In this paper, we present a decomposition that splits the overall welfare effect into a domestic market effect holding international prices constant and an international market effect as a result of changes in international prices (terms of trade effect). We demonstrate the usefulness of our decomposition approach in the context of an empirical welfare analysis of international carbon abatement policies.

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1. Introduction

Policy measures in large open economies not only cause adjustments of domestic production and consumption patterns but affect international prices via changes in exports and imports. The changes in international prices imply a *secondary* burden or benefit in addition to the *primary* domestic policy effect. A large country could exploit international market power and influence international prices at the expense of its trading partners (*beggar-thy-neighbor policy*).

Not surprisingly, policy makers in open economies are concerned about the sign and the magnitude of international spill-over effects from domestic policy intervention. The current debate on climate change policy is an example where such concerns arise. Developing countries which have not made any commitment for domestic emission abatement fear nevertheless adverse economic effects due to the abatement measures of industrialized countries. The Kyoto Protocol explicitly reflects these concerns in stating that developed countries *"...shall strive to implement policies and measures ... in such a way as to minimize adverse effects, including ... the effects on international trade, and ... economic impacts on other Parties, especially developing countries Parties ..."* (UN 1997, Article 2, paragraph 3).

Given the potential importance of international spill-overs this paper provides a decomposition of the total (general equilibrium) effects associated with domestic policy measures in open economies. We break down the total policy effect for a single country into a domestic market effect (i. e. domestic adjustment holding international prices constant) and an international policy effect (the residual effect accounting for changes in the terms of trade). Splitting the total welfare effect into these components conveys important economic information as to why a country will benefit or loose from adjustments in domestic and international markets.

We illustrate the policy relevance of our decomposition approach with an example of international carbon abatement policies. Based on a large-scale computable general equilibrium model of global trade and energy use we show that spill-over effects of domestic abatement policies on international markets have important economic consequences on both abating *and* non-abating regions..

In section 2 we lay out the decomposition approach, in section 3 we describe the policy application, and in section 4 we present our conclusions.

2. Decomposition Approach

The general equilibrium approach is an established analytical framework for evaluating the economic implications of policy intervention in open economies (Shoven and Whalley 1992). Its main virtue is the comprehensive and (microeconomic) consistent simulation of the direct and indirect effects (feedbacks or spill-overs) induced by exogenous policy changes. However, the interpretation of general equilibrium effects as a sum of a number of partial effects is difficult, in particular if the partial effects work in opposite directions. Therefore, one challenge of general equilibrium modeling is to provide decomposition methods that facilitate analysis of the various sources of total effects such as aggregate welfare changes. In the context of customs-union formation, Harrison, Rutherford and Wooton (1993) present a decomposition method that splits down the total welfare effect into two components: the consequences of induced changes in domestic prices (*home price effect*); and the effects on income of adjustments in tariff rates and endogenous changes in the pattern and volume of trade (*tariff revenue effect*).[1] Huff and Hertel (1996) describe a decomposition of welfare effects where changes in welfare are directly related to tax changes interacting with equilibrium quantity changes. Here, we show that the welfare effects of any policy intervention in large open economies can be composed of a *domestic market effect* assuming that international prices remain constant and an *international market effect* as a result of changes in international prices (terms of trade effect).

We formally present the decomposition approach along a generic static multi-region trade model (MRT). Each region's final demand structure is portrayed by a representative agent who allocates expenditure across goods so as to maximize welfare. The level of investment and public output is fixed. Production incorporates intermediate inputs and primary factors. Traded commodities of the same variety are differentiated by origin (Armington 1969). The level of aggregate foreign lending or borrowing for each region is kept constant.

For each region three classes of conditions characterize the competitive equilibrium: zero-profit, market clearance, and income balance. Associated with these conditions are three classes of variables: activity levels (for constant-returns-to-scale firms[1]), commodity prices and consumer incomes. In equilibrium, each variable is linked to one condition: an activity level to an exhaustion of product constraint, a commodity price to a market clearance condition, and a consumer income variable to an income definition equation. In our algebraic exposition, the notation

[1] In a competitive setting we may characterize technologies as CRTS without loss of generality. Decreasing returns are accommodated through the introduction of a specific factor.

Π_{ir}^{z} is used to denote the profit function of sector *j* in region *r* where **z** is the name assigned to the activity describing domestic production ($z=Y$), aggregate import formation ($z=M$) and final demand ($z=C$).

Differentiating the profit function with respect to input and output prices provides compensated demand and supply coefficients, which appear subsequently in the market clearance conditions. The notations adopted for our algebraic representation are summarized in Table 1. The equilibrium conditions are given in Table 2.

We decompose the economic effects associated with policy changes in open economies into a domestic market effect and an international market effect. The domestic market effect reflects a small open economy (SOE) setting where the level of a region's imports and exports have no effect on the terms of trade.[2] Algebraically, the SOE specification is identical to the MRT model formulation with the sole difference that prices on international markets are fixed in international currency units, i.e. prices of commodity *i* exported by region *s* are exogenously given as $\overline{p}_{is}^{x}$. Foreign closure of the SOE model requires an additional condition that states equality of the value of imports with the value of exports. Table 3 provides the algebraic summary of the SOE module for each region of the MRT model.

Table 1: Summary of notations for the generic MRT

Summary of Denotations	
N	Number of commodities (sectors)
K	Number of factors
M	Number of countries/regions
i = 1,..,N	Index for commodities (sectors)
j = 1,..,N+K	Index for commodities and factors
r,s = 1,..,T	Index for region
u	Revenue function
w	Cost function
p_{jr}	Price of domestic output good ($j \in \{1,...,N\}$) or factor ($j \in \{N+1,..., N+K\}$) in region *r*
p_{ir}^{X}	Export price for good *i* produced in region *r*
p_{ir}^{M}	Price for aggregate import good *i* imported by region *r*
p_{r}^{C}	Composite price for aggregate household demand in region *r*
Y_{ir}	Level of production for sector *i* in region *r*
M_{ir}	Level of aggregate imports for sector *i* in region *r*
C_{r}	Aggregate household consumption in region *r*
$\overline{E}_{jr}$	Endowment of region *r* with factor *j* ($j \in \{N+1,..., N+K\}$)

[2] Hence, we can omit export demand and import supply functions within the algebraic model formulation.

Table 2: Algebraic Summary of the MRT

Summary of MRT Equilibrium Conditions	
Zero profit	
Production	$\Pi_{ir}^{Y} = u(p_{ir}, p_{ir}^{X}) - w(p_{1r},..., p_{(N+K)r}, p_{1r}^{M},..., p_{Nr}^{M})$
Import aggregate demand	$\Pi_{ir}^{M} = p_{ir}^{M} - w(p_{i1}^{X},..., p_{iT}^{X})$
Final demand	$\Pi_{r}^{C} = p_{r}^{C} - w(p_{1r},..., p_{Nr}, p_{1r}^{M},..., p_{nr}^{M})$
Market clearance	
Factor markets	$\bar{E}_{jr} = \sum_{i=1}^{N} Y_{ir} \frac{\partial \Pi_{ir}^{Y}}{\partial p_{j}}$
Domestic good markets	$Y_{ir} \frac{\partial \Pi_{ir}^{Y}}{\partial p_{ir}} = \sum_{j=1}^{N} Y_{jr} \frac{\partial \Pi_{jr}^{Y}}{\partial p_{ir}} + C_{r} \frac{\partial \Pi_{r}^{C}}{\partial p_{ir}}$
Export good markets	$Y_{ir} \frac{\partial \Pi_{ir}^{Y}}{\partial p_{ir}^{X}} = \sum_{s=1}^{T} M_{is} \frac{\partial \Pi_{is}^{Y}}{\partial p_{ir}^{X}}$
Aggregate import good markets	$M_{ir} = \sum_{j=1}^{N} Y_{jr} \frac{\partial \Pi_{jr}^{Y}}{\partial p_{ir}^{M}} + C_{r} \frac{\partial \Pi_{r}^{C}}{\partial p_{ir}^{M}}$
Income balance	
Budget Constraint	$C_{r} = (\sum_{j=N+1}^{N+K} p_{jr} \bar{E}_{jr}) / p_{r}^{C}$

Table 3: Algebraic Summary of the SOE

Summary of SOE Equilibrium Conditions (" r Î {1,...,T })	
Zero profit	
Production	$\Pi_{i}^{Y} = u(p_{i}, \bar{p}_{i}^{X}) - w(p_{1},..., p_{(N+K)}, p_{1}^{M},..., p_{N}^{M})$
Import aggregate demand	$\Pi_{i}^{M} = p_{i}^{M} - w(\bar{p}_{i1}^{X},..., \bar{p}_{iT}^{X})$
Final demand	$\Pi^{C} = p^{C} - w(p_{1},..., p_{N}, p_{1}^{M},..., p_{N}^{M})$
Market clearance	
Factor markets	$\bar{L} = \sum_{j} Y_{j} \frac{\partial \Pi_{j}^{Y}}{\partial w}$
Domestic good markets	$Y_{i} \frac{\partial \Pi_{i}^{Y}}{\partial p_{i}} = \sum_{j=1}^{N} Y_{j} \frac{\partial \Pi_{j}^{Y}}{\partial p_{i}} + C \frac{\partial \Pi^{C}}{\partial p_{i}}$
Aggregate import good markets	$M_{i} = \sum_{j=1}^{N} Y_{j} \frac{\partial \Pi_{j}^{Y}}{\partial p_{i}^{M}} + C \frac{\partial \Pi^{C}}{\partial p_{i}^{M}}$
Income balance	
Budget Constraint	$C = (\sum_{j=N+1}^{N+K} p_{j} \bar{E}_{j}) / p^{C}$
Foreign closure (BOP)	$\sum_{i=1}^{N} Y_{i} \frac{\partial \Pi_{i}^{Y}}{\partial \bar{p}_{i}^{X}} \bar{p}_{i}^{X} = \sum_{i=1}^{N} \sum_{s=1}^{T} Y_{ir} \frac{\partial \Pi_{i}^{M}}{\partial \bar{p}_{is}^{X}} \bar{p}_{is}^{X}$

The SOE specification allows us to impose any change in international prices (terms of trade) parametrically by changing the values for $\overline{p}_{ir}^{X}$. Hence, we can easily check the consistency of our decomposition for any MRT policy simulation (counterfactual equilibrium). We fix international prices $\overline{p}_{i}^{X}$ for the SOE at the level p_{ir}^{X} determined by the MRT counterfactual and then initialize the level values for SOE variables using the MRT solution. Without numerical work we should be able to replicate the MRT solution for any country from an SOE perspective.[3]

Having passed the consistency check we can use the SOE framework in order to decompose the total MRT policy effect into a domestic market effect and an international market effect. Computation of the domestic market effect simply requires that we keep the international prices at the benchmark (reference) level and then impose the domestic policy change on the specific country.[4] When we impose parametrically the changes in the terms of trade as calculated by the MRT counterfactual we replicate the MRT solution using the SOE framework. Obviously, the international market effect is equal to the difference between the total (general equilibrium) policy effect and the domestic market effect.

Figure 1 illustrates the steps involved in the decomposition procedure. For the intermediate SOE equilibrium calculation (A➔B), the domestic market has no effect on international prices. Imposing the changes in terms of trade (international market effect) which are delivered by the multi-region computation (A➔C), we exactly reproduce the MRT solution from the SOE perspective (B➔C).

Of course, the MRT-SOE decomposition allows to measure the international market effect separately by commodity. We simply parameterize the SOE model with the international price for that commodity using the MRT framework. We then can measure how the change in terms of trade for the specific commodity affects economic performance in the small open economy.

[3] This procedure is equivalent to the standard replication check for calibrated models.
[4] By definition, the domestic market effect must be zero for any country where no domestic policy change applies.

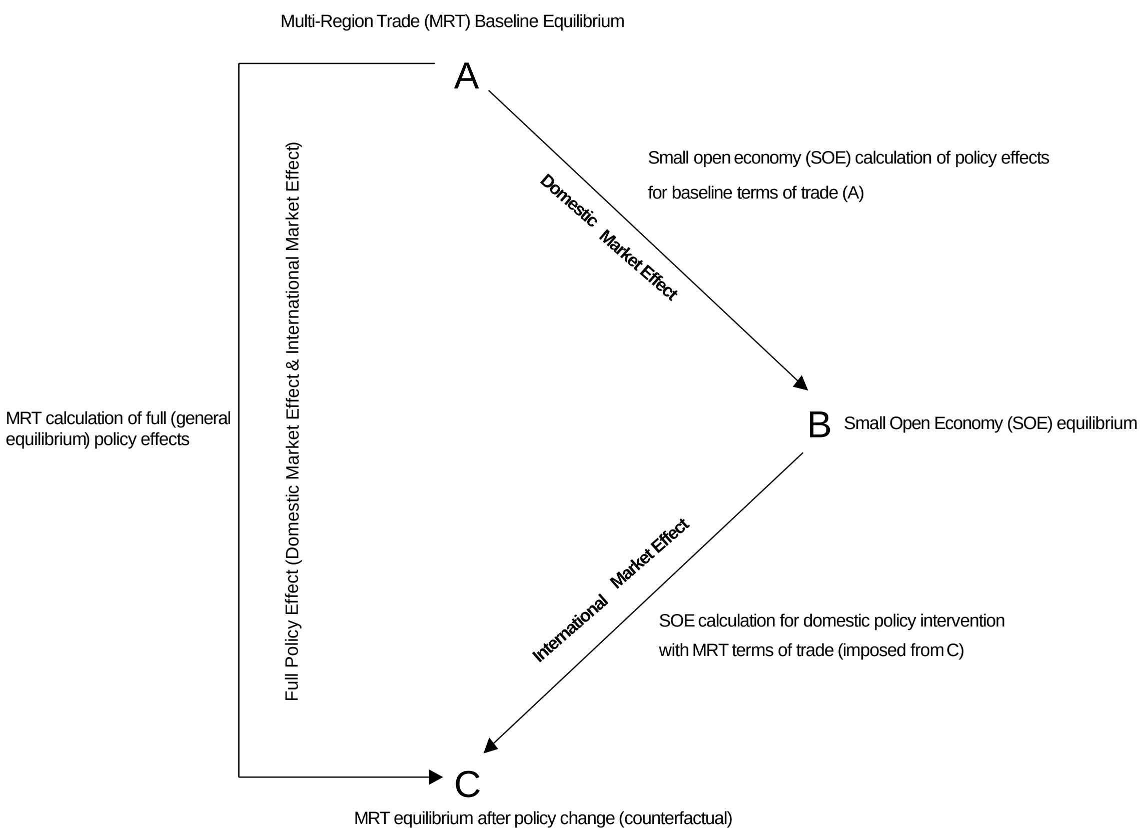

Figure 1: Decomposition procedure

3. Policy Application: Decomposing the Welfare Effects of the Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UN 1997) fixes legally binding quantified greenhouse gas emissions limitation and reduction objectives (QELROs) for Annex B parties.[5] On average Annex B parties have committed themselves to reduce greenhouse gas emissions by 5.2 % from 1990 levels in the budget period 2008 to 2012 but QELROs across Annex B parties differ.

[5] Annex B countries include industrialized countries and countries with economies in transition, such as Eastern and Central Europe and the states of the former Soviet Union.

Table 4: Quantified Emissions Limits under the Kyoto Protocol (UN 1997)

Country or Region	Label	Commitments (Percentage of 1990 Base Year Greenhouse Gas Emissions)
United States of America	USA	93
Canada	CAN	94
European Union	EUR	92
Japan	JPN	94
Former Soviet Union	FSU	100
Other OECD	OOE	107

The developing countries have refused so far any abatement commitment. The reason is that they fear negative effects of emissions limitation on their economic development and demand primary action by the developed world with large historical and current emissions.

Yet, unilateral adjustment to emission restrictions in the developing world will produce secondary spill-overs to international markets and affect the developing countries through changes of international prices. The potential importance of these international market effects (terms of trade effects) have been recognized within the Kyoto Protocol (UN 1997, Article 2, paragraph 3). In the context of international burden sharing, the quantification of the sign and magnitude of the secondary terms of trade effect at the regional level appears to be highly policy relevant.

A. Modeling Framework

The analytical framework we use is a static 7-sector, 12-region general equilibrium model of the world economy.[6] The sectors in the model have been chosen to keep the most carbon intensive sectors as separate as possible in the available data.[7] The regional aggregation covers the Annex-B parties as well as major non-Annex-B regions which are central to the greenhouse gas issue. Table 5 summarizes the 7 sectors and 13 regions incorporated in our model.

Primary factors include labor, capital and fossil-fuel resources. Labor and capital are intersectorally mobile within a region but cannot move between regions. Fossil-fuel resources are specific to fossil fuel production sectors in each region.

[6] Hence, we ignore potentially important impacts of carbon abatement on the level and pattern of investment across countries. The model provides rather conservative estimates of the cost of abatement because we would expect that carbon emission limits will reduce the return to capital and result in lower overall GDP growth in the Annex B countries.

[7] This ensures a best-guess approximation of differences in carbon intensities, the scope for substitutability across carbon-intensive goods and hence the potential for terms of trade effects triggered by carbon abatement policies.

Table 5: Overview of sectors and countries/regions (data base: GTAP 3.0; see McDOUGALL 1997)

Sectors		Regions	
Label	Long name	Label	Long name
COL	Coal	USA	United States
CRU	Crude oil	CAN	Canada
GAS	Natural gas	EUR	Europe
ROP	Refined oil products	JPN	Japan
ELE	Electricity	OOE	Other OECD
EIS	Energy-intensive sectors	FSU	Former Soviet Union
Y	Other manufactures and services	CEA	Central European Associates
		CHN	China (including Hong Kong and Taiwan)
		BRA	Brazil
		IND	India
		ASI	Other Asia
		MPC	Mexico and OPEC
		ROW	Rest of World

Production of commodities (*ROP, ELE, EIS, Y*) other than fossil fuels is captured by an aggregate production function which characterizes technology through transformation possibilities on the output side and substitution possibilities on the input side. On the output side production is split between goods produced for the domestic markets and goods produced for the export market subject to a constant elasticity of transformation. On the input side constant elasticity of substitution (CES) cost functions with three levels are employed to specify the KLEM substitution possibilities in domestic production between capital, labor, energy and material (non-energy) intermediate inputs. At the top level non-energy inputs are employed in fixed proportions with an aggregate of energy, capital and labor. The material input of good *i* in sector *j* corresponds to a CES Armington aggregate of non-energy inputs from domestic production and imported varieties. At the second level a CES function describes the substitution possibilities between the energy aggregate and the aggregate of labor and capital. Finally, at the third level capital and labor trade off with a constant elasticity of substitution. As to the formation of the energy aggregate we allow sufficient levels of nesting to permit substitution between primary energy types as well as substitution between a primary energy composite and secondary energy, i.e. electricity.

In production of fossil fuels (*CRU, GAS, COA*) labor, capital and fossil fuel inputs are aggregated in fixed proportions at the lower nest. At the top level this aggregate trades off with the sector-specific fossil-fuel resource at a constant elasticity of substitution. The latter is calibrated to be consistent with exogenously given price elasticities of fossil fuel supplies.

Final demand in each region is determined by a representative agent who is maximizing his utility subject to an income balance constraint with fixed investment. Total income of the representative household consists of factor income and taxes[8]. Final demand of the representative agent is given as a CES composite which combines consumption of an energy aggregate and a non-energy consumption bundle. Substitution patterns within the non-energy consumption bundle are reflected via Cobb-Douglas functions with an Armington aggregation of imports and domestic commodities. The energy aggregate in final demand consists of the various energy goods trading off at a constant elasticity of substitution.

All commodities are traded internationally. Crude oil and coal are imported and exported as a homogeneous product, subject to tariffs and export taxes. For all other commodities we adopt the Armington assumption of product differentiation with an explicit representation of bilateral trade flows.

B. Parameterization: Base Year Calibration and Forward Projection

The economic effects of the Kyoto Protocol depend crucially on the extent to which QELROs bind the economies in the budget period. In other words, the magnitude and distribution of costs associated with the implementation of future emission constraints depend on the Business-as-Usual (BaU) projections for GDP, fuel prices, energy efficiency improvements, etc. In our comparative-static framework we infer the BaU structure of the model's regions for 2010 using most recent projections on the economic development. We then measure the costs of abatement relative to that baseline.

As a starting point for our forward projection we use the GTAP 4 database (McDougall 1997) and OECD/IEA energy statistics (IEA 1996) for 1995 which is the most recent year for which a complete set of statistics are available.[9] We use the reconciliated benchmark data for this year to calibrate parameters of the CES functional forms from a given set of quantities and prices (given exogenous elasticities). In a second-step we do the forward calibration of the 1995 economies to 2010 based on baseline estimates by the U.S. Department of Energy (DOE 1998) for GDP growth, energy demand and future energy prices.

C. Policy Implementation and Computational Results

Our comparative-static model measures the costs of implementing Kyoto as compared to a BaU reference point in 2010 where no emission abatement requirements exist. In the policy simulation Annex B countries apply

[8] In the benchmark the model includes taxes on output, intermediate inputs, exports and imports as well as on final demand.

[9] See Babiker and Rutherford (1997) for the assembly and reconciliation of these data sources.

domestic carbon taxes which are sufficiently high to meet their individual Kyoto commitment. Revenues from carbon taxation are recycled lump-sum to the representative agent in each region.

Emission Reduction Requirements and Marginal Abatement Costs

Like non-Annex B regions which have not accepted any limitation of their future emissions at all FSU does not face a binding carbon constraint. While FSU has committed to stabilize its emissions in the budget period at 1990 emission levels, its BaU emissions in 2010 stay far below the Kyoto target (see Table 6). The low emission baseline is due to the sharp economic recession between 1990 and 2000 joint with exogenous autonomous energy efficiency improvements over the next decade. For all OECD countries the Kyoto targets are binding which implies the imposition of domestic carbon taxes. Table 6 shows that the marginal abatement costs associated with the Kyoto commitments are substantial ranging up to 300$US per metric ton of carbon for the case of JPN. The tax rates reflect the fact that the Kyoto targets which appear modest with respect to 1990 emission levels translate into much higher *effective* cutback requirements for OECD countries with respect to their BaU emission levels in 2010. For example, OOE is allowed to increase emissions by 7% over 1990 levels under the Kyoto Protocol; nevertheless, this implies an effective abatement of more than 15% in its BaU emissions by 2010. The level of abatement is a key determinant of the marginal abatement costs. The further out we are on the abatement cost curve the more costly it gets to substitute away from carbon in production and consumption. Apart from the abatement level the marginal abatement costs depend to a large extent on differences in carbon intensity for different sectors across countries. For example, JPN faces much higher carbon taxes compared to USA to achieve an almost identical relative cutback of carbon emissions. This is because JPN uses relatively little carbon in sectors with low-cost substitution possibilities, in particular electricity generation (due to nuclear power). As a consequence JPN has to cut back relatively more emissions in other sectors such as traffic where abatement comes more costly.

Table 6: Effective emission cutback requirements and marginal abatement costs (carbon taxes) in 2010

	Cutback (in % from BaU)	Carbon tax (US$ per metric ton of carbon)
USA	27.5	160.4
CAN	27.5	230.2
EUR	13.7	107.0
JPN	26.0	299.8
OOE	15.8	75.9
FSU	-48.1	0.0

Welfare Costs

The tax-induced reallocation of resources such as fuel shifting or energy savings causes efficiency costs which translate into a loss in real income for households. To gain further insights into the different sources of welfare changes associated with the implementation of the Kyoto Protocol we make use of our decomposition method.

Column "IME" of Table 7 reports the aggregate international market effect which together with the domestic market effect "DME" yields the total policy effects as stated by column "TPE" of Table 7. We see that unilateral abatement of Annex B parties produces significant secondary terms of trade effects which affect both abating Annex B and non-abating developing countries. [10] The international spill-overs induce substantial welfare losses for FSU as well as MPC and a rather small loss for ROW. All other non-abating countries benefit to varying extents from the changes in international prices associated with carbon abatement in OECD countries.

As to abating OECD countries the decomposition conveys additional information on the sign and magnitude of the primary and secondary effect. We see that international spill-overs are negative for USA, CAN and OOE whereas EUR and JPN benefit from the adjustments on international markets.

Table 7: Decomposition of welfare effects – Hicksian equivalent variation in income (% change from BaU)

	DME	WKT	ENE	TPE	IME
USA	-0.360	-0.378	-0.393	-0.395	-0.035
CAN	-0.694	-0.858	-0.976	-0.878	-0.184
EUR	-0.140	-0.063	-0.081	-0.065	0.075
JPN	-0.439	-0.382	-0.356	-0.299	0.140
OOE	-0.126	-0.474	-0.537	-0.649	-0.523
FSU	0.000	-0.420	-0.916	-1.030	-1.030
CEA	0.000	0.256	0.311	0.290	0.290
CHN	0.000	0.253	0.284	0.200	0.200
IND	0.000	0.319	0.354	0.269	0.269
BRA	0.000	0.079	0.084	0.087	0.087
ASI	0.000	0.258	0.174	0.137	0.137
MPC	0.000	-0.756	-0.865	-0.992	-0.992
ROW	0.000	-0.047	-0.038	-0.079	-0.079

DME: domestic market effect
WKT: welfare change including DME and terms of trade effects on coal and crude oil markets
ENE: welfare change including DME and terms of trade effects on all energy markets
TPE: total (general equilibrium) policy effect
IME: international market effect

[10] Of course, the secondary benefit or burden is identical to the total (general equilibrium) effect for those countries which do not undertake domestic action (i.e. their primary effect is zero).

To explain the nature of the secondary welfare benefits or losses across countries we apply our decomposition method subsequently for various international markets. Columns "DME" through "TPE" of Table 7 summarize how the domestic market effect evolves towards the full policy effect from the SOE perspective when we "switch" on successively changes in international prices determined by the MRT counterfactual solution.

Most important are the spill-over effects associated with the adjustments on international coal and gas markets which are treated as homogeneous goods (Column "WKT"). The cutback in demands for fossil energies from abating OECD countries depresses the international prices for oil and in particular for carbon-intensive coal. As a consequence countries which are net importer of gas and oil will gain whereas net exporting countries will loose. Table 8 provides a summary of the BaU net trade position in coal and crude oil across countries.

Table 8: Trade Position on Coal and Crude Oil Markets

	Coal	Crude Oil
USA	exp	imp
CAN	exp	imp
EUR	imp	imp
JPN	imp	imp
OOE	exp	imp
FSU	imp	exp
CEA	exp	imp
CHN	imp	imp
IND	imp	imp
BRA	imp	imp
ASI	imp	imp
MPC	exp	exp
ROW	exp	exp

exp: net exporter
imp: net importer

For CAN and MPC which are net exporter of both coal and crude oil the aggregate welfare effect is unambiguously negative. Likewise net importers EUR, JPN, CHN, IND, BRA and ASI experience welfare gains. For countries, which are net importer of one homogeneous fossil fuel *and* net exporter of the other homogeneous fossil fuel, the aggregate effect depends on export and import quantities as well as the relative changes in international coal and crude oil prices. FSU, for example, looses more on the crude oil export side than it benefits on the coal import side. Changes in terms of trade for the other energy goods (electricity, refined oil, and gas) cause welfare losses for Annex-B countries[11] whereas the developing countries except for ASI and MPC benefit (see above Column "ENE" of

[11] The one exception is Japan where electricity generation is mainly based on nuclear power.

Table 7). The main reason is that OECD countries loose competitiveness in electricity generation and oil processing due to the imposition of high carbon taxes.[12]

Finally, we account for changes on the non-energy markets to replicate the MRT counterfactual solution. On these markets, developing countries face adverse spill-over effects. Due to product heterogeneity, abating OECD countries can pass on part of their cost increase in domestic production to non-abating trading partners. Tax burden shifting occurs not only between abating and non-abating countries but also *among* abating OECD countries, which are typically large trading partners. This explains the welfare losses for OOE which has the lowest carbon taxes and trades intensively with other abating countries with higher carbon taxes, in particular Japan. In intra-OECD trade, OOE is therefore rather a tax burden importer than a tax burden exporter.

It should be noted that the application above serves primarily illustrative purposes with respect to our decomposition approach. Before drawing policy conclusions a comprehensive sensitivity analysis with respect to key parameters (e.g. elasticities, projections of GDP or energy demand) would be necessary.

4. Conclusions

We presented a decomposition of general equilibrium effects induced by policy intervention in trade models. When national economies are linked through international trade, adjustments of economic activities in one country will spill over to other countries via changes in export and import quantities. The associated changes in international prices implies an indirect *secondary* burden or benefit for *all* trading countries. Our decomposition splits the overall welfare effect into a domestic market effect holding international prices constant and international market effects as a result of changes in international prices (terms of trade). Decomposing the overall welfare effect into these component parts conveys important economic information as to why a country will benefit or loose from adjustments on international markets. Our decomposition represents a general concept, is intuitively appealing, and its numerical implementation within the GE framework is straightforward.

We demonstrated the usefulness of our decomposition approach in the context of an applied welfare analysis of international carbon abatement policies.

The decomposition might not only be used for a more thorough understanding of the aggregate general equilibrium effects implied by policy intervention in open economies. At the policy level, consistent cost estimates

[12] The welfare losses for MPC, ASI and FSU are related to the decrease in demand and prices for their gas exports.

on international spill-overs constitute an important criterion for evaluating the effects of domestic policies in the international context. Information on the magnitude and distribution of secondary benefits or costs from policy intervention could, for example, influence international policy agreements with respect to the design of "equitable" transfer systems.

References

Armington, P.S. (1969), A Theory of Demand for Products Distinguished by Place of Production, *IMF Staff Papers* 16, 159-178.

Babiker, M. and T.F. Rutherford (1997), "Input-Output and General Equilibrium Estimates of Embodied Carbon: A Dataset and Static Framework for Assessment", working paper 97-2, University of Colorado, Boulder.

DOE (1998), Department of Energy, Annual Energy Outlook (AEO 1998), Enerigy Information Administration http://www.eia.doe.gov

Harrison, G.W., Rutherford, T.F. and I. Wooton (1993), "An alternative welfare decomposition for customs unions", *Canadian Journal of Economics*,4, 961-968.

Huff, K.M. and T.W. Hertel (1996), "Decomposing Welfare Changes in the GTAP Model", GTAP Technical Paper No. 5, Purdue University, West Lafayette.

McDougall, R.A. (1997), ed., *Global Trade, Assistance and Protection: The GTAP 3 Data Base*, Center for Global Trade Analysis, Purdue University, West Lafayette.

IEA (1996), International Energy Agency, Energy Prices and Taxes / Energy Balances of OECD and Non-OECD countries, Paris: IEA publications.

Shoven, J.B. and J. Whalley (1992), *Applying General Equilibrium*, Cambridge University Press.

UN 1997, United Nations, *Kyoto Protocol*, FCCC/CP/1997, Geneva.