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Decomposing the Cost of Kyoto

A Global CGE Analysis of Multilateral Policy Impacts

Christoph Böhringer and Thomas F. Rutherford

Non-Technical Summary

In this paper we apply a generic procedure developed by Harrison, Horridge and Pearson (1999) in order to decompose the economic implications of the Kyoto Protocol at the cross-country level. The total economic impact for each region is split into contributions from its own emission abatement policy and those from other regions. Our analysis which is based on a large-scale computable general equilibrium model for the world economy indicates that spillover effects are an important consequence of multilateral carbon abatement policies. Emission mitigation by individual developed regions may not only significantly affect economic development and performance in non-abating developing countries but may also cause large changes in the economic costs of emission abatement for other industrialized regions. Analyzing the individual contributions across policy measures of abating countries, action on behalf of the United States produces by far the largest spillovers to other countries. Major competitors such as Europe and Japan benefit significantly from abatement in the US whereas the US - in turn - is hardly affected by abatement policies of these regions. We calculate a cross-country matrix for monetary transfer payments which would have to be assigned on a bilateral basis in order to provide compensation for the Kyoto spillovers. We show that the contributions of individual policy changes to the overall effect depend on the policy instrument. When we simply change from a price instrument (taxes) to a quantity instrument (emissions) in order to meet the Kyoto commitments the quantitative decomposition results change. However, the qualitative results remain robust suggesting that the decomposition procedure provides a useful starting point for bilateral negotiations on policy-relevant transfer payments across parties of the Framework Convention.

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Abstract

We decompose the economic implications of the Kyoto Protocol at the cross-country level, splitting the total economic impact for each region into contributions from its own emission abatement policy and those from other regions. Our analysis which is based on a large-scale computable general equilibrium model for the world economy indicates that spillover effects are an important consequence of multilateral carbon abatement policies.. We calculate a cross-country matrix for monetary transfer payments which would have to be assigned on a bilateral basis in order to provide compensation for the international spillovers associated with the implementation of the Kyoto Protocol.

Zusammenfassung

Im Rahmen einer angewandten Gleichgewichtsanalyse untersuchen wir die ökonomischen Auswirkungen des Kioto-Protokolls auf bilateraler Ebene. Hierzu zerlegen wir den gesamten Wohlfahrtseffekt für jede Region in einen Anteil, der auf die eigene Emissionsminderungspolitik zurückzuführen ist und die jeweiligen Anteile (internationale spillovers), die durch Klimaschutzpolitiken in anderen Regionen verursacht werden. Es wird deutlich, daß internationale spillovers einen wesentlichen Beitrag zu den allgemeinen Gleichgewichtseffekten multilateraler Politikmaßnahmen liefern. Wir berechnen eine Matrix von bilateralen Transferzahlungen, die als Ausgangspunkt für politikrelevante Verhandlungen über Kompensationen für internationale spillovers im Zuge der Umsetzung des Kioto-Protokolls dienen könnte.

JEL classification: C63, C68, D58, F11, Q4

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1 Introduction

Under the Kyoto Protocol, industrialized countries and economies in transition (Annex B countries), have committed themselves to reduce their greenhouse gas emissions below 1990 levels in the period 2008 to 2012. Developing countries have argued that they carry only minor historical responsibility for the increase in global CO2 concentrations and therefore have refused any abatement commitment so far. At first glance, abstinence from domestic action seems to insure the developing countries against potential costs from greenhouse gas abatement because their economic development will not be constrained by domestic emission limits. However, in a world where economies are increasingly linked through international trade, policy changes in one country cause spillover effects to all trading partners via changes in the international prices, i.e. the terms of trade.

In this context, developing countries are concerned that abatement strategies in Annex B countries negatively affect their economic development and welfare. The developed world as a large trading block might exploit international market power and influence international prices at the expense of its trading partners in the developing world, hereby passing on some fraction of the costs of abatement (“*beggar-thy-neighbor” policy*). The Kyoto Protocol explicitly reflects these concerns postulating that developed countries *“...shall strive to implement policies and measures ... in such a way as to minimize adverse ... economic impacts on other Parties, especially developing countries Parties ...“* (UN 1997, Article 2, paragraph 3). On the other hand, the developed Annex B countries fear adverse changes in the terms of trade from unilateral abatement, because their energy use will be taxed, while there will be no taxes in the developing world, hence they can expect to lose competitiveness in energy-intensive goods.

In the policy debate, the issue of induced changes in terms of trade is linked to demands for adjustment mechanisms which provide more or less explicit compensation for "unfair" spillovers. The developing world is guaranteed compensation by Annex B for induced economic costs under Articles 4.8 and 4.9 of the United Nations Framework Convention on Climate Change (UNFCC 1992). In turn, the developed world argues for compensation[1] if unilateral abatement policies provide economic gains to non-abating non-Annex B countries. This

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[1] Compensating measures also include proposals for border taxes on energy intensive imports and border subsidies on energy-intensive exports in order to mitigate negative shifts in comparative advantage.

argument may be supported by fair division theory stating that "no-one should benefit from the emission abatement burdens of others" (Helm 1999, p.11). Moulin, for example, argues that "fair division conveys the idea of no subsidization: the presence of other agents who are willing to pay higher monetary transfers than me for consuming the resources should not turn to my advantage" (Moulin 1992, p. 1333).[2]

Of course, the debate on compensation for adverse spillovers does not only take place between the developed and the developing world, but also among countries of the respective groups (see, e.g., the bargaining process on burden sharing within the EU; Böhringer, Harrison and Rutherford 1998).

The comprehensive policy evaluation of abatement strategies with respect to the distribution of potential costs and benefits across countries requires quantitative assessment of how economic performance in a specific country will not be only affected by its own action, but also by those of other regions. There is a need for uncovering the sign and the magnitude of multilateral spillovers from policy interference through international channels.

In this paper we apply a generic procedure developed by Harrison, Horridge and Pearson (1999) in order to decompose the economic implications of the Kyoto Protocol at the cross-country level. The total economic impact for each region is split into contributions from its own policy changes and those from other regions. Apart from qualitative insights into the sources of economic gains and losses across countries, the decomposition allows the measurement of the individual contributions of changes in exogenous policies (in our case: multilateral abatement measures) to the overall change in endogenous economic variables. In principle, were they able to agree on model structure and parameters, policy makers could use such information as a reference point for negotiating bilateral transfer payments according to some agreed equity principles.

For the implementation and application of the decomposition by Harrison, Horridge and Pearson, we use a static large-scale computable general equilibrium model of the world economy. Our key findings can be summarized as follows:

- Emission constraints as mandated under the Kyoto Protocol induce significant spillovers from abating Annex B countries to non-abating Non-Annex B regions. Compliance with the Kyoto

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[2] This contrasts to the position of some authors explicitly arguing that climate change protection strategies should be designed such that they favor developing countries (Simonis 1996).

targets through national abatement measures imposes welfare losses for all OECD regions whereas developing regions with exception of large energy exporters may increase welfare due to gains in comparative advantage.

- Analyzing the individual contributions across policy measures of abating countries, action on behalf of the United States produces by far the largest spillovers to other countries. Major competitors such as Europe and Japan benefit significantly from abatement in the United States whereas the United States - in turn - is hardly affected by abatement policies of these regions.
- Among developing countries, Brazil and India gain from action of all OECD countries, whereas the reverse is true for energy exporting developing regions.
- Although the specific quantitative values for the decomposed bilateral spill-overs depend on the policy instrument (here: taxes versus permits) the qualitative results remain robust. Translation of decomposed welfare effects into a matrix of bilateral transfer payments could therefore provide a starting point for bilateral negotiations on compensation negative international spillovers from domestic abatement policies.

The paper is organized as follows: section 2 provides a description of the decomposition technique; section 3 lays out the model framework in use for the impact analysis of Kyoto; section 4 discusses the numerical results; and section 5 concludes.

2 The General Equilibrium Decomposition Technique

General equilibrium provides an established micro-consistent approach for evaluating the impacts of public policy on resource allocation (*efficiency*) and the associated changes in income for economic agents ("*equity*"). It has been, and still is, widely used in analytical work for assessing policy measures, such as tax reforms, where market interactions potentially play an important role. However, for the sake of tractability, analytical approaches are typically rather simple and not sufficiently complex for applied policy analysis. Therefore, numerical models are commonly used to accommodate the systematic analysis of economic problems where analytical solutions are either not available or do not provide adequate information.[3]

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[3] For surveys on the use of numerical models in different fields, see e.g. Bergmann 1990, Kehoe and Kehoe 1994, Shoven and Whalley 1992, Peireira and Shoven 1992.

The main virtue of complex computational general equilibrium (CGE) models, i.e. the comprehensive and consistent quantification of direct and indirect policy impacts, constitutes also the major challenge for their use. As various partial effects, which may work in opposite directions, contribute to the overall effect, it can get very difficult to explain in depth the aggregate policy outcome. Numerical applications inherit some ambiguity in the interpretation of the results as long as it is not possible to make transparent the sign and the magnitude of individual effects. Therefore, procedures which allow the decomposition of general equilibrium effects in a meaningful way are very helpful for the understanding and interpretation of policy simulations. A deliberate decomposition not only facilitates analysis of the various sources of the total effects but also assures a more rigorous check for the correct numerical implementation of policy questions.[4]

In the context of multilateral policy appraisal, Böhringer and Rutherford (1999) present a decomposition that splits the overall economic effect into a domestic market effect keeping international prices constant, and an international market effect as a result of changes in international prices (terms of trade effect).[5] In other words, the decomposition allows separation of the *primary* effect of domestic policy action from the *secondary* burden or benefit transmitted via changes in international prices. Yet, the procedure is not suited for quantifying how much of the total economic impact for one specific region is due to its own action and what is contributed by the individual actions of other regions. Harrison, Horridge and Pearson (1999, henceforth "HHP") propose a linear decomposition methodology for calculating the contributions of multiple exogenous policy instruments to the resulting changes in individual endogenous variables.

The HHP method may be best explained along a simplified example where an endogenous variable Z can be expressed as an explicit function of a vector $\overrightarrow{X}$ of exogenous variables (policy instruments):

$$Z = F(\overrightarrow{X}) = F(x_1, x_2, ..., x_n)\,.$$

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[4] Typically, CGE models are calibrated to a benchmark data set in economic flows for given values of elasticities. The replication check of the benchmark equilibrium serves as a test for the consistent integration of data, but does not assure "proper" economics.

[5] The key idea is that each region of a multi-region model can be represented as a small open economy in order to separate the domestic policy effect under fixed terms of trade. The changes in international prices can then be imposed parametrically on the small open economy to yield the full policy as previously calculated in the multi-region framework.

We consider the effects of a change in X which induces a change in Z, ΔZ. One way of decomposing the total change ΔZ in the endogenous variable with respect to the individual contributions from exogenous variables would be a sequential approximation of the impacts of *one* exogenous variable while keeping *all others* constant (see e.g. Huff and Hertel 1997). Assuming that F is differentiable, the contribution of a change in the exogenous variable x_i which moves from the initial value x_{i0} to the new value x_{i1} can then be computed as the line integral:

$$\Delta Z\big|_{x_i} = \int_{x_{io}}^{x_{i1}} \frac{\partial F}{\partial x_i} dx_i \ .$$

For the numerical computation, the total change in the exogenous variable Δx_i is divided into sufficiently small steps in order to approximate the line integral through linearization.

When F is nonlinear, the total change from shocks in exogenous variables can not be decomposed in additive line-integrals for each exogenous variable starting from the *same* reference (initial) value Z_0. The impact of a change in an exogenous variable must be calculated, taking into account the contributions of *previous* changes in other exogenous variables. This implies that the decomposition is potentially sensitive to the sequential ordering of changes in the exogenous policy variables. As there are *n!* ways of sequential ordering of *n* exogenous variables, one quickly ends up with a large number of possible (different) decompositions for relatively small-scale policy experiments.[6]

For many policy packages no decomposition might be obviously more plausible than the rest. HHP therefore suggest an order-independent "natural " way of calculating contributions. On the "natural" path, the exogenous variables move *together* towards their final value along a straight line between their starting values $\overrightarrow{X}_0$ and the final values $\overrightarrow{X}_1$. The straight line between these points is obtained by changing the elements of $\overrightarrow{X}$ as a differentiable function H of some parameter t holding the rate of change in the exogenous variables constant along the path (where $\overrightarrow{X}_0 = H(t_o), \overrightarrow{X}_1 = H(t_1)$).

Figure 1 illustrates the difference between the sequential method of decomposition and the HHP approach.

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[6] In our policy simulation of Kyoto we assess the differential impacts of 6 emission abating countries, which yields 720 possible ways of decomposing the total effect.

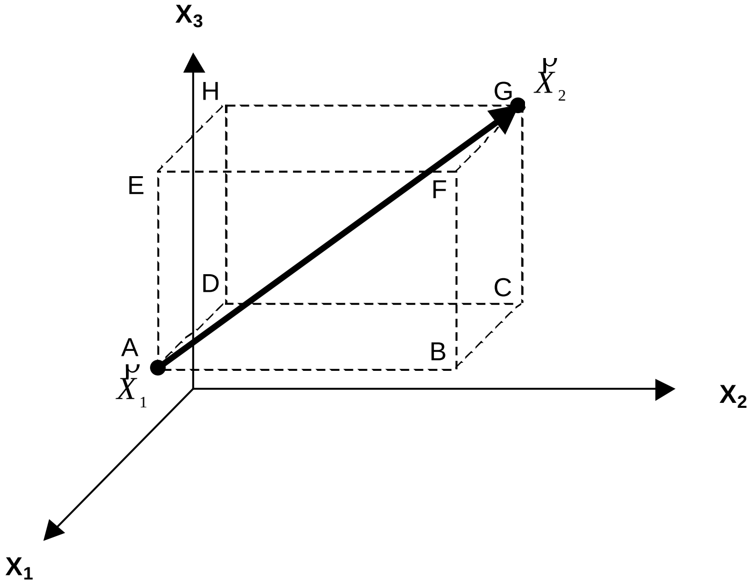

Figure 1: Sequential ordering versus "natural "path

In contrast to travelling on alternative combinations along the edges of the policy cube, the HPP method follows a straight line between the pre- and post-simulation values.

For *n* exogenous variables, multivariate calculus tell us that the total change in the endogenous variable is equal to:

$$\Delta Z = \sum_{i=1}^{n} \int_{t=t_o}^{t=t_1} \frac{\partial F}{\partial x_i} \frac{dx_i}{dt} dt$$

This concept is easily generalized to the case where the relationship between exogenous and endogenous variables is implicit, which is typically the case for applied general equilibrium models.

As HHP point out, it is possible to calculate numerical values for the gradients $\frac{\partial F}{\partial x_i} \frac{dx_i}{dt}$ at all points of the "natural" path by solving a system of linear equations. The individual contributions of changes in policy instruments x_i can then be approximated through linearization of the respective line integral which involves solving a system of linear equations *R* times, where

R renders a sufficiently small step-size $\Delta t / R$.[7] Appendix A provides the concrete description of how the decomposition can be implemented numerically.

3 Model Specification and Baseline Calibration/Parametrization

For our analysis we use a static 8-sector, 13-region CGE model of the world economy. The choice of sectors captures key dimensions in the analysis of greenhouse gas abatement such as differences in carbon intensities and the scope for substitutability across energy goods and carbon-intensive non-energy goods. The regional aggregation covers the Annex B parties as well as major non-Annex-B regions which are central to the greenhouse gas issue.[8] Table 1 summarizes the sectors and regions incorporated in our model.

Table 1: Overview of sectors and countries/regions

Sectors		Regions	
COL	Coal	CAN	Canada
CRU	Crude oil	CEA	Central European Associates
GAS	Natural gas	EUR	Europe (EU15 and EFTA)
OIL	Refined oil products	FSU	Former Soviet Union (Russian Federation and Ukraine)
ELE	Electricity	OOE	Other OECD (Australia and New Zealand)
EIS	Energy-intensive sectors	JPN	Japan
Y	Manufactures and services	USA	United States
CGD	Savings good	ASI	Other Asia (except for China and India)
		BRA	Brazil
		CHN	China
		IND	India
		MPC	Mexico and OPEC
		ROW	Rest of World

3.1 Nontechnical Model Overview

This section provides a non-technical summary of the model. The algebraic model documentation is given in Appendix B.

Primary factors include labor, capital and fossil-fuel resources. Labor and capital are intersectorally mobile within a region but cannot move between regions. A sector-specific

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[7] Note that the perspective on spillovers by HHP is different from Böhringer and Rutherford (1999). In the HHP approach, the individual contributions from exogenous policy changes include both changes in domestic as well as changes in international prices, whereas Böhringer and Rutherford separate domestic from international markets.

[8] The aggregation is based on the GTAP-E data base which reconciles the GTAP economic production and trade dataset (Mc Dougall 1997) with OECD/IEA energy statistics (IEA 1996) for 45 regions and 23 sectors (Babiker and Rutherford 1998). See Appendix C for the mapping of GTAP regions and sectors with respect to the definitions of Table 1.

resource is used in the production of primary fossil fuels (crude oil, coal and gas), resulting in upward sloping supply schedules for those goods.[9]

Production of commodities other than primary fossil fuels is captured by aggregate production functions which characterize technology through substitution possibilities between various inputs. Nested 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 the production of fossil fuels, 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 in consistency with exogenously given price elasticities of fossil fuel supplies.

Final demand in each region is determined by a representative agent who maximizes his utility subject to a budget constraint with fixed investment (i.e. given demand for the savings good). Total income of the representative household consists of factor income and taxes[10]. 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.

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[9] This model does not account for imperfectly competitive behavior on the part of oil exporting countries.

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

All commodities are traded internationally. Crude oil is 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.

An important caveat with respect to the model formulation adopted here concerns the representation of intertemporal issues. In the absence of an endogenous response of capital to changes in rates of return, the static model may fail to account for some important mechanisms through which carbon taxes affect the global economy. We leave to future work the application of the decomposition methodology illustrated here to a model with forward-looking agents and endogenous capital stocks.

3.2 Baseline Calibration

The economic effects of the Kyoto Protocol depend crucially on the extent to which quantified emission limitation and reduction objectives (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 the most recent projections on the economic development. We measure the economic effects associated with abatement measures relative to that baseline.

As a starting point for our forward projection, we use the GTAP-E database (Babiker and Rutherford 1998) which reconciles economic production and trade data (based on GTAP4 - McDougall 1997) and OECD/IEA energy statistics (IEA 1996) for 1995 - the most recent year for which a complete set of statistics is available. We use this benchmark data 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 incorporating exogenous information by the U.S. Department of Energy (DOE 1998) for GDP growth, energy demand and future energy prices. The fossil fuel production functions are finally calibrated so that they are consistent with exogenous price elasticities of supply.

4 Policy Simulations and Results

The Kyoto Protocol commits Annex B countries to the reduction of their aggregate CO_2 equivalent emissions on average by 5.2% below 1990 levels in the period 2008 to 2012. Table 2 summarizes the individual commitments by the Annex B regions as incorporated in our model.

In our simulation, we assume that Annex B countries apply domestic carbon taxes which are high enough to meet their individual Kyoto commitments. Carbon tax revenues accrue directly to the representative agent in each region. This tax policy setting is formally equivalent to a permit system where the representative agent auctions the region's Kyoto emission budget on domestic markets. The permit price then coincides with the carbon tax, both measuring the marginal costs of abatement.

Table 2: Quantified emissions limits under the Kyoto Protocol (Baron et al. 1999)

Region	Commitments in % of 1990 greenhouse gas emissions
CAN: Canada	94
CEA: Central European Associates	93
EUR: European Union and European Free Trade Area	91.5
FSU: Former Soviet Union	100
JPN: Japan	94
OOE: Other OECD	107.3
USA: United States of America	93

4.1 Effective Reduction Requirements and Marginal Abatement Costs

It is important to notice that the effective emission constraint for Annex B countries under the Kyoto Protocol must be measured against the BAU economic activity without abatement requirements.[11] Because emissions of most Annex B countries grow significantly along the baseline as compared to 1990 levels, the Kyoto targets which are stated with respect to 1990 as the base year translate into much higher effective carbon requirements with respect to BAU emission levels in 2010. For example, OOE is allowed to *increase* emissions under the Kyoto Protocol by 7% over 1990 levels, while it faces effectively the need for a *decrease* by more than 15% from BAU emissions in 2010. The one outlier is FSU whose projected emission levels for 2010 are below 1990 levels due to economic recession and industrial restructuring between 1990 and 2000.

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[11] See Böhringer, Jensen and Rutherford (2000) for the implications of alternative baseline projections on the magnitude and distribution of emission abatement costs.

Table 3 reports the effective percentage cutbacks joint with the marginal abatement costs across Annex B countries. The level of abatement is a major determinant of the marginal abatement costs. The further out we are on the abatement cost curve, the more costly it is - ceteris paribus - to substitute away from carbon in production and consumption.

Obviously, the marginal abatement costs for FSU are zero because its economic development will not be constrained by the Kyoto commitment. CEA faces a rather weak reduction requirement of only 2.3 % with respect to BAU emissions in 2010 which explains the moderate carbon tax of 11 $US per ton of carbon.

Table 3: Effective reduction requirements and marginal abatement costs

Region	% Reduction wrt 1990	% Reduction wrt 2010	Marginal Abatement Cost*
CAN	6	29.9	317
CEA	7	2.2	11
EUR	8.5	18.2	170
FSU	0	-27.2	0
JPN	6	24.3	455
OOE	-7.3	17.4	100
USA	7	30.4	287

*$US per ton of carbon

As we move towards higher reduction targets the emission taxes increase significantly ranging up to 455 $US per ton of carbon for Japan. Comparison of tax rates and reduction requirements across countries show that the relative cutback requirements are only one determinant of marginal abatement costs. The latter depend also on differences in carbon intensity for different sectors across countries. For example, JPN faces much higher carbon taxes compared to USA or CAN, although its percentage reduction target is smaller. The reason is that JPN uses relatively little carbon in sectors with low-cost substitution possibilities, e. g. 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 at the margin.

4.2 Total Welfare Costs

Table 4 summarizes the welfare implications of Kyoto measured as percentage change in real consumption with respect to BAU (positive numbers indicate welfare improvements).

We see that abatement policies by Annex B regions produce substantial spillovers to non-Annex B regions as well as between Annex B regions. Apart from MPC and ROW, all non-

Annex B countries gain a comparative advantage, i. e. improve their terms of trade (ToT). Among Annex B countries, FSU, which does not have to impose carbon taxes, faces non-negligible welfare losses through the deterioration of ToT. On the other hand, CEA experiences a significant increase in welfare despite the application of domestic carbon taxes; ToT gains for CEA are obviously large enough to offset the domestic costs of carbon abatement.

Table 4: Total welfare impact of Kyoto

Region	% Change wrt BAU consumption
CAN: Canada	-1.6
CEA: Central European Associates	0.5
EUR: EU15 and EFTA	-0.2
FSU: Russian Federation and Ukraine	-0.3
JPN: Japan	-0.5
OOE: Australia and New Zealand	-1.1
USA: United States	-0.9
ASI: Other Asia	0.2
BRA: Brazil	0.3
CHN: China	0.1
IND: India	0.3
MPC: Mexico and OPEC	-1.7
ROW: Rest of the World	-0.4
World Total	-0.5

For all OECD countries (USA, CAN, EUR, JPN, OOE), imposition of the Kyoto targets leads to economic losses, which is not surprising given their high tax rates.

To understand the welfare effects for the various regions at the aggregate level, it is useful to distinguish whether (i) regions must abate or not, and (ii) regions are either fossil energy exporters or importers.

Neglecting ToT effects, the economic impacts should be negative for abating Annex B countries and zero for non-abating non-Annex B countries. Those Annex B regions which face binding carbon limits must substitute fossil fuels with more expensive energy sources (fuel switching) or employ more expensive manufacturing and production techniques (energy savings). On the consumption side, higher energy prices imply a change in the consumption mix which results in a loss of welfare (consumer surplus). For a single abating region, the magnitude of inframarginal welfare losses depends on the level of the marginal abatement costs. Accounting for ToT, an abating region might pass on some of the price increases in their products to other countries. Note that burden shifting occurs also among abating countries. For any particular region, the terms of trade effect is determined by the composition of a *scale* effect and a *substitution* effect. For example, non-abating countries might gain export share for energy intensive goods in abating countries; however, this might be (partially) offset by a reduction in the scale of exports to abating countries as final demand in those countries shrinks with the rise in consumer goods prices.

Energy exporting nations suffer from Annex B abatement policies. The reason is that the cut in energy demand by the industrialized world[12] leads to a drop in producer prices for fossil fuels. Among fossil energy goods, the decline in prices is most pronounced for carbon-intensive coal, followed by less carbon-intensive (crude) oil and gas.

Based on the considerations above, we can give further explanation to Table 4. All developing countries, except for MPC and ROW, are large importers of fossil energies and benefit from the fall in international energy prices. MPC and ROW are exporters of fossil energies and face a loss of revenues from energy sales. With respect to trade in energy-intensive goods, developing countries gain a comparative advantage as compared to OECD countries with high energy prices. However, for MPC and ROW, this benefit is not large enough to offset the adverse effect on fossil fuel markets. Like MPC, FSU, as a large energy exporter of oil and gas, suffers from the decrease in fuel prices. Among abating OECD countries, CEA not only improves welfare due to lower energy import prices; it also improves its trade position among the heavily integrated OECD club because it faces by far the lowest carbon taxes. In contrast to all other OECD countries, CEA does not lose, but gains international competitiveness in energy intensive production. (The static nature of the model leads to an underestimate of the impacts on global capital accumulation and growth. The calculated welfare gains observed in energy-importing developing countries would most likely be absent in a dynamic formulation. See Bernstein, Montgomery and Rutherford 1999 or Böhringer and Rutherford 2000).

4.3 Decomposition of Total Welfare Impact

Whereas Table 4 conveys information on the magnitude and distribution of costs and gains from Kyoto for individual regions[13] it does not reveal how the total welfare changes can be attributed to the individual abatement policies across Annex B countries. These contributions by abating regions provide further insights into the sources of general equilibrium effects and are potentially

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[12] The expansion in energy use by some non-abating countries is by far too small in order to offset the reduced demand by Annex-B countries.

[13] Note that at the global level binding emission constraints induce a welfare loss as it restricts overall ("first-best") production and consumption possibilities (see the bottom row "WORLD" of Table 4).

important for the negotiation of transfer payments at the bilateral level. Application of the HHP decomposition with respect to carbon taxes in Annex B deliver this information. The results, presented in Table 5, show the percentage of the welfare cost for each region (rows) attributable to carbon taxes in each of the Annex B regions (columns). These numbers are obtained along a line integral in which we change the carbon taxes across abating regions at equal rates starting from zero and ending with the final carbon taxes as reported in Table 3.

Table 5: Percentage of the welfare cost for each region (rows) attributable to carbon taxes in each of the Annex B regions (columns)

	CAN	CEA	EUR	JPN	OOE	USA
CAN	92		1	-3		10
CEA	9		11	11	1	67
EUR	-15		264	-23	-4	-121
FSU		-7	18	30	4	55
JPN	-7		-8	165	-4	-47
OOE	1		7	18	58	16
USA	1		-4	-3	-1	107
ASI	10		4	-25	9	102
BRA	10		7	14	1	68
CHN	23	-1	1	-9	3	82
IND	9		7	11	1	73
MPC	8		11	11		70
ROW	7		18	17	1	57

Note that there is no column for Annex B country FSU, simply because FSU does not have to undertake any action in order to meet its Kyoto commitment. Furthermore, a negative sign indicates that the effect of the abatement measure by the column region is contrary to the change in regional welfare of the row region. The diagonal elements for abating regions indicate the percentage of welfare cost which is due to their own action.

First of all, we see that the contribution of a region from its own abatement measure is welfare decreasing. This result confirms basic economic intuition that emission constraints reduce resource productivity and induce income losses. The "own" policy effect varies substantially across abating regions. While own action is very costly for Europe (more than the double of the aggregate welfare loss) it has a negligible effect for CEA. The latter can be explained by the very moderate carbon taxes which are necessary for CEA in order to fulfill its Kyoto commitment. The larger numbers for all other regions reflect much higher carbon tax rates.

Reading Table 5 by rows it follows that action by the USA produces by far the largest spillovers to other countries. This finding is consistent with the fact that USA plays a major role on international markets for fossil fuels and must impose rather high carbon taxes to cope with its Kyoto target. Abatement polices in OOE and CEA on the other hand have very small impacts on other regions which can be traced back to the moderate tax rates joint with small shares in overall trade volumes.

With respect to spillovers from other regions' action we can split the OECD countries in two groups. For USA and CAN the total welfare impacts are rather independent of the abatement activities in other OECD countries. This indicates that action by each of their trading partners in the developed world produce offsetting effects on international markets. On the other hand CEA, EUR, JPN and OOE are rather sensitive to abatement action by their abating trading partners. The welfare implications are however opposite for CEA, EUR and JPN as compared to OOE. While CEA, EUR and JPN benefit from actions of all other OECD countries (in particular from abatement in the USA) the reverse is true for OOE. FSU is negatively affected by spillovers from all OECD countries except for CEA.

Among developing countries IND and BRA gain from action of all OECD countries, whereas the opposite holds for MPC and ROW. ASI and CHN suffer from high carbon taxes in JPN but benefit from carbon taxes in all other countries.

We can translate the above percentage changes in welfare from individual policy action into monetary units. The resulting Table 6 could then be interpreted as a cross-country matrix for transfer payments which have to be assigned on a bilateral basis in order to provide compensation for the Kyoto impacts.

Table 6: Compensating transfers from region (rows) to region (column) in billion dollars annually between 2008 and 2012 (carbon tax policy)

	USA	CAN	EUR	JPN	OOE	FSU
CAN	-0.03					
EUR	1.45	0.22				
JPN	0.96	0.14	-0.13			
OOE	-0.14	-0.01	-0.09	-0.18		
FSU	-0.08		-0.03	-0.05	-0.01	
CEA	0.10	0.01	0.02	0.02		-0.01
CHN	0.16	0.05		-0.02	0.01	
IND	0.08	0.01	0.01	0.01		
BRA	0.12	0.02	0.01	0.03		
ASI	0.23	0.02	0.01	-0.06	0.02	
MPC	-1.46	-0.17	-0.23	-0.23		
ROW	-0.35	-0.04	-0.11	-0.10	-0.01	

In our exposition of compensating transfers we have netted out payments between abating countries such that we derive net transfers in present value terms. A positive entry indicates compensation claims of the row region towards the column region. For example, USA should compensate the OPEC countries plus Mexico (MPC) with roughly 1461 million dollars annually to offset the adverse impact of its abatement policy on that region. Likewise, Europe has to transfer nearly the same amount to the USA to make up for the benefits EUR experiences from USA action

Despite the apparent tidiness of this calculation, there remain substantial uncertainty regarding the estimated values. One key uncertainty concerns the decomposition procedure itself because - as we will see below - the decomposition proposed by Harrison, Horridge and Pearson does not resolve all ambiguities..

Complementary to the decomposition of the total welfare effect using a price instrument (emission taxes) we could just as easily perform the decomposition using a quantity instrument (emission permits). For the latter, we reduce the emission budgets of abating countries in equal proportions, starting from BAU emission levels towards the emission quantities as imposed by the Kyoto Protocol. The quantity instrument produce exactly the same aggregate changes in endogenous variables as the price instrument procedure. However, as indicated by comparing Tables 5 and 7 (or likewise Tables 6 and 8), there are differences in the quantitative estimates for the contributions by individual policy measures.

Table 7: Percentage of the welfare cost for each region (rows) attributable to emission permit systems in each of the Annex B regions (columns)

	CAN	CEA	EUR	JPN	OOE	USA
CAN	78		4			18
CEA	9		12	12	1	67
EUR	-10		214	-17	-2	-85
FSU	-4	-4	26	23	2	57
JPN	-5		-5	141	-1	-30
OOE	2		12	22	35	29
USA	2					98
ASI	10		6	-20	4	100
BRA	10		7	14	1	68
CHN	18		4	-4	2	80
IND	8		7	12	1	72
MPC	8		11	12		69
ROW	7		17	17	1	59

The reason is that the two procedures for approximate the line integrals of individual policy changes follow a different path through the same outcomes. Obviously, the decomposition approach proposed by HHP does not resolve all ambiguities. In our policy application, the qualitative results are largely the same, however there are considerable different magnitudes in welfare changes and associated potential transfer payments. We therefore conclude that while the HHP decomposition procedure is insightful, it does not provide an unambiguous estimate of bilateral transfer payments which would compensate for spillovers from Annex B action.

Table 8: Compensating transfers from region (rows) to region (column) in billion dollars annually between 2008 and 2012 (carbon tax policy)

	USA	CAN	EUR	JPN	OOE	FSU
CAN	-0.04					
EUR	1.21	0.18				
JPN	0.74	0.12	-0.12			
OOE	-0.13	-0.01	-0.08	-0.12		
FSU	-0.09		-0.04	-0.04		
CEA	0.10	0.01	0.02	0.02		-0.01
CHN	0.16	0.04		-0.01		
IND	0.08	0.01	0.01	0.01		
BRA	0.12	0.02	0.01	0.03		
ASI	0.22	0.02	0.01	-0.05	0.01	
MPC	-1.44	-0.17	-0.23	-0.25		
ROW	-0.36	-0.04	-0.10	-0.10	-0.01	

5 Conclusions

In this paper we evaluated the welfare implications of the Kyoto Protocol for the world economy. We used a new decomposition procedure developed by Harrison, Horridge and Pearson to investigate the sources of welfare changes across regions induced by greenhouse gas emission constraints.

Our simulations provide interesting insights into the qualitative interdependencies of multilateral abatement policies. We have shown that the contributions of individual policy changes to the overall effect depend on the policy instrument. When we simply change from a price instrument (taxes) to a quantity instrument (emissions) in order to meet the Kyoto commitments the quantitative decomposition results change. However, the qualitative results remain robust suggesting that the decomposition procedure provides a useful starting point for bilateral negotiations on policy-relevant transfer payments across parties of the Framework Convention.

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Appendix A: Algebraic Model Summary

This appendix provides an algebraic summary of the equilibrium conditions for our comparative-static model designed to investigate the economic implications of the Kyoto Protocol in 2010 as compared to a Business-as-Usual economic development where no carbon abatement policies apply. Before presenting the algebraic exposition we state our main assumptions and introduce the notation.

- Nested separable constant elasticity of substitution (CES) functions characterize the use of inputs in production. All production exhibits non-increasing returns to scale. Goods are produced with capital, labor, energy and material (KLEM).
- A representative agent (RA) in each region is endowed with three primary factors: natural resources (used for fossil fuel production), labor and capital. The RA maximizes utility from consumption of a CES composite subject to a budget constraint with fixed investment (i.e. fixed demand for the savings good). The aggregate consumption bundle combines demands for fossil fuels, electricity and non-energy commodities. Total income of the RA consists of factor income and taxes (including carbon tax revenues).
- Supplies of labor, capital and natural resources are exogenous. Labor and capital are mobile within domestic borders but cannot move between regions; natural resources are sector specific.
- All goods, except for crude oil, are differentiated by region of origin. Nested CES functions characterize the choice between imported and domestic varieties of the same good (Armington). Crude oil is imported and exported as a homogeneous product.

Two classes of conditions characterize the competitive equilibrium for our model: zero profit conditions and market clearance conditions. The former class determines activity levels and the latter determine price levels. In our algebraic exposition, the notation Π_{ir}^{z} is used to denote the profit function of sector *j* in region *r* where *z* is the name assigned to the associated production activity. Differentiating the profit function with respect to input and output prices provides compensated demand and supply coefficients (Shepard's lemma), which appear subsequently in the market clearance conditions. We use *i* (aliased with *j*) as index for commodities (sectors), *r* (aliased with *s*) as index for regions and *d* as index for the demand category ($d=Y$: intermediate demand, $d=C$: private household demand, $d=G$: investment demand, *d=I*: investment demand). The label *EG* represents the set of energy goods and the label *FF* denotes the subset of fossil fuels. Tables A.1 – A.6 explain the notations for variables and parameters employed within our algebraic exposition.

A.1 Zero Profit Conditions

1. Production of goods except fossil fuels:

$$\prod_{ir}^{Y} = p_{ir} - \sum_{j\notin EG} \theta_{jir}\, p_{Yjr}^{A} - \theta_{ir}^{KLE}\left[\theta_{ir}^{E}\, {p_{ir}^{E}}^{1-\sigma_{KLE}} + (1-\theta_{ir}^{E})\left(w_r^{\alpha_{jr}^{L}}\; v_r^{\alpha_{jr}^{K}}\right)^{1-\sigma_{KLE}}\right]^{\frac{1}{1-\sigma_{KLE}}} = 0 \qquad i\notin \text{FF}$$

2. Production of fossil fuels:

$$\prod_{ir}^{Y} = p_{ir} - \left[\theta_{ir}^{Q}\, {q_{ir}}^{1-\sigma_Q} + (1-\theta_{ir}^{Q})\left(\theta_{Lir}^{FF}\, w_r + \theta_{Kir}^{FF}\, v_r + \sum_j \theta_{jir}^{FF}\, p_{Yjr}^{A}\right)^{1-\sigma_Q}\right]^{\frac{1}{1-\sigma_Q}} = 0 \qquad i\in \text{FF}$$

3. Sector-specific energy aggregate:

$$\prod_{ir}^{E} = p_{ir}^{E} - \left\{\theta_{ir}^{ELE}\, p_{\{Y,ELE,r\}}^{A^{1-\sigma_{ELE}}} + (1-\theta_{ir}^{ELE})\left[\theta_{ir}^{COA}\, p_{\{Y,COA,r\}}^{A^{1-\sigma_{COA}}} + (1-\theta_{ir}^{COA})\left(\prod_{j\in LQ} p_{Yjr}^{A^{\beta_{jir}}}\right)^{1-\sigma_{COA}}\right]^{\frac{1-\sigma_{ELE}}{1-\sigma_{COA}}}\right\}^{\frac{1}{1-\sigma_{ELE}}} = 0$$

4. Armington aggregate:

$$\prod_{dir}^{A} = p_{dir}^{A} - \left[\left(\theta_{dir}^{A}\, {p_{ir}}^{1-\sigma_A} + (1-\theta_{dir}^{A})\, {p_{ir}^{M}}^{1-\sigma_A}\right)^{\frac{1}{1-\sigma_A}} + t_r^{CO2} a_i^{CO2}\right] = 0$$

5. Aggregate imports across import regions:

$$\prod_{ir}^{M} = p_{ir}^{M} - \left(\sum_s \theta_{isr}^{M}\, p_{is}^{1-\sigma_M}\right)^{\frac{1}{1-\sigma_M}} = 0$$

6. Household consumption demand:

$$\prod_{r}^{C} = p_{r}^{C} - \left(\theta_{Cr}^{E}\, {p_{Cr}^{E}}^{1-\sigma_{EC}} + (1-\theta_{Cr}^{E})\left[\prod_{i\notin EG} p_{Cir}^{A^{\gamma_{ir}}}\;)\right]^{1-\sigma_{EC}}\right)^{\frac{1}{1-\sigma_{EC}}} = 0$$

7. Household energy demand:

$$\prod^{E}_{Cr} = p^{E}_{Cr} - \left\{ \theta^{E}_{\{ELE,C,r\}}\, p_{ELE,r}^{\;1\text{-}\sigma_{ELE,C}} + (1-\theta^{E}_{\{ELE,C,r\}}) \left[\left(\sum_{i\in EG`\{ELE\}} (\theta^{E}_{iCr}\, p^{A}_{Cir}{}^{\;1\text{-}\sigma_{NELE}}) \right)^{\frac{1}{1\text{-}\sigma_{NELE}}} \right]^{1\text{-}\sigma_{ELE,C}} \right\}^{\frac{1}{1\text{-}\sigma_{ELE,C}}} = 0$$

A.2 Market Clearance Conditions

8. Labor:

$$\overline{L}_r = \sum_i Y_{ir} \frac{\partial \Pi^{Y}_{ir}}{\partial w_r}$$

9. Capital:

$$\overline{K}_r = \sum_i Y_{ir} \frac{\partial \Pi^{Y}_{ir}}{\partial v_r}$$

10. Natural resources:

$$\overline{Q}_{ir} = Y_{ir} \frac{\partial \Pi^{Y}_{ir}}{\partial q_{ir}} \qquad i \in FF$$

11. Good markets:

$$Y_{ir} \frac{\partial \Pi^{Y}_{ir}}{\partial p_{ir}} = \sum_{dj} A_{djr} \frac{\partial \Pi^{A}_{djr}}{\partial p_{ir}} + \sum_{s} M_{is} \frac{\partial \Pi^{M}_{is}}{\partial p_{ir}}$$

12. Sector specific energy aggregate:

$$E_{ir} = Y_{ir} \frac{\partial \Pi^{Y}_{ir}}{\partial p^{E}_{ir}}$$

13. Import aggregate:

$$M_{ir} = \sum_{d} A_{dir} \frac{\partial \Pi^{A}_{dir}}{\partial p^{M}_{ir}}$$

14. Armington aggregate:

$$A_{dir} = \sum_{j} Y_{jr} \frac{\partial \Pi^{Y}_{jr}}{\partial \; p^{A}_{dir}} + C_r \frac{\partial \Pi^{C}_{r}}{\partial p^{A}_{dir}}$$

15. Household consumption:

$$C_r\, p_r^C = (\, w_r \bar{L}_r + v_r \bar{K}_r + \sum_{j \in FF} q_{jr} \bar{Q}_{jr} + t_r^{CO2} \overline{CO2}_r + p_{CGD,r} \bar{Y}_{CGD,r} + \bar{B}_r$$

16. Aggregate household energy consumption:

$$E_{Cr} = C_r \frac{\partial \Pi_r^C}{\partial p_{Cr}^E}$$

17. Carbon emissions:

$$\overline{CO2}_r = \sum_{di} A_{dir} a_i^{CO_2}$$

Table A.1: Sets

i	Sectors and goods
j	Aliased with i
r	Regions
s	Aliased with r
EG	All energy goods: Coal, crude oil, refined oil, gas and electricity
FF	Primary fossil fuels: Coal, crude oil and gas
LQ	Liquid fuels: Crude oil, refined oil and gas
d	Demand categories: Y = intermediate, C = household and I = investment

Table A.2: Activity variables

Y_{ir}	Production in sector *i* and region *r*
E_{ir}	Aggregate energy input in sector *i* and region *r*
M_{ir}	Aggregate imports of good *i* and region *r*
A_{dir}	Armington aggregate for demand category *d* of good *i* in region *r*
C_r	Aggregate household consumption in region *r*
E_{Cr}	Aggregate household energy consumption in region *r*

Table A.3: Price variables

p_{ir}	Output price of good *i* produced in region *r* for domestic market
p_{ir}^E	Price of aggregate energy in sector *i* and region *r*
p_{ir}^M	Import price aggregate for good *i* imported to region *r*
p_{dir}^A	Price of Armington aggregate for demand category *d* of good *i* in region *r*
p_r^C	Price of aggregate household consumption in region *r*
p_{Cr}^E	Price of aggregate household energy consumption in region *r*
w_r	Wage rate in region *r*
v_r	Price of capital services in region *r*
q_{ir}	Rent to natural resources in region *r* ($i \in$ FF)
t_r^{CO2}	CO_2 tax in region *r*

Table A.4: Cost shares

θ_{jir}	Share of intermediate good *j* in sector *i* and region *r* (i$\notin$FF)
θ_{ir}^{KLE}	Share of KLE aggregate in sector *i* and region *r* (i$\notin$FF)
θ_{ir}^{E}	Share of energy in the KLE aggregate of sector *i* and region *r* (i$\notin$FF)
α_{ir}^{T}	Share of labor (*T*=*L*) or capital (*T*=*K*) in sector *i* and region *r* (i$\notin$FF)
θ_{ir}^{Q}	Share of natural resources in sector *i* of region *r* (i$\in$FF)
θ_{Tir}^{FF}	Share of good *i* (*T*=*i*) or labor (*T*=*L*) or capital (*T*=*K*) in sector *i* and region *r* (i$\in$FF)
θ_{ir}^{ELE}	Share of electricity in energy demand by sector *i* in region *r* (i$\notin$FF)
θ_{ir}^{COA}	Share of coal in fossil fuel demand by sector *i* in region *r*
β_{jir}	Share of liquid fossil fuel *j* in liquid fossil fuel demand by sector *i* in region *r* (i$\notin$FF, j$\in$LQ)
θ_{isr}^{M}	Share of imports of good *i* from region *s* to region *r*
θ_{dir}^{A}	Share of domestic variety *i* in Armington aggregate for demand category *d* in region *r*
θ_{Cr}^{E}	Share of energy in aggregate household consumption in region *r*
γ_{ir}	Share of non-energy good *i* in non-energy household consumption demand in region *r*
$\theta_{ELE,C,r}^{E}$	Share of electricity in aggregate household energy consumption in region *r*
θ_{iCr}^{E}	Share of non-electric energy good *i* in the non-electric household energy consumption in region *r*

Table A.5: Endowments and emissions coefficients

$\overline{L}_r$	Aggregate labor endowment for region *r*
$\overline{K}_r$	Aggregate capital endowment for region *r*
$\overline{Q}_{ir}$	Endowment of natural resource *i* for region *r* (i$\in$FF)
$\overline{B}_r$	Balance of payment surplus in region r (note: $\sum_r \overline{B}_r = 0$)
$\overline{CO_2}_r$	Endowment of carbon emission rights in region *r*
$a_i^{CO_2}$	Carbon emissions coefficient for fossil fuel *i* (*i*$\in$*FF*) in demand category *d* of region *r*

Table A.6: Elasticities

σ_{KLE}	Substitution between energy and value-added in production (except fossil fuels)	0.3
σ_{FF}	Substitution between natural resources and other inputs in fossil fuel production calibrated consistently to exogenous supply elasticities μ_{FF} .	μ_{COA}=0.5 μ_{CRU}=1.0 μ_{GAS} =1.0
σ_{ELE}	Substitution between electric and non-electric energy in production	0.1
σ_{COA}	Substitution between coal and liquid fossil fuel aggregate in production	0.5
σ_{M}	Substitution between imports from different regions	8
σ_{A}	Substitution between the import aggregate and the domestic input	4
$\sigma_{ELE,C}$	Substitution between electric and non-electric energy in household energy consumption	1
σ_{NELE}	Inter-fuel substitution in final fossil fuel demand	2

Appendix B: Mapping to GTAP-E Sectors and Regions

The regions and sectors of the model are aggregated from the GTAP-E data base which incorporates most recent harmonized economic and energy data for 45 regions and 23 sectors (see Babiker and Rutherford 1998).

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$TITLE   Aggregation from GTAP_E to 13 regions and 8 goods

Set mapi mapping GTAP-E goods /

GAS.GAS Natural gas works
ELE.ELE Electricity and heat
OIL.OIL Refined oil products
COL.COL Coal transformation
CRU.CRU Crude oil

I_S.EIS Iron and steel industry (IRONSTL)
CRP.EIS Chemical industry (CHEMICAL)
NFM.EIS Non-ferrous metals (NONFERR)
NMM.EIS Non-metallic minerals (NONMET)
TRN.EIS Transport equipment (TRANSEQ)
PPP.EIS Paper-pulp-print (PAPERPRO)

T_T.Y   Trade margins
AGR.Y   Agricultural products
OME.Y   Other machinery (MACHINE)
OMN.Y   Mining (MINING)
FPR.Y   Food products (FOODPRO)
LUM.Y   Wood and wood-products (WOODPRO)
CNS.Y   Construction (CONSTRUC)
TWL.Y   Textiles-wearing apparel-leather (TEXTILES)
OMF.Y   Other manufacturing (INONSPEC)
SER.Y   Commercial and public services
DWE.Y   Dwellings,

CGD.CGD Investment composite /;

SET MAPR  mapping GTAP-E regions /
 AUS.OOE    Australia
 NZL.OOE    New Zealand
 JPN.JPN    Japan
 KOR.ASI    Republic of Korea
 IDN.MPC    Indonesia
 MYS.ASI    Malaysia
 PHL.ASI    Philippines
 SGP.ASI    Singapore
 THA.ASI    Thailand
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VNM.ASI    Vietnam
CHN.CHN    China
HKG.CHN    Hong Kong
TWN.CHN    Taiwan
IND.IND    India
LKA.ASI    Sri Lanka
RAS.ASI    Rest of South Asia
CAN.CAN    Canada
USA.USA    United States of America
MEX.MPC    Mexico
CAM.ROW    Central America and Caribbean
VEN.ROW    Venezuela
COL.ROW    Columbia
RAP.ROW    Rest of Andean Pact
ARG.ROW    Argentina
BRA.BRA    Brazil
CHL.ROW    Chile
URY.ROW    Uruguay
RSM.ROW    Rest of South America
GBR.EUR    United Kingdom
DEU.EUR    Germany
DNK.EUR    Denmark
SWE.EUR    Sweden
FIN.EUR    Finland
REU.EUR    Rest of EU,
EFT.EUR    European Free Trade Area
CEA.CEA    Central European Associates
FSU.FSU    Former Soviet Union
TUR.ROW    Turkey
RME.MPC    Rest of Middle East
MAR.ROW    Morocco
RNF.MPC    Rest of North Africa
SAF.ROW    South Africa
RSA.ROW    Rest of South Africa
RSS.ROW    Rest of South-Saharan Africa
ROW.ROW    Rest of World  /;
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