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Climate Change Policy and Global Trade (CCGT)



Final report on the implementation of the scenario results and the results for emission limitations with flexible mechanisms (ET, JI, CDM) for different trade regimes.

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1. TRADE LIBERALIZATION.

1.1. Introduction.

1.1.1. Foreword

The issue of the reduction of the levels of tariff and non-tariff barriers below the ones corresponding to the GATT agreement of 1994 has been raised in the circles of international organizations such as the WTO, the World Bank, etc. Programs of trade liberalization based on the reduction schedules of Regional Trade Agreements are leading towards the same direction. The expansion of world trade that is expected to take place due to these reductions is considered by the same groups as an important factor contributing to an increase in world production and poverty reduction especially in developing countries.

As occurred when the GATT agreement was under examination, a great number of general equilibrium models has been developed aiming at quantifying the consequences of the possible reductions in trade barriers at regional and global levels. Focusing on providing answers to specific questions brought forward each time in international forums, these models are forced to examine a narrow segment of reductions of tariff and non-tariff barriers regarding either some specific groups of products (agricultural, textiles) or some specific groups of countries (ASEAN, for instance).

On the theoretical level, the existence of tariffs results in a distorted distribution of resources among products and countries. Therefore, if the hypothetical reduction of tariffs leads to a more effective utilization of production resources, an expansion of world trade, and an increase of world output, then their abolition is expected to magnify these results.

On the other hand, it is natural for all countries – and even more for the developing ones – to express their increased concerns for the distribution of the predicted benefits. These concerns are nowadays so strong that, as it has been shown by the failure of the 3rd World Trade Organization Ministerial meeting in Seattle, full liberalization of external trade remains a hypothetical exercise. Nevertheless, such an experiment is of vital importance in order to test the validity of the arguments of each side. These issues will be considered in the analysis of the first part of this chapter.

It is evident that growth without any changes in the production process leads to more pollution. In recent years key among environmental concerns has been the issue of climate change. The elimination of tariff and non-tariff barriers and the imposition of the emissions restriction policy interact in two ways: on the one hand they act competitively. Trade liberalization leads to a higher level of

economic activity by wiping out distortions on the efficient distribution of resources resulting from the imposition of tariffs. The imposition of emission constraints reduces economic activity by introducing what amounts from the purely economic point of view to a distortion in the markets. Given the uneven impact of these two distortionary factors on countries and sectors of production, the first question brought up is which of the factors prevails at the regional and global levels. From another point of view, these factors can be complementary to each other. In view of the imposition of restrictions on emissions, the evolving question is whether the abolition of tariffs facilitates the abatement effort of the countries or not. We deal with these questions in the second part of this chapter.

1.1.2. Brief description of the GEM-E3 model

In order to study the effects of full liberalization of international trade and the restriction of emissions in the post-Kyoto period, the latest version of GEM-E3-World general equilibrium model was utilized [Capros *et al* (1997)]. Before presenting the modifications that were made to the model in order to sufficiently respond to the needs of this study, the most important characteristics of the core model are briefly described.

GEM-E3 is a multi-country applied general equilibrium model covering the world divided in 17 regions (Table 1) that are linked through endogenous trade of goods and services. The model considers 4 economic agents (households, firms, government and foreign) and 18 production sectors (and goods) (Table 2). It is based on an entire representation of a Social Accounting Matrix for each region (including Input-Output table and National Accounts), an Investment Matrix per region, a Consumption Matrix per region, and a Trade Matrix at the World level.

Table 1: GEM-E3 Regional Aggregation.

	Countries and Regions
AUZ	Australia, New Zealand
JAP	Japan
EAS	Korea, Indonesia, Malaysia, Philipinnes, Singapore, Thailand, Vietnam, Hong Kong, Taiwan
CHI	Chine
IND	India, Shri Lanka, Rest of Asia
NAM	USA, Mexico, Canada
LAM	Argentina, Brazil, Chile, Uruguay, Central America and Caribbean, Rest of South America, Rest of Andean Pact
NEU	Denmark, Sweden, Finland
GEU	Germany
BEU	UK
REU	Rest of European Union
OEU	Iceland, Norway, Switzerland, Turkey
CEA	Central European Associates
FSU	Former Soviet Union
NAF	Morocco, Rest of North Africa, Rest of Middle East
AFR	South Africa, Rest of Southern Africa, Rest of Sub Saharan Africa
ROW	Rest of the World

Table 2: GEM-E3 Sectoral Aggregation and COICOP classification.

Products and Sectors	Consumption Categories
1 Agriculture	1 Food, beverages and tobacco
2 Coal	2 Clothing and footwear
3 Oil	3 Housing and water charges
4 Gas	4 Fuels and power
5 Electricity	5 Household equipment and operation excluding heating and cooking appliances
6 Ferrous and non ferrous metals*	6 Heating and cooking appliances
7 Chemical Products*	7 Medical care and health
8 Other energy intensive*	8 Transport equipment
9 Electronic Equipment*	9 Operation of transport
10 Transport equipment*	10 Purchased transport
11 Other Equipment Goods*	11 Communication
12 Other Manufacturing products	12 Recreational services
13 Construction	13 Miscellaneous goods and services
14 Food Industry	
15 Trade and Transport*	
16 Textile Industry	
17 Other Market Services*	
18 Non Market Services	

* Sectors with Imperfect Competition in the modified model

Each productive sector in the core model, which coincides with the column of an Input-Output table, is assumed to consist of virtually infinite number of firms that produce a homogeneous good under perfect competition. The technology of production of all sectors is characterized by constant returns to scale and production functions have nested constant elasticity of substitution specifications. Taking into account the restrictions imposed by technology, each producer tries to maximize his profit and generates a demand for factors of production, which in GEM-E3 are capital, labor, energy, and materials (KLEM-type production function). The quantity of each factor of production is determined endogenously in the model from the interaction of supply and demand in the corresponding markets. In capital markets, the supply of capital for a specific period of time is constant and equal to the stock of capital that is available in the same period. Nevertheless, producers can increase the stock of capital through time by investment expenditures. The ability to invest and, therefore, to determine the available physical stock of capital for the next period is one of the dynamic characteristics of the model.

The investment decisions of producers depend on two factors: the first factor is the quantity of capital possessed by each producer in the current period; the second factor is the desired quantity of capital, which is determined during the profit maximization process, taking into account a longrun rate of return on capital. The model has two options for the determination of this longrun rate of return: it is either determined exogenously, based on the data available in the base year, or it is set equal to the dual price of the restriction of stability in the current account for each country. The desired quantity of capital is also dependent on exogenous expectations about the evolution of the economy. The producer therefore decides for his future investments comparing the desired with the available quantity of physical capital. The model is capable of dealing with neutral technological progress, as well as labor-, capital-, energy-, and material-augmenting technological progress.

Consumption expenditure, in combination with the supply of labor, is determined in the model during the process of the intertemporal utility maximization of the representative household under the intertemporal restriction of its income. This is done through a two-stage maximization: at the beginning, total consumption expenditure and leisure of the households are determined using the steady-state formulation of the above maximization problem. Indirectly at this stage, the aggregate savings and the supply of labor are determined. On the second stage, under the restriction of total consumption expenditures, a static utility function is maximized in order to determine the demand for the 13 consumption categories. With the utilization of the Consumption Matrix, these categories are translated

into demands for the 18 products that correspond to the level of disaggregation used in this version of the model.

Regarding aggregate demand, the GEM-E3 model uses a nested-Armington [Armington (1969)] specification. On the upper level of this aggregate demand function it is supposed that domestic buyers (producers and consumers) use a composite good that combines domestic and imported goods that are considered as imperfect substitutes. On a second stage, imported goods are distinguished depending on their country of origin.

Given the prices of domestically produced goods and imports, the domestic buyer tries to minimize the cost of the composite good based on the above structure, determining in this way the demand for domestically produced goods and imported goods. The demand for exports is also determined endogenously since it follows as the sum of the demand for imports of all other countries for the products of one country.

Government behavior is determined by external factors. Public expenditures are also determined completely exogenously, by supposing that they increase at a specific rate each year.

Prices that clear all markets for goods and factors of production are simultaneously determined with the interaction of the supply and demand functions in the framework defined above.

Except from the transactions related to the production sphere, GEM-E3 also covers the distributive transactions that take place in an economy as they are registered in the lower right part of a Social Accounting Matrix. Institutional sectors (households, firms, government, foreign), apart from income they receive from their endowment in factors of production (wages, rents), are involved in transactions that redistribute income, such as taxes, donations, etc. Taking into account all these transactions (productive and redistributive), the savings of each institutional sector that finance its investments are determined. The surplus of each sector is defined as the difference of its savings and investments; in aggregate though, the sum of the surpluses of all sectors in an economy is equal to zero, satisfying the Law of Walras.

Except from the core model, GEM-E3 embodies an environmental module, which connects economic activity to the emissions caused by the use of coal, crude oil, and gas during their production and consumption processes. In the framework of this model, the effects of environmental policies such as taxation, tradable pollution permits, and global constraints on emissions can be analyzed.

The modifications made in GEM-E3 for the purposes of the CCGT project have to do with the core model, mainly in the production process and the external sector, while leaving unchanged the environmental module.

The first modification refers to the status and technological conditions under which some productive sectors operate. Specifically, it is assumed that the market structure is imperfectly competitive in the sectors that have a large potential for economies of scale [Capros *et al* (1998)]. These sectors – mainly intermediate and equipment goods industries – are assumed to have a finite number of symmetric firms operating in the market under an oligopolistic market regime. The rest of the sectors have infinite firms under perfect competition.

The introduction of economies of scale in the model was made possible through the adoption of the hypothesis that the total cost function is composed of two parts [Pratten (1988)], a part representing the variable cost and a part representing the fixed cost. Production functions remain the same as in the core model and maintain the property of constant returns to scale. Thus the variable cost part is represented by the marginal cost function. Economies of scale are introduced in the analysis with the inclusion of fixed costs in the model. This part of the cost is independent of the level of production; both the average fixed cost and the average total cost are reduced as the level of production increases, with economies of scale emerging in this sector.

The second modification refers to the homogeneity of the goods produced by firms in the sectors that are characterized by imperfect competition. Specifically, it

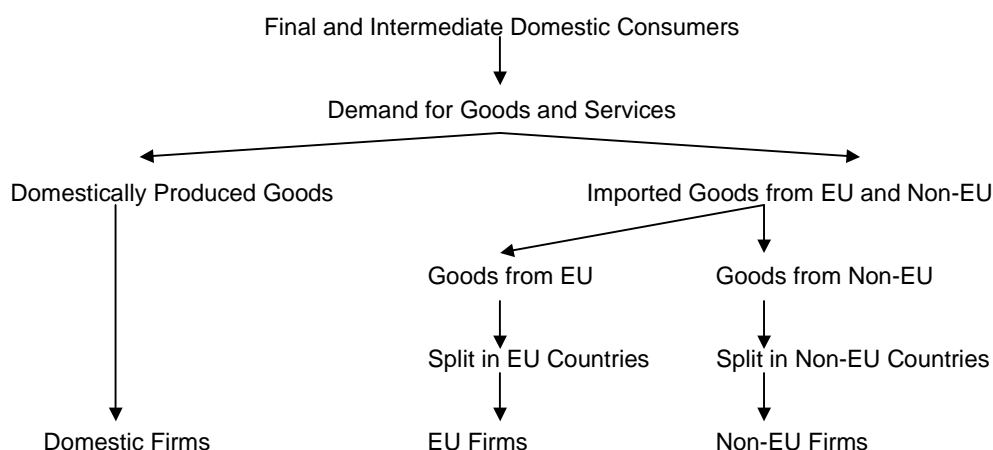
is assumed that firms in these sectors do not produce a homogeneous good but horizontally differentiated varieties of a product. These varieties are assumed to be imperfect substitutes. The existence of many varieties of a good enables a different specialization of demand named in modern economic literature as “love of variety” property [Dixit and Stiglitz (1977)]. According to this theory firms and households love variety and prefer the consumption of two units of different varieties of a product than the consumption of two units of the same variety. The adoption of the product varieties approach is commonly used in current literature because among other things it makes use of a sort of endogenous growth possible; this is obvious if we consider that, according to the “love of variety” approach, the same level of utility can be achieved with a smaller amount of differentiated products.

Another modification made to the core of the GEM-E3 model refers to the pricing policy of the firms in imperfectly competitive sectors. As mentioned above, the number of firms in these sectors is finite. The entry of a firm in such a sector depends on the level of demand its product, which has to cover the total cost of production of this good (fixed and variable). In cases where the demand for the product of this sector is low, the average fixed cost is so big that the newcomer firm ends up with losses. Based on the argumentation above, firms in imperfectly competitive sectors control, to a certain degree, the demand of the sector and have the ability to sell at prices higher than marginal cost. Thus in the model it is supposed that firms in imperfectly competitive sectors price their products setting a mark-up on their marginal cost. This mark-up depends on the perception of the elasticity of demand. Actually the model calculates endogenously three elasticities of demand and, therefore, three mark-up rates. This occurs because the model assumes that the firm sells its products in three markets: home, European, and rest of the world. In this we are incorporating notions of price discrimination. This issue will be brought up in the discussion of the modification of the external sector. The assessment of these three perceived elasticities is made using the Nash-Cournot hypothesis with zero and invariant conjectures. The number of firms existing in each imperfectly competitive sector is also endogenously determined. This is made possible by making the hypothesis that the entry of new firms in a sector is continued until total profits inside the sector turn to zero (Zero-Profit Condition).

The fourth modification refers to the specialization of demand in the model. This change was necessary in order to broaden and diversify the substitution abilities among products of the same sector coming from different origins. In order to be able to distinguish among different origins of imports, a four-level nested-Armington type function is used (Figure 1). On the first level, the domestic consumer of the product has the ability to choose between the domestically produced good and the imported good regardless of origin. On the second level, since the quantity of the domestically produced good is determined, the decision is made for the distribution of demand for the different varieties of the good produced by home firms according to the “love of variety” principle. Also on this level, imports are distinguished between imports from Europe and imports from the rest of the world. On the third level, the distribution of imports from Europe to imports from each country inside the region is made; the same occurs for the imports from the rest of the world. On the fourth level, imports from each country are distributed among the different varieties produced by the firms in this country¹.

Figure 1: Market Segmentation in GEM-E3

¹ The complexity of this structure is due to the need for differentiation of the elasticities of substitution coming from the various origins. Since the Armington aggregator is actually a function with constant elasticity of substitution, using only one nesting level would carry the assumption that goods have the same elasticity of substitution regardless of the country of origin.



1.1.3. Baseline Assumptions

According to the usual practice in general equilibrium models, the first step in the course of a study is the construction of a business-as-usual scenario, the results of which will be the basis of comparison for all alternative scenarios.

In the majority of cases the analysis is made with static models that are applied in only one period. In these cases, the construction of a business-as-usual scenario is limited to the calibration of the parameters of the model using the statistical data of the base year. In this way the model embodies the existing structure of the economy and usually requires no further adjustment. However, the “free trade” and “soft landing” simulations examined in this study require a different sort of treatment. The base year in the GEM-E3 model is 1995 while the simulations examined refer to the post-Kyoto period (2010-2030). Since, GEM-E3 is a general equilibrium model with several recursive dynamic characteristics, a solution to the above problem would be to solve the model for the 1995-2030 period and consider that the results are composites of a business-as-usual scenario. However, such a practice would be a simple transfer of the structural characteristics of the world economy in 1995 to the world economy in 2030. In order to avoid this solution, exogenous predictions for the evolution of some crucial variables such as GDP and CO₂ emissions have been used by modifying in an appropriate way the structure of the economies of the regions of the model. The above modification was made possible by making reasonable assumptions for the exogenous technological progress and the exogenous expectations about the evolution of the economy. Specifically, the predictions for the evolution of GDP during the 1995-2030 period are displayed in Table 3.

Table 3: Reference GDP growth compared to 1995

	1995	2000	2005	2010	2015	2020	2025	2030
Australia	1.00	1.12	1.24	1.39	1.54	1.72	1.92	2.14
Japan	1.00	1.12	1.27	1.42	1.59	1.79	2.00	2.24
East Asia	1.00	1.16	1.35	1.58	1.91	2.46	3.14	4.01
China	1.00	1.19	1.36	1.63	2.04	2.57	3.23	4.14
India	1.00	1.14	1.29	1.52	1.83	2.26	2.83	3.71
North America	1.00	1.15	1.30	1.48	1.69	1.91	2.16	2.45
Latin America	1.00	1.13	1.25	1.40	1.56	1.84	2.19	2.66
Nordic Europe	1.00	1.11	1.22	1.36	1.49	1.66	1.83	2.04
Germany	1.00	1.09	1.21	1.33	1.46	1.63	1.79	1.95
UK	1.00	1.10	1.21	1.35	1.50	1.67	1.83	2.02
Rest of Europe	1.00	1.11	1.25	1.38	1.51	1.66	1.84	2.06
Other Europe	1.00	1.14	1.30	1.49	1.74	2.14	2.64	3.25
Central European Associates	1.00	0.93	1.13	1.39	1.70	2.11	2.60	3.18
Former Soviet Union	1.00	0.92	1.15	1.42	1.69	2.10	2.59	3.17
North Africa	1.00	1.12	1.28	1.50	1.82	2.29	2.90	3.73
Africa	1.00	1.19	1.42	1.70	1.98	2.39	2.88	3.54
ROW	1.00	1.13	1.26	1.44	1.65	2.06	2.57	3.15

The evolution of CO₂ emissions was provided by the POLES model (Table 4).

As regards tariff and non-tariff barriers, the application of the rules according to the decisions of international agreements valid as of today is assumed in the business-as-usual scenario.

The basic hypothesis at the world level is that there exists full implementation of the commitments that have been agreed at the Uruguay Round. The most important pieces of information that can be quantified in the framework of the Uruguay Round are tariff and non-tariff barriers imposed on international trade at the world level.

Only the most important regional trade agreements from the viewpoint of international trade have been retained in the business-as-usual scenario.

Furthermore, it is assumed that China joins the WTO by 2005.

Table 4: Reference growth of CO₂ emissions compared to 1995

	1995	2000	2005	2010	2015	2020	2025	2030
Australia & New Zealand	1.00	1.16	1.19	1.26	1.39	1.48	1.65	1.90
Japan	1.00	0.97	0.94	0.95	0.98	1.00	1.03	1.05
East Asia	1.00	1.19	1.37	1.66	2.04	2.45	2.99	3.53
China	1.00	1.24	1.70	1.99	2.27	2.54	2.85	3.22
India	1.00	1.32	1.88	2.41	3.03	3.70	4.40	5.12
North America	1.00	1.11	1.13	1.20	1.26	1.32	1.36	1.42
Latin America	1.00	1.21	1.28	1.53	1.79	2.07	2.36	2.67
Nordic Europe	1.00	1.13	1.13	1.19	1.31	1.31	1.38	1.38
Germany	1.00	0.99	0.92	0.93	0.97	0.99	1.01	1.00
UK	1.00	1.04	1.02	1.04	1.09	1.15	1.18	1.24
Rest of Europe	1.00	1.08	1.10	1.14	1.20	1.24	1.26	1.27
Other Europe	1.00	1.17	1.29	1.46	1.67	1.88	2.13	2.42
Central European Associates	1.00	0.94	0.94	1.00	1.07	1.13	1.18	1.26
Former Soviet Union	1.00	0.87	0.83	0.93	1.09	1.23	1.35	1.44
North Africa	1.00	1.20	1.29	1.46	1.67	1.91	2.16	2.46
Africa	1.00	0.95	1.29	1.74	2.29	2.86	3.62	4.36
Rest of the World	1.00	0.93	1.20	1.53	1.93	2.47	2.93	3.27
Annex B	1.00	0.97	0.96	1.01	1.10	1.17	1.24	1.29
TOTAL	1.00	1.10	1.21	1.35	1.52	1.68	1.86	2.04

In both the business-as-usual and the policy scenarios special care has been given to the current account of each country, which is significantly affected due to the nature of the exercises of this study. A reduction of tariffs would very probably cause a continuously increasing deficit in the balance of payments mainly for the developing countries. This point is also – directly or indirectly – a permanent source of debate in the negotiations for further liberalization in international trade in the WTO framework. In order to avert such an evolution in the simulations of the model, it was assumed that the ratio of the current account to GDP remains constant for developing countries for the entire time period under examination. For each country this ratio is equal to the corresponding ratio in 1995, which has been calculated using actual data. The introduction of this restriction to the model results in the endogenization of the longrun rate of return on capital, as it has been explained in section 1.2. The longrun rate of return on capital affects directly the demand for investment and the demand for durable consumption goods, and indirectly the demand for imports. Thus when the ratio of the current account to GDP tends to diverge from the predefined level, the model increases or decreases imports in order to neutralize such a phenomenon.

1.2. “Full Liberalization” scenario

1.2.1. “Full liberalization ” Scenario Assumptions

An experiment assuming totally free trade was designed in order to study the distortion introduced by trade barriers to the world level of production and the resulting welfare losses, as well as to focus on the differences in environmental damages from the evolution of the world trade institutional regime.

The elimination of tariff and non-tariff barriers will normally lead to a reduction in government revenues. In some developing countries, government revenues from tariffs are as high as 10% to 20% of total government revenues. In some studies similar to the present, the need for the imposition of other supplementary measures in order to compensate for the loss of government revenues due to the tariff abolition is discussed [Weisbrot and Baker (2002)]. The lack of counterbalance measures in the presence of a hypothetical elimination of tariffs will result in the overestimation of the benefits from free trade because, in

essence, this is equal to the provision of consumers with an additional exogenous income. For this reason in most of the models it is assumed that, in parallel to the elimination of tariffs, a lump-sum tax providing the same amount of revenues to the government is imposed. The imposition of another kind of tax on products (sales tax) is not considered appropriate because these taxes distort the distribution of resources. Theoretically, therefore, it would be meaningless to replace the distortionary role of tariffs with an equally distortionary role of taxes on products. The adoption of a lump-sum tax, although it can be introduced in a model relatively easily, is a simplification that is not very realistic. The way that this issue is treated in this study is the following: Three types of buyers of imported goods that benefit from tariff abolition are examined in the model; households that purchase imported consumption goods, producers that import intermediate inputs, and the government that imports public consumption goods. In order to treat the benefit from the elimination of tariffs in a neutral way, we compensate the benefits of all three types of buyers for a reduction on their level of income. This is achieved by increasing the income tax rate for households and firms and reducing public expenditures in a way that the budget deficit of each country remains the same as in the business-as-usual scenario.

1.2.2. Policy Shocks and Transmission Mechanisms in the GEM-E3-Model

In order to provide insights on the way that the GEM-E3 model responds to the abolition of tariff and non-tariff barriers, the adjustment process of the model following the initial shock is described in Figure 2. The variables, the values of which will initially diverge from the ones of the baseline, are the following:

1. Prices of imports, which will be reduced by the amount of the corresponding tariff rates according to the hypotheses of the scenario, and
2. Capital inputs, which are increased compared to the baseline because the elimination of tariffs in 2010 results in the increase of investments for the period 2010-2030.

In order to decompose the results caused by each of the above factors, it is assumed that no increase of capital inputs takes place initially.

1.2.2.1. A Reduction of the Prices of Imports due to the Elimination of Tariffs

According to the hypotheses of the model, imported quantities of each product are combined with the corresponding domestically produced quantities of the same product through a function of Armington type so as to form a composite good, which is then allocated to consumption, intermediate inputs, and investments.

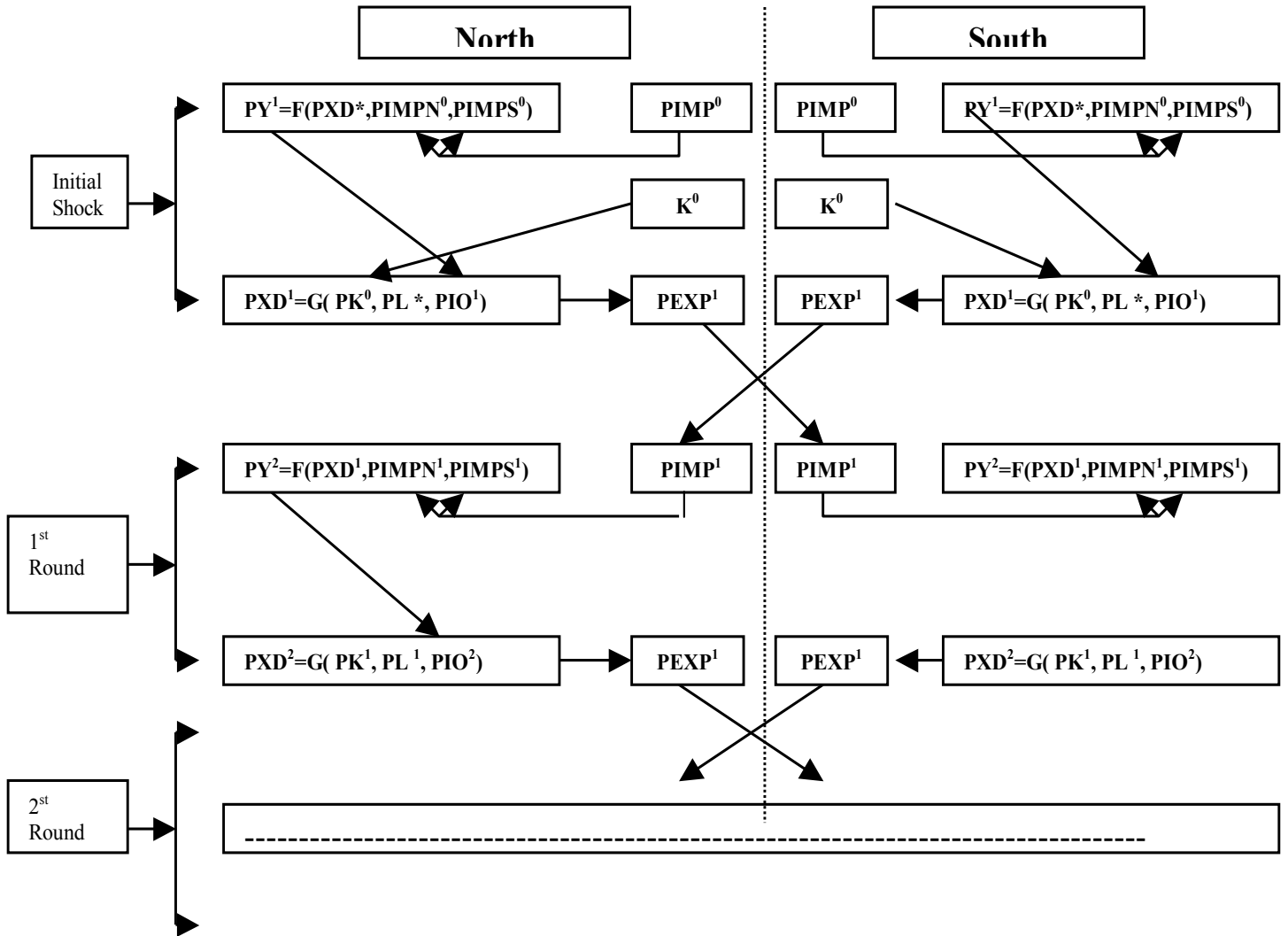
In Figure 2 the total imports of product i (with price $PIMP^0$) are distinguished, for the sake of the clarity of the presentation, into imports from the North (with price $PIMP^N^0$) and in imports from the South (with price $PIMP^S^0$). During the initial perturbation the price of the domestically produced good i (PXD^*) remains constant, therefore the price of the composite good i (PY) decreases due to the reduction of the prices of the imported goods.

The decrease in the price of the composite good i depends on the following factors:

- The amount of the reduction in the price of imports.
- The elasticities of substitution among goods i with different origin in the Armington function.
- The value shares of goods i with different origin.

Given the differentiation of the above factors by region and good, general conclusions for the exact amount of the reduction of the price of the composite good cannot be drawn.

Figure 2: The Adjustment Process in GEM-E3



However, it can be concluded with certainty that the reduction of the price of the composite good will be smaller in size than the corresponding reduction in the price of imported products, assuming that there exists a fraction of the composite good that is produced domestically.

More specifically, the higher the value share of the domestically produced good in the total value of the composite good, the smaller is the decrease in the price of the composite good compared to the reduction of the price of the imported goods. In a similar way, the reduction of the price of the composite good i is affected more from the reduction of the price of imports from the country with the bigger value share in the total value of the composite good.

Knowing the reduction of the price of the composite good i at the initial shock and without possessing additional information, the direction of the change in the quantity demanded for the composite good i cannot be foreseen *a priori*. The reductions of the prices of all goods are not uniform due to the different tariff

rates, resulting in a substitution effect that decreases the quantities demanded for the goods the prices of which have been reduced less than others. Nevertheless, it can be generally said that the reduction of the prices of imports will cause a substitution of the domestically produced good, increasing (decreasing) the demand for imports more (less) than the demand of the domestically produced good.

As far as production is concerned, products are considered by the model to be produced using technology described by a constant elasticity of substitution (CES) production function that combines capital, labor, and intermediate consumption.

After the initial disturbance, the model goes through a second cycle of adjustments with the production functions as the main axis. Given the payments to capital (PK^0)², labor (PL^*), and the domestic production (PXD^*), the reduction – from the previous stage – of the prices of the intermediate inputs (PIO^1) result in the reduction of the marginal cost of production of all goods. An additional effect is the reduction of the fixed cost in the sectors that are structured in a monopolistically competitive way. This reduction of cost generates excess profits in all sectors and, therefore, leads to the entry of new firms in the markets. These adjustments result in the reduction of the price of domestic production PXD^* . Using the same arguments, the reduction of the price of domestic production will be smaller than the reduction of the price of intermediate inputs. Furthermore, the bigger the value shares of intermediate inputs in the total value of production, the bigger this reduction will be. The increase or decrease in production of specific products cannot be foreseen without knowing the conditions of substitution of goods in the various uses. Regarding quantities of the factors of production demanded, labor and capital will be partially substituted and so the demand for these inputs will increase less (decrease more) compared to the demand for intermediate inputs.

The reduction in the price of production of a good leads, according to the hypotheses of the model, directly to the decrease in the price of exports (for the exporting country) and the price of imports (for all other countries). At that point a new round of adjustments – with the same qualitative characteristics as the previous round but with smaller reductions in prices – is initiated. This procedure is continued until a new equilibrium is found in the model.

1.2.2.2. An Increase in the Initial Capital Inflow.

In this case we suppose that the prices of imported goods remain stable, therefore the initial disturbance is created in the domestic production of goods where, given the quantities of labor and intermediate inputs to the production of a good, the increased supply of capital leads to a reduction in its price as well as the price of production of all goods. The reduction in the price of production is smaller than the reduction in the return on capital and is higher when the value share of capital in the total value of production is high.

Referring to external trade, the reduced price of production of a good results, according to the hypotheses of the model, in a reduction of the price of exports in the country that produces the good and, therefore, in a reduction of the price of imports in the country that imports the good. If we take import prices as given, the reduction in the price of domestic production leads to a smaller reduction (in percentage terms) of the price of the composite good that can be used for domestic demand.

An *a priori* prediction of the quantity of a product produced cannot be made without the prior knowledge of the quantitative changes that take place. In the market of factors of production there is a partial substitution of labor and intermediate inputs that increase (reduce by a smaller percentage) the demand for capital compared to the demand for the other factors of production.

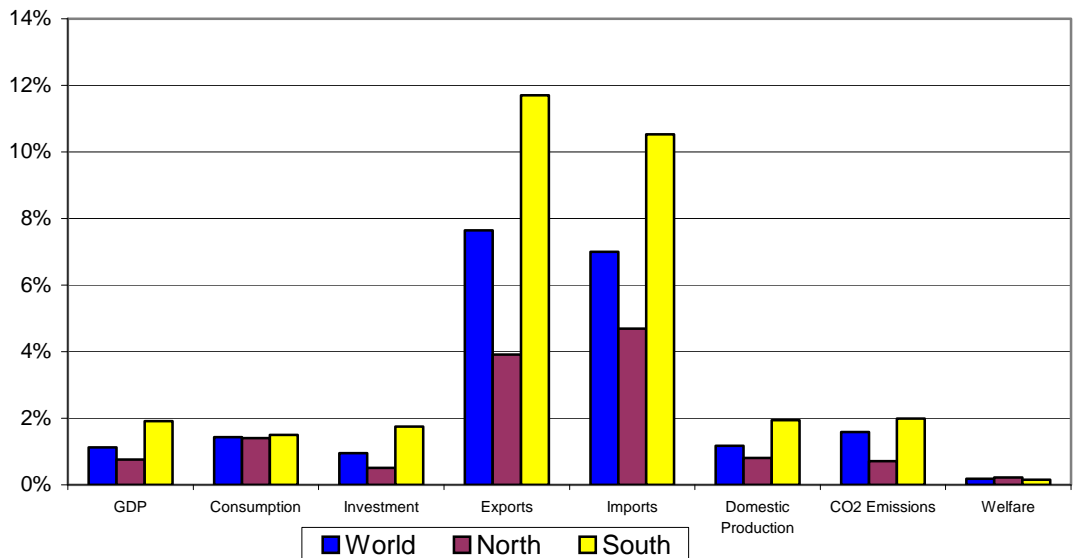
² It is supposed, as previously, that the initial stock of capital remains the same.

1.2.3. Aggregate Macroeconomic Results at the World Level

The simulated results concerning the main macroeconomic magnitudes at the world level due to the elimination of tariffs are presented in Figure 3. The main finding of the “full liberalization” scenario is that the total elimination of tariffs leads to an increase of world GDP and welfare level; this is even stronger in the developing countries. More specifically, world GDP increases by 1.1% compared to the baseline. The GDP in countries of the so-called South grows at about double that rate (1.9%) of the so-called North (0.8%). The main factor contributing to this is the redistribution of world trade in favor of the countries of the South.

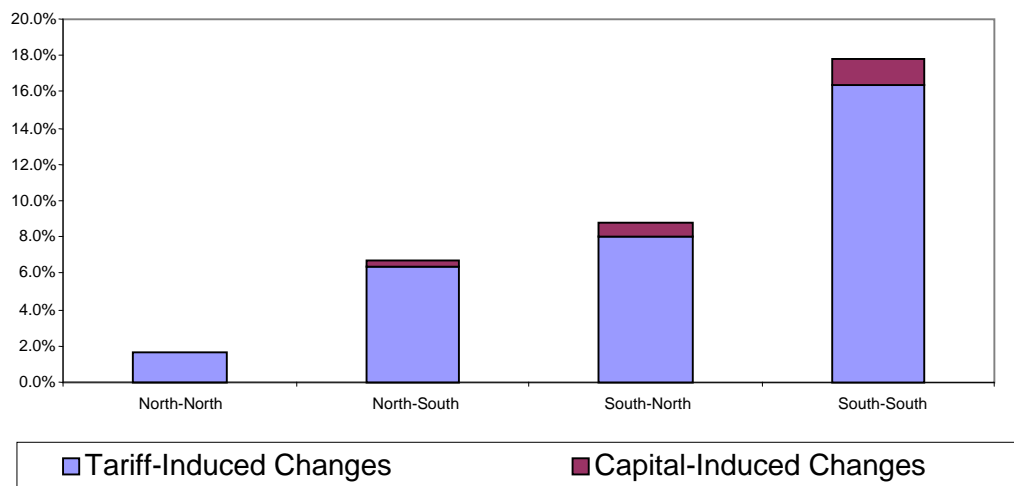
The exports of the South increase at a higher rate than its imports contributing to the increase of GDP. On the other hand, the imports of the North increase at a higher rate than its exports, thus moderating the GDP increase in the countries of the North. Moreover, the improvement of the trade balance of the South compared to the North creates the relatively higher increase in the domestic production and investments in the South.

Figure 3: Full Liberalization scenario (% changes from baseline in 2030).



A more detailed analysis of the redistributions in international trade as simulated by the “full liberalization” scenario is conducted with the assistance of Figure 4. Most of the increase in exports (and imports) of the South is due to the increase of the trade among the countries of the South that increases faster than all other bilateral transactions. The increase of the total exports of the North is mainly due to the increased exports to the South and less due to the increase in the trade among the countries of the North. It is also obvious that the improvement in the trade balance of the South is due to the relatively higher increase of the exports of the South compared to the increase of the imports from the North.

Figure 4: Full Liberalization scenario: Exports (% changes from baseline in 2030)



The direction of these results can be explained using the arguments of Section 1.2.2. The average percentage of tariffs imposed by developing countries on their imports are almost three times as much as the corresponding percentages in the countries of the North. In general, developing countries impose higher tariffs on their imports compared to the countries of the North in all categories of products both to collect money and to protect the domestic industries from competition. Tariffs on traditional (agricultural, textile, and food) products are also significantly higher than the tariffs imposed on industrial products; it is therefore logical for the transactions among countries of the North to have a small tariff rate because they are composed mainly of industrial products. The average tariff rate for the imports of the North from the South is higher because these transactions are mainly composed of traditional products. Following the same reasoning, the highest average tariff rate is imposed on the transactions among the countries of the South that are composed of agricultural products foods and textiles.

Table 5: Initial changes in import prices and capital volume (2030)

	North-North	North-South	South-North	South-South
% Import price change due to tariff abolition	-2.8	-3.3	-9.2	-12.1
Value shares of imports to total domestic demand (%)	4.5	3.9	9.3	5.2
Value shares of domestically produced goods to total domestic demand (%)	91.6			85.5
% Change in Capital volume	0.5			1.5
Value share of capital to total value of domestic production (%)	15.9			21.4
Value share of Labour to total value of domestic production (%)	44.8			33.5
Value share of intermediate consumption to total value of domestic production (%)	39.3			45

The initial reduction in the price of imports, which creates the strongest effects, will be proportionate to the reduction of tariffs in each market. Therefore, based on the data of Table 5, the prices of the imported goods from the South decrease more than the prices of the imports of the North in all markets. The most significant initial reduction (12.1%) is observed in the trade prices among the countries of the South.

Table 6: % Changes from baseline in the volumes and prices of imports (2030)

	% changes from baseline					
	Tariff Abolition effect		Capital increase effect		Total effect	
	North Imports	South Imports	North Imports	South Imports	North Imports	South Imports
	(1)	(2)	(3)	(4)	(5)	(6)
Volumes						
North exports	1.6	6.4	-0.1	0.4	1.5	6.8
South exports	7.9	16.2	0.7	1.4	8.6	17.5
Prices						
North exports	-3.6	-10.1	0.3	0.2	-3.2	-9.9
South exports	-6.0	-14.9	0.0	0.0	-6.0	-14.9

In Table 6 (columns 5 and 6) are presented the final reductions in the import prices resulting from the simulation under the hypothesis of full tariff abolition. The prices of imported goods decrease in all regions more than the initial reductions due to secondary effects. A comparison of the changes of import prices in Table 5 and Table 6 lead to the conclusion that the secondary effects enhanced the relative reduction of the prices in favor of Southern exports. Consequently, the substitution effects in all markets result in a higher increase of the exports of the South. In Table 6 it is shown that exports of the South to the North increase by 6.8% while the trade among the countries of the South increases three times more.

Table 7: % Changes from baseline in the prices and volumes of domestic demand and production (2030)

	% changes from baseline					
	Tariff Abolition effect		Capital increase effect		Total effect	
	North	South	North	South	North	South
	(1)	(2)	(3)	(4)	(5)	(6)
Volumes						
Domestically Produced goods	0.5	-0.9	0.1	0.7	0.5	-0.3
Domestic Demand	0.8	1.0	0.1	0.6	0.9	1.6
Prices						
Domestically Produced goods	-0.9	-2.5	0.3	0.0	-0.6	-2.5
Domestic Demand	-1.2	-4.1	0.3	0.1	-0.9	-4.1

Similarly, the price of domestic supply decreases more in the markets of the South for two reasons: the first refers to the relatively bigger decrease in the prices of imported goods; the second is that the domestically produced goods have a smaller value share in the South than in the North. The reduced price of the domestic supply, which results after the initial perturbation, causes the reduction of the price of domestic production and exports in the following way: if we ignore initially the increased capital inflow, the reduction of the price of the domestic supply of goods will lead to a substitution of labor and capital for the less expensive intermediate uses in the production process.

The reduction of the price of domestic production and exports is bigger for the South, at this stage of adjustments, for two reasons: the first is that the price of intermediate uses is reduced, according to the arguments stated above, more in the South; the second is that the value share of the intermediate uses is higher in

the production of the South. This is logical if we take into account that the production process of the South is less efficient and therefore more expensive in terms of material inputs. The amounts of these changes are presented in Table 8 (columns 1 and 2). The volume of production in the South is increased by 1.9% in order to satisfy the increased demand for exports that has covered the small reduction of domestic demand. The increase of production is powered by the increased utilization of intermediate inputs by 1.2% and the increased inputs of labor by 0.7%. The substantial reduction of 4.3% in the prices of intermediate inputs resulted in the substitution of capital and labor inputs. It can also be inferred that the substitution effect in the production of the South is stronger than the positive income effect, resulting in lower returns on capital and labor by 0.1% and 1.4% respectively.

Table 8: % Changes from baseline in production function variables (2030)

	% changes from baseline					
	Tariff Abolition effect		Capital increase effect		Total effect	
	North	South	North	South	North	South
	(1)	(2)	(3)	(4)	(5)	(6)
Volumes						
Capital	0.0	0.0	0.4	1.7	0.4	1.7
Labour	0.0	0.7	0.1	0.5	0.0	1.2
Intermediate Consumption	0.6	1.2	0.1	0.8	0.7	2.0
Domestic Production	0.7	1.2	0.1	0.7	0.8	1.9
Prices						
Capital	0.3	-0.1	-0.4	-2.9	-0.1	-3.0
Labour	0.2	-1.4	0.4	1.4	0.7	0.1
Intermediate Consumption	-1.2	-4.3	0.3	-0.1	-1.0	-4.4
Domestic Production	-0.8	-2.8	0.3	0.0	-0.5	-2.9

The production of the North increases by 0.7% mainly due to the increased contribution of intermediate inputs by 0.6%. In contrast to the South, the positive income effect is greater than the substitution effect, resulting in increased returns to capital and labor by 0.3% and 0.2% respectively.

Similar results have been obtained for the adjustments made in the categories of demand other than exports. The reduction in the price of goods creates a positive income effect³ in the level of consumption, which contributes to increased consumption in both the Northern and the Southern markets. This result is further enhanced from the increase in income caused by the expansion in production. In the same way, the increase in demand leads to the entry of new firms and, therefore, in the increase in the demand for investments. It follows from the above arguments that the South will have a bigger increase in demand for investments.

According to the hypotheses of the scenario, the elimination of tariff rates takes place in 2010, thus the increased investments in the subsequent years generate an increased quantity of capital. The qualitative characteristics of the adjustments created by the elimination of tariff rates are the same for all this period. It is reasonable therefore for the investments in the South to increase faster. The total increase of capital is 1.7% for the South and 0.4% for the North compared to the baseline (Table 8). The capital increase in the South results in a significant reduction in the return on capital, which, in addition to the lower returns due to tariff abolition, leads to a final decrease of 3% in its price. On the other hand, the higher volume of capital increases the demand for labor, which leads to higher wages; however, due to the lower price of labor that resulted from the elimination of tariffs, the final increase in wages is only marginal. The capital increase in the North has the same impact on the returns on capital and wages as in the South,

³ When we refer to the positive income effect, we imply the one resulting from secondary adjustments. The income effect from the initial shock has been compensated from the increased income tax rate.

though less pronounced. However, because of the higher demand for labor and capital that results from the tariff abolition which increases the prices of both factors of production, the final impact is a marginal decrease in the return on capital and a noticeably higher increase in wages than that in the South. Thus the negative impact from the increased demand for capital on the return on capital is enough to compensate for the positive income from free trade in the North, enhances the negative impact from trade liberalization in the South, and favors wages in both regions.

1.2.4. Sectoral Results at the World Level

At the sectoral level, the results of the simulation for the world are presented in Table 9. The elimination of the substantial tariff burden faced by the traditional sectors (agricultural, textiles and food products) results in the substantial increase of international trade for these products. Therefore, it is important to highlight that imports of agricultural products increase by 24.4% while imports of food products and textiles by 10.7% and 9.4% respectively. It has to be noted that the average tariff rates for these product categories at the world level are as high as 17.5% for agricultural products, 14.5% for food products, and 11% for textiles. The cumulative increase of capital during the period 2010-2030 has enhanced these results, increasing world trade by 1.1% in agricultural products and about 1% in food products. The effects of this capital increase in the trade of textiles are substantially smaller (0.3%).

Table 9: % Changes from baseline in world sector variables (2030).

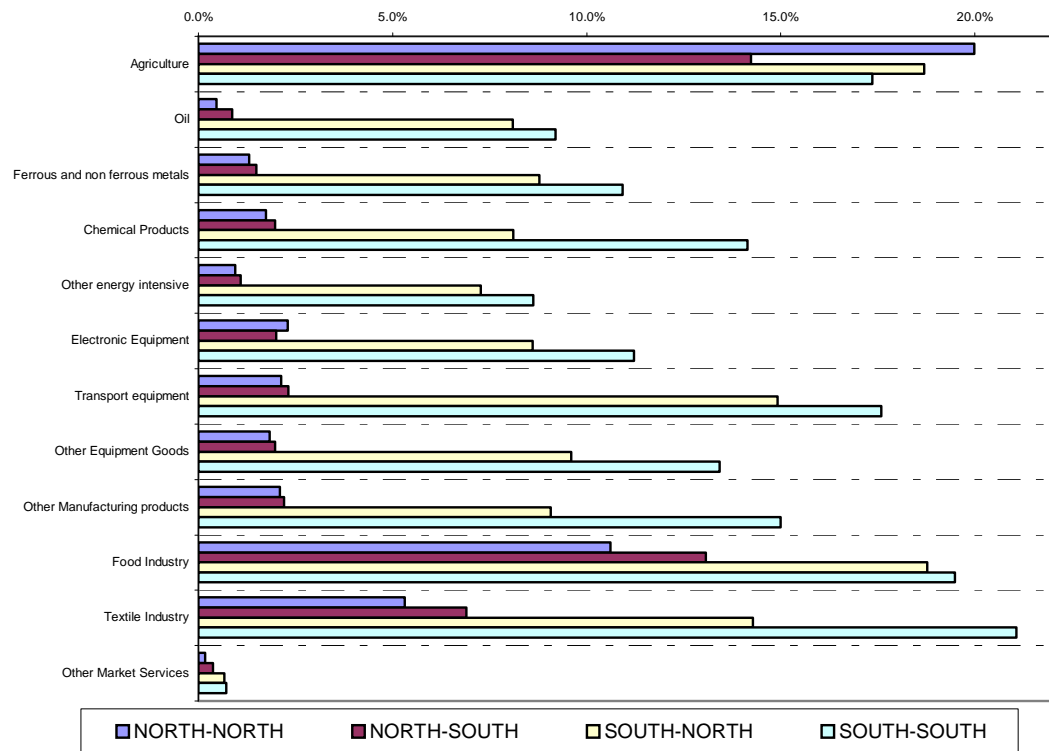
Product	% changes from baseline					
	Imports			Domestic Production		
	Tariff Abolition effect	Capital increase effect	Total effect	Tariff Abolition effect	Capital increase effect	Total effect
	(1)	(2)	(3)	(4)	(5)	(6)
Agriculture	24.4	1.1	25.5	0.6	0.7	1.3
Oil	2.5	0.2	2.7	0.3	0.6	0.9
Ferrous and non Ferrous metals	6.9	0.6	7.5	0.1	0.5	0.6
Chemical Products	7.1	0.6	7.7	0.8	0.5	1.2
Other energy intensive	5.2	0.9	6.2	0.2	0.5	0.7
Electronic equipment	5.8	0.3	6.1	0.9	0.2	1.1
Transport Equipment	9.7	0.0	9.7	1.0	-0.1	0.9
Other Equipment Goods	6.3	0.5	6.8	0.3	0.4	0.7
Other Manufacturing Products	10.2	0.6	10.8	0.6	0.5	1.1
Food industry	10.7	0.8	11.5	1.5	0.5	2.1
Textile industry	9.4	0.3	9.7	2.7	0.4	3.1

The highest increase in trade for industrial products is observed in “Other Manufacturing Goods” (10.2%) and in the “Transport equipment” category (9.7%).

The textiles sector, according to Table 9, increases production at the world level by 3.1%, percentage that is the highest among all other sectors. The food sector follows with a 2.1% and the agricultural sector with a 1.3% increase. As far as the non-traditional sectors are concerned, the highest increases in production are in the “Chemical Products”, “Electronic equipment” and “Other Manufacturing Goods” categories with 1.2% and 1.1% respectively.

An analysis of the structure of tariff rates both in sectoral and in regional levels is needed prior to providing an explanation for these results and analyzing the reallocation of external trade and production. Figure 5 assists in this analysis.

Figure 5: Full Liberalization: average tariff rates (2030).

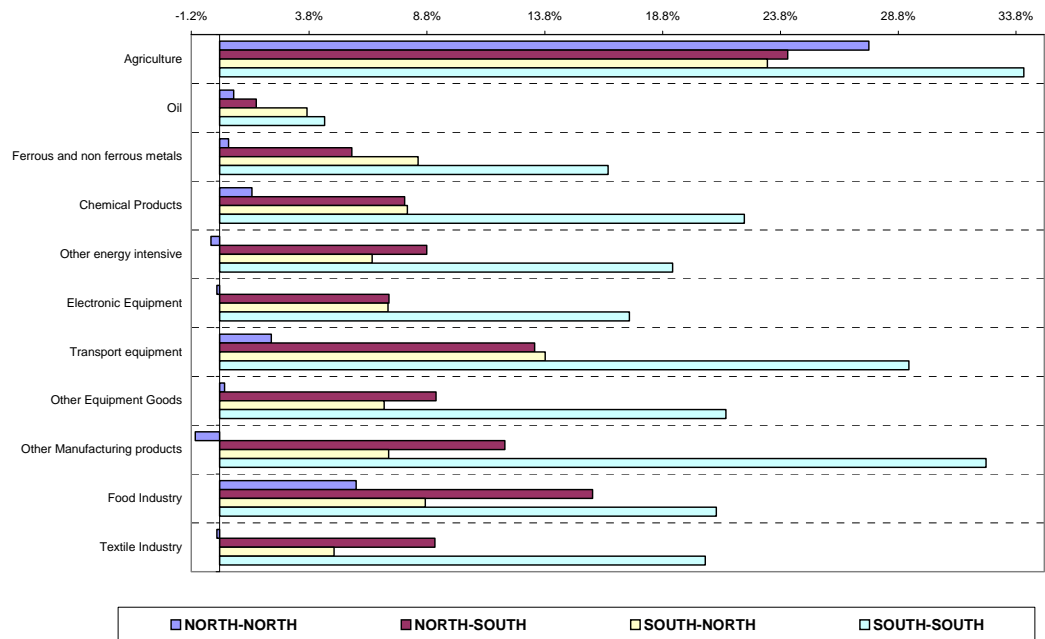


An observation of Figure 5 reveals an enormous differentiation of the tariff rates not only among products but also among regions. Referring to products, tariff peaks⁴ are a characteristic of traditional products (agricultural, food, textiles) in all regions. As far as the regions are concerned, it is obvious that the developing countries of the South impose significantly higher tariffs compared to the developed countries of the North. In reality, the majority of the products imported from the countries of the South face tariff peaks, with the textiles as the most marked case; these peaks in the trade among countries of the South exceed 20%. Another characteristic case is agricultural products that face the highest tariff rates in the trade among countries of the North. Moreover, the agricultural products are the only case that the North imposes higher tariff rates than the South. An example is the high protection of US products from European exports. Tariffs imposed on industrial products, except from food products, by the countries of the North are below 5%. With the exception of the “Electronic Equipment” category, imports of the North from the South have higher tariff rates than the imports among the countries of the North. On the other hand, with the exception of agricultural products, tariff rates imposed on trade among countries of the South are higher than the tariff rates imposed on imports of the South from the North.

The changes in imports from baseline due to the tariff abolition are shown in Figure 6. In general, this tariff structure determines the pattern of the substitutions taking place in the world market in the simulations.

⁴ Tariff peaks are conventionally defined to be tariffs exceeding 15%.

Figure 6: Full Liberalization (% Changes of the volume of imports from baseline in 2030).



Two general observations can be made with the assistance of this diagram: the first relates to the developing countries. For almost all goods, trade among countries of the South displays the highest increases. Apart from the increase in the agricultural products sector (33.5%), a significant increase is observed in the trade of “Other Manufacturing Goods” (32.6%), “Transport equipment” (29.3%), and “Chemical Products” (22.6%) categories; these results accord with the tariff structure described above. It has to be noted that trade among countries of the South increases more than 15% for all goods but oil. The second observation concerns only developed countries: excluding agricultural products, the highest rates of increase for all product categories are observed in imports of the North from the South. Apart from the food products that show the highest increase of 15.8%, substantial increases are achieved in the imports of “Transport equipment” (13.5%) and “Other Manufacturing Goods” (12.6%) products categories.

1.2.5. Aggregate Macroeconomic Results at the Regional Level

According to the economic theory, full liberalization of world trade results in the increase in world economic activity. This increase is mainly due to:

- a. The distortion of the distribution of resources both at sectoral and regional levels due to the existence of tariffs, the elimination of which forces each country to specialize in the production of goods in which it has a comparative advantage. In such a way with the same quantity of factors of production it is possible to produce an increased quantity of all goods at the world level.
- b. The income effect resulting from the reduction of prices of imported goods: with a given level of income consumers can purchase more goods after the elimination of tariffs. The increased demand leads to increased production under the assumption that there are underutilized factors of production that are mobilized towards covering the increased needs. In the design of the scenario it has been assumed that a large portion of this income effect is compensated by the increase in income tax rates in

order for the public budget to remain the same as in the baseline. Nevertheless, the increased economic activity generated due to the more effective distribution of resources increases tax revenues, partially compensating the loss of revenues from the elimination of tariffs. Thus the tax rates do not increase so much as to totally wipe out the income effect from the elimination of tariffs but enough to cover the difference.

The distribution of increased world activity in the various regions of the world depends on the weight of these two factors in each country. In order to explain the results of the simulation, some indications for the above factors are presented in Table 10.

Table 10: Aggregate macroeconomic results at the regional level (2030)

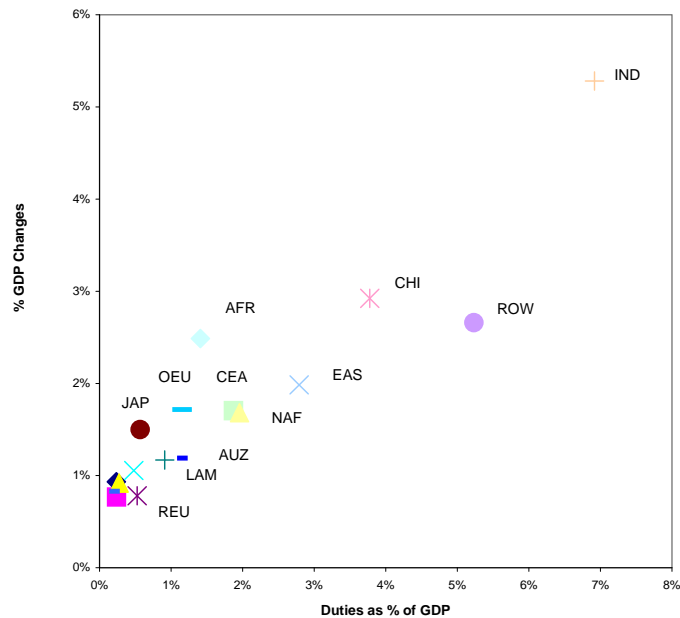
	Average Duty Rate (%)	Change in capital volume (%)	% changes from baseline			
			GDP	Exports	Imports	Domestic Production
			(1)	(2)	(3)	(4)
Australia	5.9	0.9	0.9	4.3	7.3	0.9
Japan	8.2	0.6	1.4	7.2	9.3	1.4
East Asia	7.9	1.0	1.8	9.8	8.8	2.0
China	18.4	2.0	2.9	20.4	23.4	3.0
India	28.2	8.1	5.1	40.8	31.0	4.7
North America	3.0	0.3	0.5	4.5	5.0	0.5
Latin America	8.3	0.5	0.9	10.9	9.0	0.9
Nordic Europe	1.2	0.5	0.6	1.6	2.6	0.7
Germany	1.4	0.4	0.6	2.3	3.2	0.7
UK	2.1	0.6	0.8	1.9	3.7	0.8
Rest of Europe	2.1	0.4	0.4	2.9	3.9	0.8
Other Europe	4.6	0.4	1.5	4.4	3.8	1.4
Central European Associates	6.5	1.2	1.5	8.1	5.7	1.5
Former Soviet Union	1.2	0.6	0.6	1.5	2.5	0.5
North Africa	6.4	0.6	1.4	6.6	5.9	1.3
Africa	5.7	2.4	2.1	6.3	6.5	1.9
Rest of the World	24.8	1.1	2.9	40.9	21.3	2.2

The average tariff rates on imports in each region of the world are presented in column 1 of Table 10. Developing regions such as India, the Rest of the World, and China apply a higher tariff protection on their imports, which is expressed through average tariff rates almost 20 times higher than those of the European countries. Among developed countries, Japan has the highest average tariff rate; it is worth mentioning that Japan is one of the few countries of the world that do not participate in any regional agreement.

The scaling of the average tariff rate among countries provides clear indications both for the extent of the distortion in the distribution of resources and for the extent of the income effect created in each country from the tariff abolition. Income from tariff rates for developing countries are a significant part of their GDP, which in the case of the three regions mentioned above exceeds 5%. Tariff abolition therefore increases substantially the purchasing power of the consumers of these countries resulting in an increased level of total demand. One could note that the extensive tariff protection of these countries allows home industries to produce with relatively high cost in sectors where do not have a comparative advantage. Therefore the high average tariff rates imply a high distortion in the distribution of resources. As it has been explained in Section 1.2.2, the heavier is the tariff burden on imports of a country, the bigger are the reductions on the prices of domestically produced goods after the elimination of tariffs. This results in improvement in competitiveness for the products of this country in the international markets, and increased demand for exports.

The increase in total demand generates increased needs for factors of production and mainly for investments on fixed capital, with the lower prices of the imported capital goods being an additional factor in favor of increased investments. Column 2 of Table 10 shows the increase in capital inputs compared to the baseline that result from the increased investments as simulated by the model for the period 2010-2030. For the reasons mentioned above, it can be observed that the highest increases in capital inputs take place in the countries that have the highest tariff rates. Such increased capital inputs enable a positive response of domestic production to the increased demand generated by the tariff abolition. This ability to expand capital inputs together with the more effective allocation of resources resulting from the removal of distortions eventually leads to increased overall levels of activity. Figure 7 depicts the positive correlation between the relative percentage of tariffs to GDP and the rate of increase of GDP resulting from the model simulation under discussion.

Figure 7: The relation of the reduction of duties and the increase of GDP in 2030.



It is a usual observation in applied research on international trade that international trade increases at a higher rate than GDP. The data of Table 10 strongly support this observation. This attribute has been explained in economic theory in many ways. One of these explanations that is related to the analysis developed in this section refers to the significant reduction of tariffs that has taken place over the last fifty years. The most important interpretations explaining that the reduction of tariffs favors international trade more than domestic production activity are the following:

The demand for imports has a higher elasticity than the demand for domestic goods; thus for the same reduction in prices, relatively more quantities of imported goods are demanded. According also to the reasoning developed in Section 1.2.2, in general equilibrium conditions the prices of domestically produced goods are reduced less than the prices of imports, which is a fact that favors demand for imports even more than domestic production. A second reason is the impact of the “love of variety” characteristic that is taken into account by the model, which acts towards increased demand for imports. According to the “love of variety” property, the increase in the level of income of the consumer will be directed towards the variety that has the lowest percentage in the composite

good. Due to the existence of tariffs, imported varieties comprise a smaller percentage of the composite good than the domestic varieties, thus consumers spend the additional income generated by the elimination of tariffs to buy more of the imported varieties.

2. CLIMATE POLICY.

2.1. The Kyoto Period.

2.1.1. Introduction

In this part of the book, the issues of trade in goods and permits and their implications on welfare under the imposition of restrictions on emissions are studied using the CCGT general equilibrium model (for a detailed description of the model see Section ...). The scenarios examined are differentiated depending on which of the Annex B countries are assumed to comply with the Protocol, the existence of excess emission rights ("hot air") and its utilization by the Former Soviet Union.

In the scenario simulations it is assumed that the abating countries meet their individually assigned targets according to the Kyoto Protocol inside one club or "bubble". These targets are assumed to represent endowments in emission rights that can be traded inside the club.

The examination of these topics is made in two stages. In the first stage the permits traded inside the bubbles are assumed to be supplied under perfect competition. Following an "echeloning" sequence regarding the number of participating countries, we have examined the implications of the construction of different abatement clubs (Section 2.1.2). In the second stage, it is assumed that the Former Soviet Union supplies its emission rights monopolistically (Section 2.1.3). The summary and main conclusions of the findings for the Kyoto period are provided in Section **Error! Reference source not found.**

2.1.2. Perfectly Competitive Permit Markets

The scenarios that were simulated for the Kyoto period under perfectly competitive permit markets are the following:

- Scenario I (All Annex B countries – AB): All Annex B countries are provided with permit endowments according to the Kyoto Protocol (Table 11) and are assumed to form one abating club. When all Annex B countries participate in the bubble, the overall restriction is equal to the one implied in the Kyoto Protocol.
- Scenario II (All Annex B countries plus the Rest of the World – AB+ROW): As in Scenario I and, in addition, developing countries join the club with a permit allowance that represents their emissions in the baseline. Developing countries were not considered as participants in the Kyoto Protocol; the United States have brought up the implications of the absence of these countries (Rest of the World in this model) as one of the major reasons for their withdrawal. The inclusion of developing countries in the abating club in this scenario is made in order to provide an insight on the usefulness of the clean development mechanisms when there are no transaction costs involved.
- Scenario III (All Annex B countries without the United States – AB-USA): As in Scenario I but excluding the United States. Under the current evolution of the negotiations, the implications of the withdrawal of the United States from the Kyoto Protocol are of vital importance for all countries since the United States are one of the major polluters and their absence could imply a degeneration of the process. This scenario is examined in order to study the effects of the United States withdrawal on the effectiveness of the process and on the cost that the rest of Annex B countries have to bear.
- Scenario IV (All Annex B countries without the United States and the Former Soviet Union – AB-USA-FSU): As in Scenario III but excluding the Former

Soviet Union. A usual topic of discussion regarding the Kyoto Protocol is the significance of the “hot air” endowment of the Former Soviet Union: how these emission rights affect the abatement effort of other participants and the additional costs/benefits this might involve. A first observation that can be made is that it reduces the environmental effectiveness of the process, providing to Annex B countries the option to avoid domestic action without equivalent emissions reduction elsewhere and, therefore, should not be granted to the Former Soviet Union. In this scenario it is assumed that the United States do not sign the Protocol and, for illustrative purposes, that the Former Soviet Union is also excluded.

- Scenario V (Europe and the Central European Associates – EC): The abating club consists of Europe and the Central European Associates with the allocation of permits as in Scenario I. This scenario provides insights on the implications on trade and welfare of the joint abatement effort of an enlarged Europe.
- Scenario VI (Europe Alone – EA): Europe abates alone. In this scenario it is assumed that the Kyoto agreement collapses and that Europe decides to reduce its emissions alone according to its Kyoto target.

All the scenarios above imply an effective emission constraint. This constraint generates a non-negative shadow cost of reducing the last ton of carbon inside the bubble, which is equal to the marginal cost of abatement. When the permit market is perfectly competitive, as it is assumed in this section, the marginal cost of abatement represents the market-clearing price of emission permits.

The carbon value, together with the emission allowances and the level of the emissions attained, determine the value of the transfers due to permit trade among countries and agents in the model. The demand for permits depends on the difference between scenario emissions and emission rights allocated according to the Kyoto Protocol. Abatement flexibility increases with permit market enlargement because it affords wider opportunities for cost-effective abatement options. As it is shown in Table 11, primarily the Former Soviet Union and secondarily the Central European Associates are provided with emission rights that represent more emissions than in the baseline. On the other hand, the smallest permit allowance compared to baseline emissions among Annex B countries is provided to the United States. Among non-“hot air” owners, Australia has the highest permit endowment.

Table 11: Ratio of permit endowment to baseline emissions (2010)

United States	0.726
Europe	0.825
Japan	0.797
Canada	0.805
Australia	0.855
Central European Associates	1.028
Former Soviet Union	1.319

The net position of each country in the permit market depends on the initial endowment in emission rights and the relative cost of abatement, which is reflected on the final reduction in emissions in the scenario compared to the baseline. This level of reduction is dependent on the restriction inside the club and not on the difference between the regional allowance in emission rights and baseline emissions. Each country reduces emissions until the marginal cost of reducing one ton of carbon is equal to the permit price. If at this point the amount of the emissions reduced inside the region exceeds the difference between baseline emissions and the Kyoto target, then this country is a net exporter of permits.

The highest restriction on emissions for a club is imposed when Europe alone meets its Kyoto target (17.5% fewer emissions compared to the baseline in 2010). In this case the carbon value is €₉₉ 115.11, which is the highest among all scenarios. This price reflects the high cost of reducing emissions inside Europe when no flexibility mechanisms (emissions trading, joint implementation, clean development mechanisms) are offered outside this region.

The carbon value drops to €₉₉ 67.31 when the Central European Associates trade permits with Europe, not only due to the “hot air” provided to Eastern Europe, resulting in an overall constraint representing 86.1% of baseline levels, but also due to the higher abatement potential in this region compared to Europe. The difference between the level of emissions implied by the permit endowment and emissions in the scenario determine if a country is a net seller or purchaser of permits. As is shown in Table 12, the percentage reduction for Central European Associates is twice as big as the reduction in Europe, thus, given their favorable endowment in emission rights, they end up selling permits to Europe.

Table 12: % Reduction of emissions compared to baseline in all scenarios (2010)

	AB+ROW	AB	AB-USA	AB-USA-FSU	EC	EA
World	-7.18	-5.88	-0.85	-2.49	-1.51	-1.49
Europe	-2.49	-9.04	-2.67	-13.36	-11.61	-17.52
Central European Associates	-7.21	-20.62	-6.53	-28.15	-24.87	
Japan	-2.21	-8.70	-2.62	-12.36		
Canada	-3.71	-12.30	-3.92	-18.08		
Australia	-4.42	-15.54	-4.86	-20.96		
Former Soviet Union	-5.10	-15.37	-4.50			
United States	-5.05	-15.22				
Rest of the World	-10.61					

In the AB-USA-FSU scenario, where the Central European Associates is the only region providing “hot air” for trade in the bubble, the restriction of emissions inside the club is 15.7% fewer emissions compared to baseline in 2010. The simulated carbon value for this scenario is €₉₉ 82.83. For this price of permits the Central European Associates make the most significant abatement effort among the countries in the club which, combined with their favorable allowance, makes them net sellers of permits. The only non-“hot air” owner that sells permits in this scenario is Australia, which abates substantially more than its 14.5% target. Canada, Europe, and Japan make smaller reductions than those implied by their individual regional targets, thus they end up net purchasers of permits.

The inclusion of the Former Soviet Union in the club (AB-USA scenario) creates a scenario with the lowest restriction in the club (3.6%) compared to baseline emissions in 2010. The simulated carbon value of €₉₉ 13.72 is the lowest among all scenarios examined in this part of the book. The “hot air” owners are the only regions that sell permits in this scenario; the Central European Associates register the biggest emission reductions compared to the baseline and, in combination to their endowment in excess emission rights, they are net sellers of permits. The Former Soviet Union reduces its emissions less than Australia; however, the differences in their assigned targets as percentages of their baseline emissions in 2010 result in their opposite positions in the permit market: the Former Soviet Union is a net seller of permits and Australia is a net purchaser of permits. Canada, Europe, and Japan are net purchasers of permits because they reduce their emissions less than is implied by their individual assigned targets.

The overall restriction in the club in the AB scenario represents 86.6% of baseline levels, with a simulated carbon value of €₉₉ 57.95. At this level of carbon value,

apart from the “hot air” owners, Australia is also a net seller of permits because it makes an emission reduction bigger than that implied by its target.

The enlargement of the permit market with the inclusion of the developing countries in the bubble (AB+ROW scenario) results in an overall constraint representing 92.8% of baseline levels. At the simulated price of permits of €₉₉ 18.07, developing countries, which have a target equal to their baseline emissions, register the biggest emission reduction, thus they sell permits. The “hot air” owners reduce their emissions more than the other Annex B countries; given their favorable permit endowments, they are net sellers of permits in this scenario. The rest of the Annex B countries reduce their emissions less than it is implied by their targets, thus they purchase permits.

In order to appreciate the importance of these net flows for the individual regions, Table 13 below gives the percentage of the value of permit sales (+) / purchases (-) in total private consumption.

Table 13: Permit sales/purchases as % of private consumption in all scenarios (2010)

	AB+ROW	AB	AB-USA	AB-USA-FSU	EC
Europe	-0.04	-0.07	-0.03	-0.05	-0.06
Central European Associates	0.20	1.46	0.14	2.74	2.00
Japan	-0.04	-0.07	-0.03	-0.07	
Canada	-0.09	-0.13	-0.07	-0.04	
Australia	-0.04	0.02	-0.03	0.13	
Former Soviet Union	0.96	3.89	0.72		
United States	-0.10	-0.17			
Rest of the World	0.10				

The “hot air” owners (the Former Soviet Union and the Central European Associates) have a positive income inflow whenever they are participating in the abatement effort. This transfer of income is maximized for the Former Soviet Union when all Annex B countries participate in the process (AB scenario) because the carbon value is the highest among the scenarios that they are inside the club. The maximum for the Central European Associates is reached in the AB-USA-FSU scenario, because this scenario has the highest permit price among the ones they participate.

The United States make significant emission reduction when they participate; however, their permit endowment represents a smaller percentage of the baseline emissions compared to all other countries, this is why they have the highest relative transfers.

Canada, which does not make substantial emission reduction when it participates, has also an allocation of emission rights that represents significantly fewer emissions than in the baseline, thus the resulting transfer of income is significant.

In the least-cost allocation of the reduction of emissions in the model, Japan makes the smallest abatement effort implying that this region is characterized by costlier abatement options. Moreover, its permit endowment covers considerably fewer emissions than in the baseline. Nevertheless, this transfer of income does not represent more than 0.07% of their total private consumption; this is due to the fact that the emissions produced in Japan per unit of consumption in the baseline are substantially fewer than in the other regions.

Australia has relatively high abatement potentials, which, in combination to the favorable permit endowment (see Table 11) results in small losses (or even gains) in income from permit trade.

Europe has a relatively favorable allocation in emission rights but also relatively low abatement potentials. This region is in all cases a net purchaser of permits

but the expenditures for permits do not exceed 0.07% of total private consumption expenditure.

Countries are not affected in a uniform way by the restriction imposed on emissions and the resulting transfers of income due to permit trade. The distortion of the relative prices of goods has a different impact on each region due to the differences in consumption and production patterns. The higher prices of fuels paid by both final consumers and firms initiate a substitution process towards less carbon-intensive fuels and products. Coal, which has the highest emission factor among fuels, is substituted for oil and gas; furthermore, energy-intensive inputs are substituted for less energy-intensive inputs, labor, and capital.

The economic agents in the model adjust to the cost that is introduced by the restriction of emissions by responding to the altered prices of goods, services, and factors of production by changing their consumption patterns of intermediate and final goods for firms and households respectively. In equilibrium, the changes in the consumption mix, given the new prices, correspond to the maximum level of profits and welfare for firms and households respectively.

The sum of all adjustments occurring in the demand for sectoral output in the presence of the carbon value is mirrored in the activity levels (Table 14). Sectoral activity takes into account the impacts of the carbon value on the prices of fuels, the relative prices of production of each sector, and the income effects generated by the different levels of dependence of the production and consumption patterns on fuels.

Table 14: % Changes in production compared to baseline in the AB scenario (2010)

	Annex B	Non-Annex B
Energy-Intensive Industries	-0.9	1.6
Coal	-18.0	-7.0
Refined Petroleum and Coal Products	-7.0	1.6
Crude Oil	-3.8	-3.0
Natural Gas	-9.2	-2.7
Electricity	-5.3	1.3
Rest of Industry	-0.1	0.0

The most important role in the adjustment towards the new equilibrium is played by energy sectors. The demand for coal is significantly influenced by the imposition of a carbon value. The demand for oil and gas is also substantially affected, but less than coal due to the lower emission factor of these fuels compared to coal. The fuel mix used for electricity generation in each region determines the increase in the price of electricity and the resulting reduction in the demand for this sector.

The reduction in the production of energy-intensive industries, which are affected by the higher prices of energy, reaches almost 1% due to the fact that the amount of fuels used in their production process comprises a big portion of their total intermediate inputs.

Concerning the demand for the rest of industries sector, the low consumption of fuels and energy-intensive products as a share of their total intermediate inputs result in changes that are not significant.

The welfare of the representative agent in the model is based on the level of consumption, which is positively dependent on wages, rents on capital and resource endowments, and taxes, while it is negatively dependent on expenditures on investment and government consumption.

The combination of baseline emissions, emission allowances, the relative ease of abatement, and the carbon value determine the net transfers of income to the sellers of permits, which is the initial "shock" to the different agents and

economies in the model. Thus permit sales are a positive income inflow to the selling country that can be used to increase consumption of domestically produced goods and imported goods, as well as to increase productive capacity through investment.

The abatement costs and the different relative prices refine the changes in income from permit sales/purchases, adjusting the economies to a new equilibrium where choices are optimized in view of the new economic conditions.

The carbon value imposed on fuels inside the abating club increases the prices faced by the consumer (households as final consumption and firms as intermediate inputs) of all goods depending on their consumption (and its composition) of energy and energy-intensive inputs. These higher prices stimulate a partial substitution of these goods for others whose increases in prices are lower. Therefore consumption shifts towards less energy-intensive patterns inside the club.

The higher prices of domestic consumption lead to a lower level of demand, thus the prices paid to producers are lower than in the baseline. In such a case these lower prices create a comparative advantage for the countries inside the club because it results in relatively lower export prices for these countries.

On the other hand, households in non-abating countries increase their consumption of energy because it becomes less expensive than in the baseline. For the same reason, firms outside the club substitute non-energy inputs for energy inputs in the production process. The lower prices of energy in non-abating countries reduce the cost of production in all sectors, each depending on the amount of fuels used in the production process as a percentage of total intermediate inputs. The new price level also implies that the price of goods as faced by the final consumer, offered both in the domestic and international markets, is lower than in the baseline.

Final consumers and firms in abating countries substitute domestically produced goods for imports because they become relatively less expensive. This means that the reduction in the demand for domestically produced goods due to the higher prices caused by the imposition of the carbon value is enhanced even further.

The lower prices of fossil fuels outside the club lead to a higher level of total domestic demand in these countries, pushing the level of total production upwards.

The cost of production in energy-intensive sectors in non-abating countries is reduced due to the lower internationally traded prices of fuels. This is why all abating countries have higher imports from and lower exports to non-abating countries (Table 15). The imports of energy-intensive products in the Former Soviet Union and the Central European Associates from countries in the club are increased compared to baseline for two reasons: on the one hand these regions lose their comparative advantage in the production and exports of energy-intensive products they have in the baseline (which is due to their low energy cost), and on the other hand they have a higher income due to the sales of permits.

The higher level of production in the countries outside the club also involves higher emissions than in the baseline: this is the “carbon leakage” effect, which is an important factor in determining the overall environmental impact and, furthermore, assists in comparing the efficiency of each policy. The impact of carbon leakage on the reduction of emissions in the abating club is shown in Figure 8. The total length of each bar shows the hypothetical reduction of emissions if carbon leakage was not present.

Among the scenarios simulated in this part of the book, the EA scenario has the highest carbon leakage measured in terms of emission increases of non-abating regions as a percentage of the reduction in the abating club (34.2%). The joint abatement effort of Europe and the Central European Associates, due to the amount of “hot air” available in this region, involves a lower target for the abating club, thus a smaller reduction of emissions, but the smaller amount of carbon

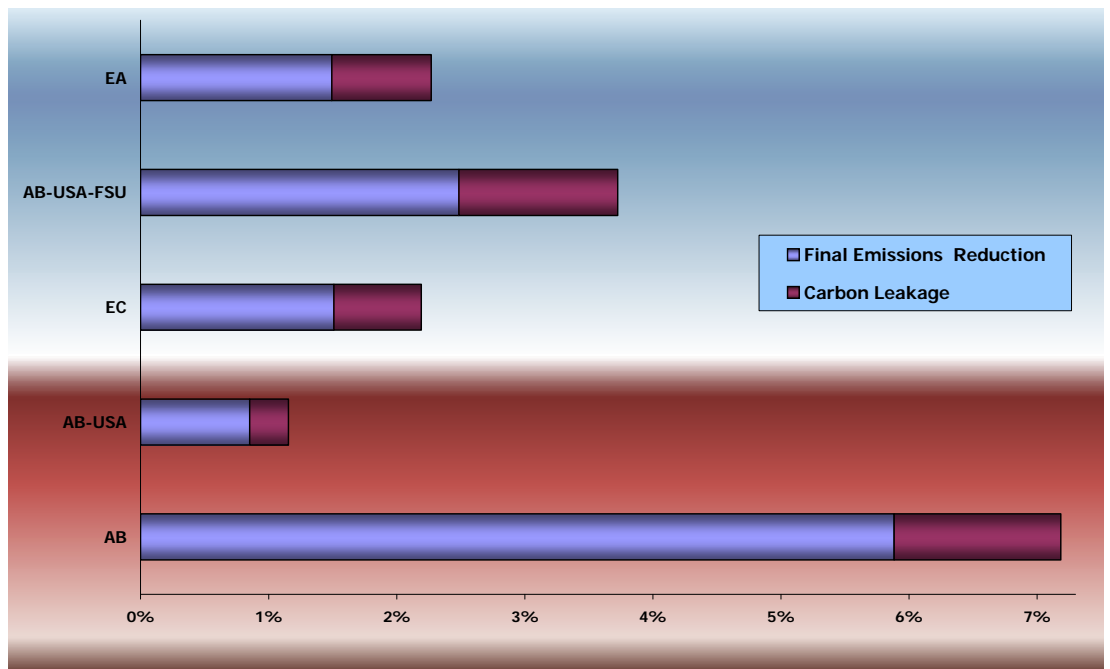
leakage leads to a final reduction that is slightly better than when Europe abates alone.

Table 15: % Change from baseline in the volume of imports of energy-intensive products (2010)

		I m p o r t e r							
		Europe	Japan	Canada	Australia	Central European Associates	Former Soviet Union	United States	Rest of the World
E x p o r t e r	Europe	-0.06	-0.37	-0.88	-0.03	0.86	3.72	-0.45	-0.67
	Japan	-0.19		-1.02	-0.17	0.69	3.56	-0.59	-0.80
	Canada	-0.34	-0.63		-0.31	0.52	3.37	-0.80	-0.96
	Australia	-1.25	-1.53	-2.03	-1.27	-0.43	2.47	-1.62	-1.86
	Central European Associates	-4.73	-5.16	-5.56	-4.77	-4.06	-1.35	-5.15	-5.33
	Former Soviet Union	-8.35	-8.87	-9.22	-8.48	-7.75	-5.11	-8.78	-8.80
	United States	1.03	0.70	0.18	1.04	1.92	4.82		0.39
	Rest of the World	1.25	0.92	0.41	1.26	2.15	5.05	0.84	0.61

The carbon leakage measured in terms of emission increases of non-abating regions as a percentage of the reduction in the abating club is also high when neither the United States nor the Former Soviet Union participate in the club (33.3%). In AB-USA and AB scenarios carbon leakage is significantly lower compared to the AB-USA-FSU scenario, reaching 26.2% and 18.1% respectively. The enlargement of the permit market in the AB+ROW scenario, where no carbon leakage exists by definition, leads to the biggest reduction in global emissions (7.2%).

Figure 8: Final reduction of emissions and carbon leakage in all scenarios (2010)



The welfare implications of each scenario are presented in Table 16. The changes in welfare have the same direction as the net transfers of income in the permit market. Exceptions to this rule are Canada, Australia, and developing countries for the scenarios where they are inside the abating club, and the Former Soviet Union for the scenarios where it is outside the abating club.

Canada, Australia, and developing countries are heavily dependent on the production and exports of energy and energy-intensive products; the imposition of the restriction in the club reduces significantly both the domestic demand and the demand for exports of the sectors that comprise a large portion of their total production. This reduction in their production reduces the demand for their resource endowments, thus their rents, lowering the welfare of the representative agent.

The Former Soviet Union, which is a major exporter of energy and energy-intensive products, faces a reduction in the demand for exports of these products compared to the baseline. The returns to its resources are thus reduced due to the lower level of demand for the energy sectors, resulting in a lower level of welfare.

Table 16: % Changes in welfare from baseline in all scenarios (2010)

	AB+ROW	AB	AB-USA	AB-USA-FSU	EC	EA
Europe	-0.02	-0.18	-0.06	-0.36	-0.32	-0.48
Central European Associates	0.28	1.17	0.11	1.58	1.07	0.02
Japan	0.01	-0.13	-0.05	-0.27	0.04	0.05
Canada	-0.29	-0.72	-0.14	-0.54	-0.02	-0.02
Australia	-0.27	-0.40	-0.13	-0.41	-0.04	-0.04
Former Soviet Union	0.87	3.69	0.74	-0.48	-0.37	-0.33
United States	-0.09	-0.23	0.00	0.00	0.01	0.01
Rest of the World	-0.08	-0.09	-0.02	-0.06	-0.03	-0.05

The highest cost for Europe is observed when it meets its Kyoto target alone (0.48%). The rents for resource endowments are reduced in all countries, with the most pronounced reduction occurring in the abating region. The higher level of production in all regions but Europe lead to the increase in the demand for labor and capital, which increases wages and returns on capital. In Japan, the United States, and the Central European Associates this income is enough to compensate for the lower rents of fossil fuels, thus these regions are better off than in the baseline. This is not the case for the rest of the countries that end up with a lower level of welfare.

The cost for Europe is lower when it forms a bubble together with the Central European Associates. The same arguments as in the EA scenario are valid for the rest of the regions, with the Central European Associates realizing a significant increase in their welfare due to the revenues from permit sales.

In the AB scenario the “hot air” owners are the only regions with a higher level of welfare compared to the baseline; this is due to the revenues from the sales of permits that are enough to compensate for the significantly lower rents of their resource endowments and their returns on labor and capital due to the lower level of demand and production.

The exclusion of the United States from the club produces results of the same direction as in the AB scenario, though of a smaller magnitude due to the lower carbon value: the Former Soviet Union and the Central European Associates have smaller gains and the rest of the regions smaller losses.

In the AB-USA-FSU scenario the results on welfare of the AB-USA scenario are enhanced, though not reaching their levels in the AB scenario, with the exception of the Former Soviet Union. Its exclusion from the abating club leads to a higher

level of production in this region compared to the AB scenario and lower compared to the baseline due to the lower demand for exports. The increase in the production of non-energy sectors compared to the baseline increases the demand for labor and capital and their returns; this additional income though is not enough to compensate for the lower rents to their energy endowments, thus it has a substantial loss in welfare.

In the AB+ROW scenario it is not only the “hot air” owners but also Japan that have a higher level of welfare. This is due to the income from permit sales that the representative agent in Japan receives for the permits sold in the internal market that compensate for the lower wages and returns on capital because of the lower level of demand and production. The rest of the Annex B regions have a lower welfare for the same reasons as in the AB scenario. In developing countries the revenues from permit sales partially compensate for the losses in the returns of factors of production and resources, thus the Rest of the World ends up with marginally smaller losses compared to the AB scenario.

Compared to the AB scenario, all countries without excess emission rights have smaller welfare losses or even gains in the AB+ROW scenario and the “hot air” owners have smaller gains because of the lower carbon value.

In the case that the United States do not participate in the abatement effort, the level of welfare in this country does not change from baseline. The cost of compliance for all non-“hot air” owners and the gains of the Former Soviet Union and the Central European Associates are reduced. If we further exclude the major “hot air” supplier, the welfare implications on the participating regions and developing countries increase while the United States do not experience a change in welfare from baseline.

2.1.3. Monopolistic Permit Supply

In this section it is assumed that the Former Soviet Union supplies its “hot air” monopolistically. The monopolist can control the supply of permits, meaning that it can increase or decrease the supply of permits in order to maximize its benefits from permit trade. Since the lower the supply of permits, the higher their internationally traded price, it would be profitable for the Former Soviet Union to restrict its supply in order to increase the revenues from permit sales, as long as its sales do not fall faster than the price increases. Such a practice increases the carbon value and thus the cost of implementation of the Kyoto Protocol.

In situations of limited permit supply, there are two markets for permits: the domestic market (of the Former Soviet Union) and the international market (of the club). In general, the carbon value in the domestic market is lower (or even zero) than in the international market. As the monopolist increases the supply of permits in the international market, the permit price is reduced in the international market and increased in the domestic market.

In a partial-equilibrium model, the solution to this market of emission rights would be the point where the Former Soviet Union maximizes revenues from sales of permits. However, in a general equilibrium model, where all markets are interconnected and the effects from a change in one market are reflected in all the other markets, the optimum solution is given by the point where the Former Soviet Union maximizes its level of welfare; this point is usually not the same as the revenue-maximization level.

The methodology used for these simulations is the following: to start with, the Former Soviet Union is allowed to sell only a small portion of its “hot air” endowment in the international permit market. This portion is gradually increased in small steps until perfect competition supply is reached. The optimum position for the monopolist is obtained at the supply “step” where its welfare is maximized.

Clearly when the supply of the monopolist is lower the net exporters of permits will have higher benefits from permit sales and permit importers can be expected to have higher welfare losses.

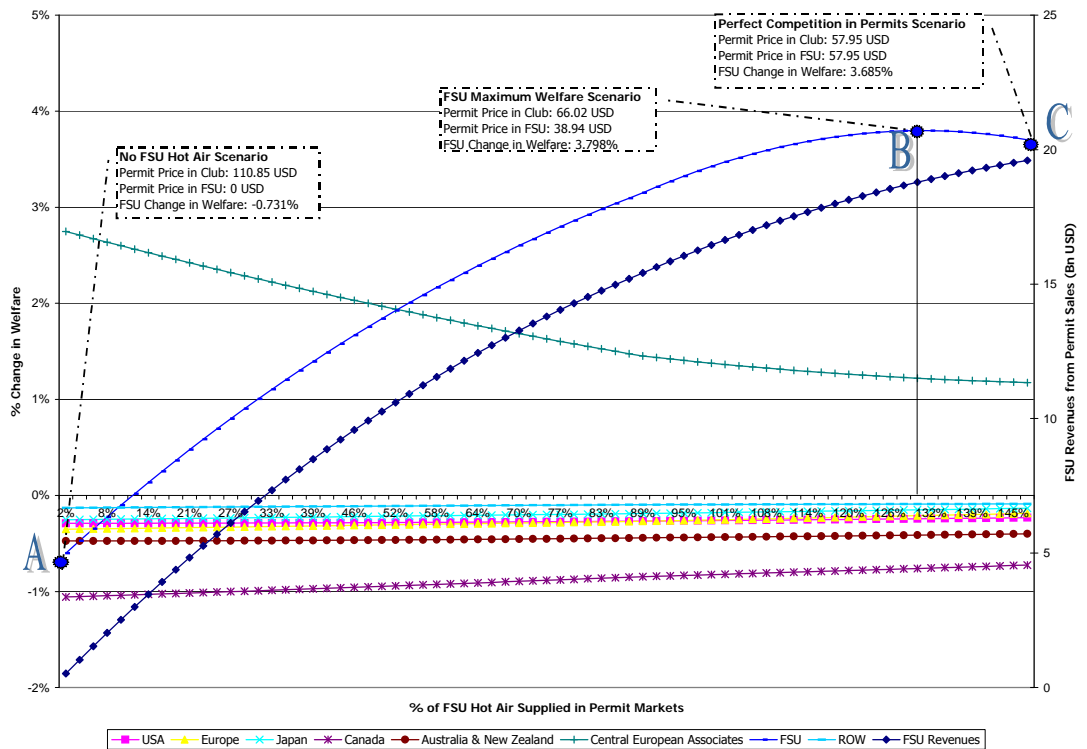
The scenarios that were simulated for the Kyoto period under imperfectly competitive permit markets are the following:

- Scenario VII (All Annex B countries – AB_IC): As in Scenario I but with the Former Soviet Union supplying its “hot air” monopolistically. This scenario was simulated in order to examine the impacts of possible restrictive practices of the Former Soviet Union in permit markets in the abatement effort of Annex B countries.
- Scenario VIII (All Annex B countries without the United States – AB-USA_IC): As in Scenario III but with the same assumption for the Former Soviet Union as above regarding the utilization of its “hot air”. In the absence of the United States for the abatement process the percentage of the “hot air” inside the club is bigger, thus its utilization has a higher impact on the determination of the permit price.
- Scenario IX (Europe, the Central European Associates, and the Former Soviet Union – ECF_IC): As in Scenario V with the addition of the Former Soviet Union and monopolistically structured permit market.

2.1.3.1. AB_IC scenario

When the Former Soviet Union does not supply any emission permits for trade (point A in Figure 9), then the situation is identical to a scenario where all Annex B countries apart from the Former Soviet Union meet their Kyoto targets inside one club. In this scenario the carbon value is €₉₉ 110.85, making the abatement effort very costly. The cost in terms of welfare for Japan, the United States, and Europe is significant (0.25%, 0.29%, and 0.35% respectively), higher for Australia & New Zealand (0.47%), and very high for Canada (1.06%).

Figure 9: Annex B abatement with imperfect competition in permit markets



The Central European Associates decrease their emissions from baseline by more than a third, leading to significant gains in welfare by 2.79% because of the high revenues from permit sales.

The Former Soviet Union has not only no revenues from permit sales but also significantly decreased demand for exports of fossil fuels, meaning lower total demand and production. This has a negative impact on the level of welfare of 0.73%. The Rest of the World is marginally worse off by 0.13% for the same reasons.

As the supply of emission rights increases, all regions in the club – apart from the monopolist – face a continuously decreasing carbon value. When welfare is maximized for the monopolist (point B in Figure 9), all countries in the club apart from the Former Soviet Union reduce their emissions slightly more than in the perfect competition scenario (point C in Figure 9) due to the higher carbon value. However, the abatement effort made by the Former Soviet Union is much lower (reduction of 9.7% instead of 15.4% for the perfectly competitive market). These results are due to the fact that the price for emission rights in the club is also higher than in the perfect competition scenario, at €₉₉ 66.02, but differs from the price in the internal permit market of the Former Soviet Union, which is only €₉₉ 38.94. The aggregate reduction in the global emissions is 5.87%, which is slightly smaller than in the perfect competition scenario not only due to the marginally increased emissions of the Rest of the World (higher carbon leakage) but also because of the increased emissions of the monopolist compared to the perfect competition case: these two effects combined exceed the additional emission reduction made by the rest of the regions in Annex B.

The welfare implications are similar to the perfect competition case though amplified due to the higher carbon value (Table 17). The Rest of the World has also lower welfare level because of the lower demand for energy exports that leads to lower demand for – and therefore the rents paid to – their energy endowments.

Table 17: % Change in welfare from baseline in the AB and AB_IC scenarios (2010)

	AB	AB_IC
World	-0.11	-0.12
Europe	-0.18	-0.21
Central European Associates	1.17	1.22
Japan	-0.13	-0.15
Canada	-0.72	-0.76
Australia	-0.40	-0.41
Former Soviet Union	3.69	3.80
United States	-0.23	-0.24
Rest of the World	-0.09	-0.09

The Central European Associates act as a “free rider” in this permit market structure, since they realize increased revenues from emission right sales compared to the case where the Former Soviet Union supplies its rights perfectly competitively, without reducing the amount of permits it sells in the international market.

The Former Soviet Union acts monopolistically, discriminating perfectly the price it charges for carbon permits sold inside and outside the region, therefore it benefits both from the higher price it receives for the emission rights it sells in the international permit market and the lower price – meaning lower cost of abatement – inside the region. The welfare increase achieved in this region is higher, but not substantially so, compared to the perfect competition scenario.

Overall, the cost of implementing the Kyoto Protocol in all Annex B countries when the Former Soviet Union uses monopolistic practices in the permit market is 0.12% lower welfare for the world.

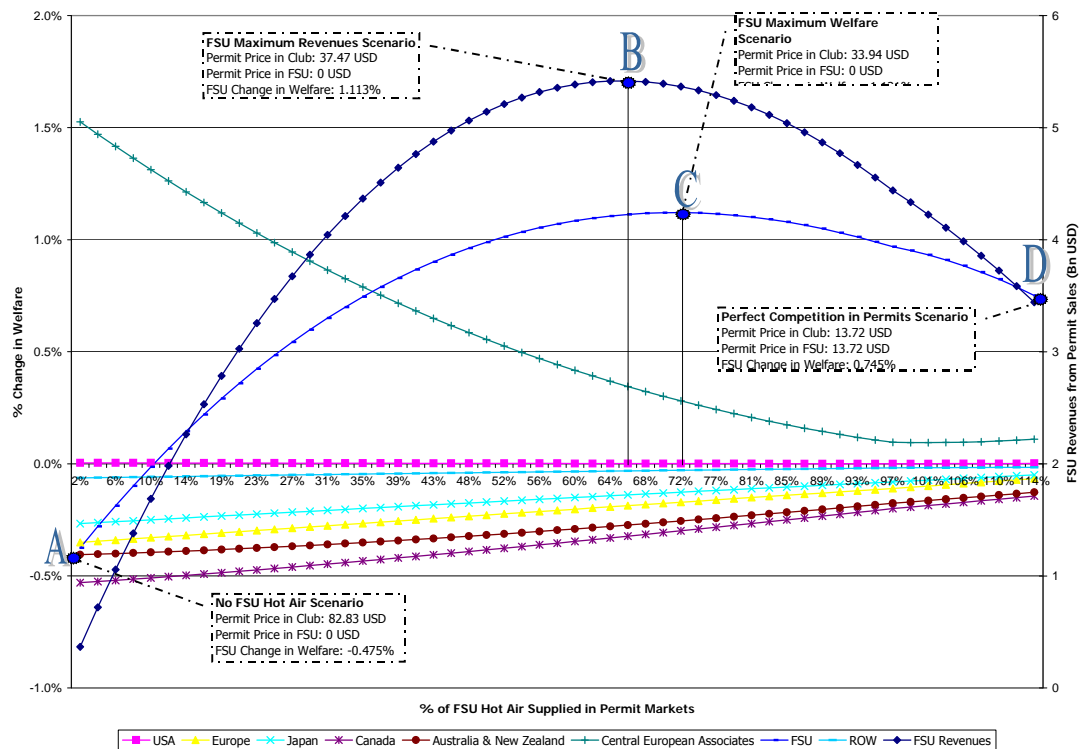
The demand for fossil fuels decreases in Annex B countries due to their higher consumption prices. The demand for the products of the rest of the sectors decreases in all regions, except from the demand for the rest of industry sector in the Former Soviet Union that increases because it becomes relatively less expensive than the other sectors of the economy due to its low consumption of fuels. The only non-abating region, the Rest of the World, has increased demand for the products of all sectors due to the lower cost of energy.

2.1.3.2. AB-USA_IC scenario

The benchmark case in the study of the monopolistic permit supply is the compliance of all Annex B countries with the Kyoto Protocol, meaning that they are supplied with emission rights as many as they are provided by the agreement, with the exception of the United States, which is what seems to be the most likely arrangement.

When the Former Soviet Union supplies no “hot air” in the international permit market (point A in Figure 10), then the only excess emission rights available in the market for trade are those of the Central European Associates. The welfare in this region increases by 1.58% due to the €99 82.83 paid for each permit sold in the market. The welfare level of the rest of the regions is reduced due to the high cost of abatement.

Figure 10: Annex B – USA with imperfect competition in permit markets



The effort needed to comply is reduced as the Former Soviet Union allows for a fraction of its “hot air” to be traded internationally, lowering in this way the world price of emission permits. When supplying about 66% of its “hot air” (point B in

Figure 10), revenues from sales are maximized for the monopolistic supplier at a substantially lower carbon value of €₉₉ 37.47, giving 1.11% higher welfare for the Former Soviet Union.

The rest of the countries in the club face a lower cost of abatement, due to the lower price per emission right they have to pay; their cost in terms of welfare is about half of what it is when the Former Soviet Union is not supplying any permits. The Central European Associates gain only 0.35% in welfare due to the lower amount of revenues from sales of permits.

By increasing the supply of “hot air” to 72% of its endowment (point C in Figure 10), the Former Soviet Union maximizes its level of welfare at 1.12% despite the fact that the revenues from permit sales are lower. This is due to the fact that the demand for imports from the Former Soviet Union is higher compared to point B due to the lower carbon value inside the club. This increased demand for exports of the Former Soviet Union increase the production of fossil fuels inside this region, leading to higher payments to resources and higher income from taxation in private consumption, output, imports, exports, and intermediate consumption. Due to the lower carbon value the revenues from permit sales are lower for the Central European Associates, thus their increase in welfare (0.28%) is smaller than in point B. The other regions in the club, facing a lower permit price, have a smaller reduction in welfare. The slightly decreased level of welfare compared to the baseline of the Rest of the World is due to the lower demand for fossil fuels globally and, therefore, to the lower rents paid to resource endowments.

The reduction of global emissions of 1.22% is small but it is higher than when we do not allow for monopolistic practices on behalf of the Former Soviet Union. The countries of the club reduce their emission levels significantly, except from the major “hot air” supplier that increases emissions by 1.4% compared to the baseline, which is a substantial deviation from the 4.5% reduction in emissions of the perfect competition scenario. This is due to the higher demand for (and consumption of) fossil fuels inside the Former Soviet Union. Emissions also increase by the non-participants, the United States and the Rest of the World, leading to a high carbon leakage effect.

The point that the supply of permits is perfectly competitive (point D in Figure 10) is reached when the Former Soviet Union reduces its baseline emissions by 4.5%, selling about 114% of the excess emission rights they were endowed with. The lower demand for fossil fuels inside the Former Soviet Union compared to point C results in the lower rents to fuel endowments, thus lower level of welfare.

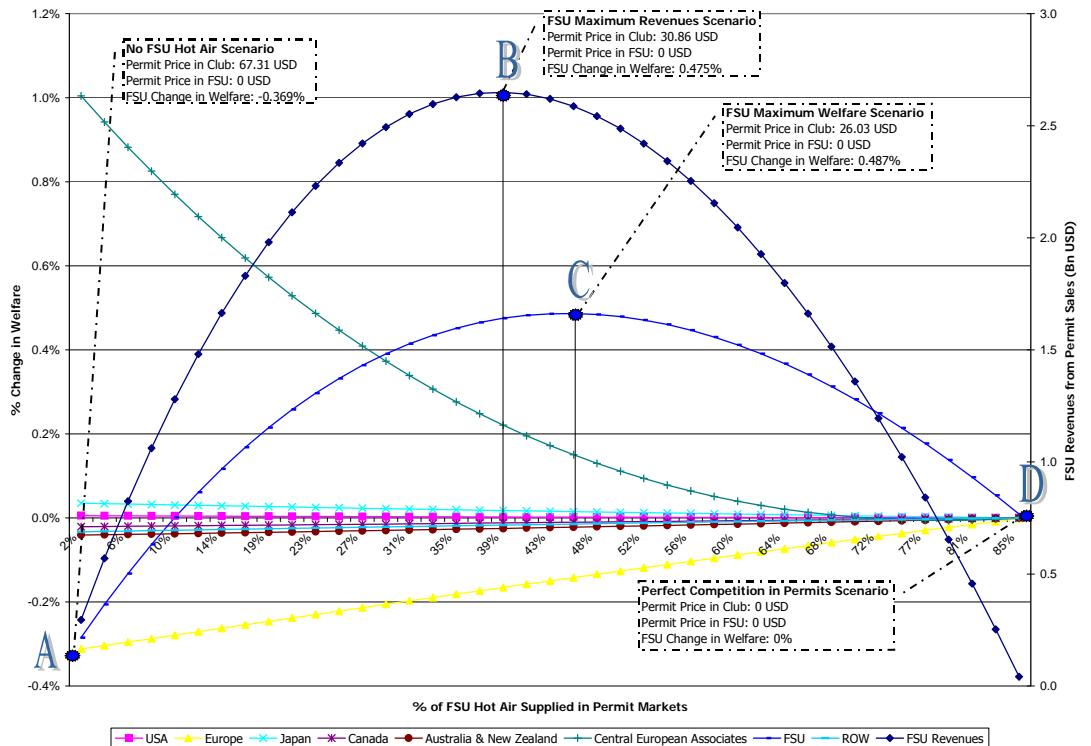
2.1.3.3. ECF_IC scenario

The abatement effort of Europe and the Central European Associates has different effects on welfare depending on the availability of excess emission rights from the Former Soviet Union and the way this “hot air” is manipulated.

The “hot air” available in this club exceeds the amount of emissions that have to be reduced in Europe according to the Kyoto Protocol (the restriction in the club is non-binding). If the Former Soviet Union does not restrict the supply of permits, the carbon value is driven to zero because supply exceeds demand.

When no carbon permits are sold from the monopolistic supplier (point A in Figure 11), then the abatement effort is expensive for Europe and very profitable for the Central European Associates, gaining more than 1% in terms of welfare. The carbon value inside the club increases the price of fuels, thus the demand for domestic and imported energy is reduced; The resource endowment of the Former Soviet Union receives lower rents due to the decrease in the demand for fossil fuels in the abating regions; welfare, therefore, is negatively affected by 0.37% although no abatement is made inside the region.

Figure 11: EU, Central European Associates, and Former Soviet Union with imperfect competition in permit markets scenario



As the supply of carbon permits increases due to the fact that more “hot air” becomes available from the Former Soviet Union, the value of carbon permits decreases, making the abatement effort less costly for Europe. On the other hand, the welfare of the Central European Associates decreases as the supply of the monopolist increases due to the lower revenues from permit sales, thus they are worse-off compared to point A. The Former Soviet Union gains not only from the increase in carbon revenues but also from the smaller decrease in the rents paid to their resources; this is due to the smaller decrease in the demand for exports of fossil fuels inside the club as the carbon value drops.

Revenues from emission rights sales are maximized for the Former Soviet Union (point B in Figure 11) when supplying 39.3% of their “hot air” endowment at €₉₉ 30.86 with a resulting change in welfare of 0.48%. At that point the Central European Associates gain only 0.22% and Europe is better off than when no “hot air” was available because they pay less than half the permit price.

The optimum choice for the Former Soviet Union, however, is not that level of supply of emission rights, as it would be in a partial-equilibrium model; by supplying 6.2% more of their “hot air” endowment (point C in Figure 11), they find their revenues decreasing due to the lower price of €₉₉ 26.03 but the increase in the rents paid for their resources is enough to compensate for the lower permit sales. Again, the Central European Associates lose revenues due to the lower price, ending up with just a 0.15% overall gain in welfare, while Europe complies to the Kyoto Protocol with a cost of only 0.14%.

The carbon value is €₉₉ 26.03 for Europe and the Central European Associates, and zero for the Former Soviet Union due to the abundant emission rights available inside the country that have not been offered in the international permit market because they would lower their price thus reduce the revenues from permit sales; in other words, the increased offer of permits would result in lower welfare level for the Former Soviet Union.

The overall effect in global emissions is weakened due to the carbon leakage effect, which is noticeably high in this case.

Any increase from point C on in the supply of permits leads to lower welfare level for both suppliers due to the sharp decline in the price of emission rights. The total amount of "hot air" from both regions exceeds the demand for permits by Europe, therefore when the Former Soviet Union supplies more than 85% of its "hot air" endowment, the price of permits drops to zero and the scenario is identical to the baseline.

2.1.4. Welfare implications and environmental effectiveness

It can be generally expected that emission abatement policy carry a cost in terms of welfare losses and that such losses increase more than linearly with the size of the reduction implied by the policy. It is also generally accepted that within a competitive emission permit market the wider the effort is spread the smaller these losses are likely to be since the scope of cost effective emission reduction options is enlarged. The analysis using computable general equilibrium models however can go beyond these generally accepted principles and look at secondary welfare effects that arise from the fact that economies are interconnected through international trade in a manner that the adjustment to a constraint in one country/region may have repercussions on the economies and ultimately the welfare of other countries/regions even when the latter do not participate in the abatement effort. Such secondary effects have been exposed in the previous sections and materialize mainly through movements in prices of the goods directly affected by the abatement effort (fossil fuels), energy-intensive products as well as other goods that, from a first look, are relatively immune to the changes implied by the abatement effort.

The issues addressed in this section are:

- Taking total welfare and environmental impacts (direct and indirect) what can be said in terms of the environmental efficiency implied in the different scenarios examined?
- To what extent restrictive practices in the market of internationally traded permits affects this environmental efficiency?

The environmental impact and the cost of abatement per ton of carbon in terms of welfare are presented in Table 18. The first column shows the percent reduction in world emissions implied by the scenario and includes carbon leakage effects. The second and third columns show the average cost in terms of welfare (consumption) loss per ton of carbon reduced in 2010 for the World and EU 15. The European Union is shown separately because it is the subject of special focus of the CCGT project and has been retained on all the abatement clubs considered. The scenario with the highest environmental effectiveness and the lowest cost in welfare is the AB+ROW case, which is equal to the implementation of the Kyoto Protocol together with clean development mechanisms free of transaction cost. This result is due to the fact that the abating countries take advantage of the least expensive way to abate all around the world, thus lowering the cost of compliance significantly. Furthermore, the higher prices of fuels do not generate any substitution effects towards the increase of energy imports because all countries are abating, thus the lack of carbon leakage prevents the overall environmental impact from shrinking.

Table 18: % Change in emissions from baseline and cost in private consumption per ton of carbon in each scenario (2010)

	Total Emission Reduction	Cost Per ton of Carbon	
	% changes from baseline	World	Europe
AB	-5.88	60.53	27.15
AB+ROW	-7.18	20.19	2.19
AB-USA	-0.85	74.67	65.90
AB-USA-FSU	-2.49	206.73	123.71
EC	-1.51	186.44	183.42
EA	-1.49	298.03	275.37
AB_IC	-5.87	67.51	31.13
AB-USA_IC	-1.22	158.23	121.09
ECF_IC	-0.69	145.01	177.37

Not surprisingly the scenario with the highest environmental effectiveness and the lowest cost in welfare is the AB+ROW case. Such a scenario apart from offering a wider option of cost effective emission reduction options also minimizes the perturbation to the world economic and trade system and avoids carbon leakage. Less obvious however is the extent to which such an arrangement could be environmentally efficient (one third of the average cost compared to the all Annex B case) and the even greater efficiency in terms of EU effort. Unfortunately this scenario is purely hypothetical.

The withdrawal of the United States from the Kyoto process dramatically reduces the environmental impact mainly because of the increased significance of "hot air" in the remainder of the club. However the efficiency of abatement in terms of worldwide welfare loss is not substantially increased. The cost per ton to the EU however more than doubles.

Excluding additionally the Former Soviet Union improves the environmental impact (mainly through the removal of hot air) but increases very substantially the cost both for the World and the EU.

Were the EU attempt to meet its target alone (with the rest of the world undertaking no abatement effort) both the environmental impact would be small (-1.5% decrease in world emissions) and the cost per carbon abated very high and naturally borne overwhelmingly by the EU. On the other hand including the Accession countries would leave the environmental impact intact (despite the inclusion of hot air available in these countries) while average costs are reduced by more than one third.

The exercise of monopolistic practices by the FSU in the context of Annex B wide Club would leave the environmental impact unaffected the restriction of supply being almost exactly compensated by additional carbon leakage in developing countries. On the other hand the increase in average abatement costs would be almost insignificant. The effects of restrictive practices are very different in the context of a reduced market (excluding the USA): reducing the hot air available enhances the environmental impact but average abatement costs approximately double. Monopolistic practices are necessary in the case when all non-European signatories of the Protocol drop out of the process if any environmental impact is to be preserved. The cost to the EU in this case however remains high.

2.2. The Post-Kyoto Period: “Soft Landing” Scenario

2.2.1. “Soft Landing” Scenario Assumptions

The “soft landing” scenario used in this study is based on the definition of Criqui and Kouvaritakis (1997). It is a realistic scenario, taking into account the differences among countries in the emissions per capita (which reflects the responsibility for the reduction of pollution) and GDP per capita (reflecting the ability to afford the cost of abatement). The abatement effort is gradual and the horizon of emission stabilization and eventual reduction depends on both rates mentioned above. Annex B countries, for instance, which have high emissions per capita rate and also high GDP per capita, have tight targets from the beginning of the post-Kyoto period. On the other hand, developing countries have a smoother path of reduction of emissions, as implied by the amount of permits they are supplied compared to their baseline. Consequently, emission allowances are calculated based on the initial situation of each country that determines its ability and responsibility to abate.

The reduction schedule is based on the Soft Landing CO₂ only-“only” scenario of the Greenhouse Gas Emission Control Strategies project⁵ [Criqui (2002)]. The emission rights allocated in the framework of the “soft landing” scenario are presented in Table 19. Annex B regions are assumed to form an abating club for the Kyoto period and all countries are assumed to join this club in 2015 and thereafter.

Table 19: Emission rights in the “soft landing” scenario

	1995	2010	2030
Australia & New Zealand	1.00	0.99	0.89
Japan	1.00	0.90	0.64
East Asia	1.00	0.00	2.83
China	1.00	0.00	2.82
India	1.00	0.00	5.09
North America	1.00	0.00	0.97
Latin America	1.00	0.00	2.86
Nordic Europe	1.00	0.91	0.76
Germany	1.00	0.88	0.61
UK	1.00	0.93	0.79
Rest of Europe	1.00	0.98	0.78
Other Europe	1.00	0.00	1.98
Central European Associates	1.00	0.93	0.86
Former Soviet Union	1.00	0.85	0.72
North Africa	1.00	0.00	2.40
Africa	1.00	0.00	4.20
Rest of the World	1.00	0.00	3.83

A market for pollution permits is created when a limited amount of “property rights” on emissions are distributed to the economic agents. These represent a right to pollute equal to the amount of emission rights owned by the polluter. These rights can be traded among economic agents (and among all countries).

The emission permits are distributed according to a grandfathering principle to the firms and to the households of each country. Economic agents have then to

⁵ Research Project N° EVK2-CT-1999-00010, Thematic Programme: Environment and Sustainable Development of the DG Research (Fifth Framework Programme), EU

compare the cost of reducing emissions below his endowment, to the benefit from selling their permits to the market.

The underlying assumption of perfectly competitive permit markets that has been made in this version of the GEM-E3 model implies that the carbon value is the shadow price of the globally imposed restriction. The extent of the reduction of emissions in each country depends on the relative ease of abatement: the reduction of the emissions of a country with relatively low cost of abatement is bigger than that of a country with relatively high cost of abatement regardless of their endowments in permit rights. More specifically, the reduction of emissions is made up to the point that the cost of reducing an additional ton of CO₂ is equal to the world permit price. The difference between the regional allocation in emission rights, which depends on the scenario assumptions for the regional endowments, and the volume of emissions of a country, determines the amount of permits that are sold or purchased by this country.

2.2.2. The Adjustment Process

In order to explain the impacts of the policy of restriction on emissions on the various macroeconomic variables, the resulting changes have to be separated into initial systemic disturbances and secondary effects. These initial disturbances can be assessed by making some preliminary analysis of the abatement potential in the different regions in conjunction with other factors that affect the market of permits.

2.2.2.1. Initial Systemic Disturbances

The magnitude of the changes generated by the initial systemic disturbances is bigger than the ones initiated by the secondary effects. This is also a necessary condition in order for a general equilibrium model to converge to a new equilibrium point. The introduction of a restriction in the market for emission permits, which is part of the environmental module embodied in the core model, causes initial disturbances both in the supply and in the demand of goods and services.

On the supply-side, the initial disturbance refers to the prices of the energy inputs due to the burden of the carbon value imposed on these inputs. The imposition of the same carbon value to all countries leads to different increases in the prices of fossil fuels for two reasons. The first is that the three primary fuels (coal, oil, gas) examined in the model have different CO₂ emission factors: coal has the highest factor, followed by oil and gas. The bigger is the amount of coal as a percentage of the bundle constituting the energy input, the higher is the increase in the price of this bundle. The second reason is that fossil fuels have a different price in each region. The prices of energy inputs in countries that have significant reserves of energy resources are often lower. The same occurs in countries that have low tariffs and taxes on fossil fuels. Thus the imposition of the same burden results in a higher increase in the prices of fossil fuels in the countries with the lower price levels of these goods. The magnitude of the impacts of the initial disturbance on the supply-side of each country is displayed in column (1) of Table 20.

The highest increases in the unit cost of energy are observed in the Former Soviet Union, the Central European Associates, and China due to both the high percentage of coal in the energy bundle of these regions and to the low prices of energy inputs inside these regions. It is evident that the different increases in the unit cost of energy depend on the various impacts that the above factors have on each country. The relatively lower prices of coal and oil in the Former Soviet Union and the Central European Associates compared to China increase the unit energy cost more than in China despite the fact that coal is a significantly smaller part of their energy bundles. On the other hand, the smallest increase in the unit cost of energy is observed in Latin America, where oil is a big part of the energy bundle but comes with a high price. The same comments *mutatis mutandis* can be made for the major oil producers such as North Africa-Middle East, Africa, and East Asia. Among developed countries, the highest increase in the unit cost of

energy is observed in North America mainly due to the relatively lower taxes imposed on these inputs in this region.

Table 20: Changes in the unit energy cost and the share of the value of net exports of permits in disposable income (2030)

	Unit Energy Cost	Value of Net Exports of Permits
	% change from baseline (1)	% share of disposable income (2)
Australia	49.9	-0.8
Japan	22.1	-0.1
East Asia	30.0	-0.3
China	112.0	2.6
India	73.2	4.0
North America	74.7	-0.1
Latin America	18.5	0.3
Nordic Europe	37.1	-0.2
Germany	48.2	-0.1
UK	45.6	-0.2
Rest of Europe	40.4	-0.2
Other Europe	24.7	-0.1
Central European Associates	113.1	-0.5
Former Soviet Union	114.1	-2.4
North Africa	36.8	0.3
Africa	20.3	0.7
Rest of the World	36.9	0.6

The initial disturbance on the demand-side is caused by the sales and purchases of emission rights. These transactions affect the demand factors in two ways: on the one hand they increase (decrease) the disposable income of households, increasing (decreasing) the part that goes to consumption. On the other hand these transactions are transfers to (from) the external sector, affecting the current account of each country. For the simulations of this study, the restriction of stability of the ratio of the current account to GDP for developing countries was imposed. This was achieved by allowing the model to endogenously change the level of the real interest rate that results as the dual price of this restriction. When a developing country sells permits – with its GDP, imports, and exports remaining stable – its current account tends to improve, violating the restriction. The compensating mechanism acts towards reducing the real interest rate of this country and thus increasing its imports until the restriction is met. Imports increase indirectly through the increase of consumption and investment. Consumption increases because with a lower real interest rate current consumption is preferable than future consumption. Therefore savings are reduced in favor of consumption. Investment increases because the reduction in the real interest rate lowers the cost of financing investment projects. This initial increase in demand, given the domestic supply and the prices of imported goods, generates an increase in the prices of domestically produced goods and an increase in imports. The opposite adjustments occur in the case that a developing country purchases permits. The distribution of emission rights and the relative ability of each country to reduce its emissions as well as the level of the carbon value determine the amount and direction of sales and purchases of permits. In countries with relatively low cost of abatement and relatively favorable initial

allocation of permits such as India and China, the sales of permits are substantially high. Conversely, in countries with relatively small quantities of emission rights compared to their baseline emissions such as the Former Soviet Union, the amount spent on the purchases of permits is highly significant, having the anticipated consequences on the disposable income and the current account.

2.2.2.2. Secondary Effects

On the supply-side, the higher cost of energy inputs results in an increase in the cost of production of goods and services. However, the increase in the cost of production will be lower than the increase in the price of the energy inputs because the prices of the other cost elements increase less than the prices of fossil fuels. A higher increase in the cost of production is faced by sectors that are more energy-intensive, such as electricity, ferrous and non-ferrous metals, chemicals, etc. The higher cost of energy inputs initiates substitution mechanisms in the production process. These substitutions will occur not only between fossil fuels, depending on the emission factor of each fuel, but also between energy inputs and other non-energy-intensive inputs. The result of these substitutions is the significant reduction in the demand for all three primary fuels and mainly for coal, which has the highest emission factor. Substitutions – to a smaller extent – and a noticeable reduction in demand will occur also in the case of energy-intensive products.

On the demand-side, the increase in the prices of fossil fuels results in their substitution in consumption for other non-energy products. This reduction will be even bigger for the countries the disposable income of which is decreased due to purchases of permits. The opposite takes place in the case of the net sellers of permits, where this reduction is partially compensated. A comparison of the increase in the unit energy cost in all countries and the change in disposable income (see Table 20) leads to the conclusion that the substitution effect is substantially more important than the income effect, resulting in reduction in the demand for all fossil fuels in all countries.

The increase in the price of energy has an impact on the prices of durable goods, affecting the decisions of the consumer. Specifically, in the model it is supposed that the producer combines the use of durable goods with energy in order to produce a composite service such as heating, cooking, and transport, thus the price of energy is a part of the user cost of durables. This means that an increase in the price of energy reduces the demand for durable consumption goods.

The imposition of the same carbon value in all countries, as it has been mentioned above, results in higher increases of prices of fossil fuels in the regions with relatively less expensive energy goods. This occurs mainly in the countries that are major producers of fossil fuels. The effect of the abatement scenario on these countries is to create a comparative disadvantage vis-à-vis the rest of the countries. This comparative disadvantage is very pronounced with respect to energy-intensive sectors, with a noticeable reduction in exports of these goods too. An important channel of diffusion of this comparative disadvantage is electricity and domestic transport, which make a marginal contribution to international trade but constitute a significant input for the rest of the sectors.

On the other hand, countries with relatively high energy prices before the imposition of the restriction on emissions gain a comparative advantage in energy-intensive sectors.

The reduction of production in the energy-intensive sectors initiates a reduction of employment and of the level of capital employed. The resulting surplus in the labor force puts a pressure on the labor market, forcing wages to lower levels. The same occurs in the capital markets. The reductions in wages and employment are bigger in more labor-intensive countries. A part of the surplus labor force is absorbed in other sectors that are not affected substantially from the burden on energy inputs. These sectors according to economic theory are labor-intensive sectors such as agriculture, food industry, textiles, and market and

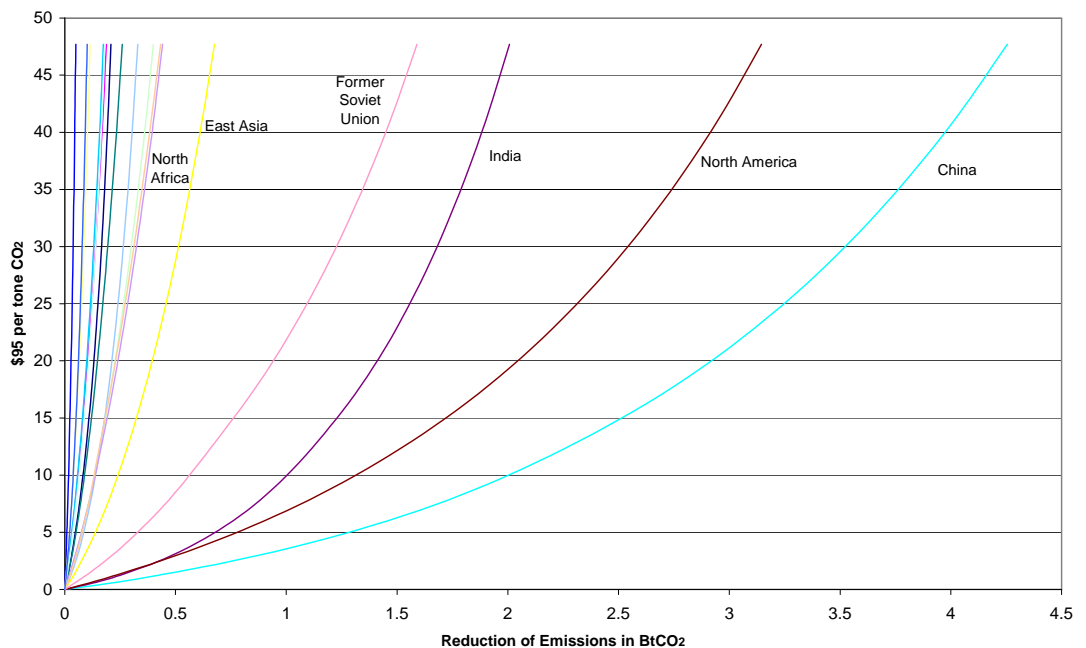
non-market services. The countries that are more labor-intensive gain a comparative advantage in these sectors. Similar adjustments occur for capital in the capital-intensive sectors.

2.2.2.3. Abatement Potentials

The abatement process can also be viewed from the prism of Marginal Abatement Cost Curves (MACCs), which is one of the most widely used tools for evaluating different emissions trading schemes. It has been shown in many studies and is a conclusion of the present scenario evaluation that MACCs are to a great extent independent of the participation or not of a country in a market scheme for sales and purchases of emission permits as well as to the distribution of permits to the various countries that participate in this market [Ellerman and Decaux (1998)]. They are mainly dependent on the economic structure of a country; a change in their position in the two-dimensional space reflects a change in the effectiveness of this structure. Such a change occurs, for instance, with the tariff abolition as simulated in the model. In computable general equilibrium models, when a restriction on emissions of a country is imposed, the carbon value results as a dual value of this restriction. In this study, the MACCs are derived by repeated simulations of the GEM-E3-World model under alternative assumptions for the global emission restriction. A pair of carbon value and abated emissions for each country is generated in each simulation. The MACC for each country is then the locus of these pairs in the two-dimensional space.

A representative picture of the differences in the emissions abatement potential of each region as they are depicted by the MACCs can be found in Figure 12.

Figure 12: Reduction of emissions in absolute terms by region (2030)

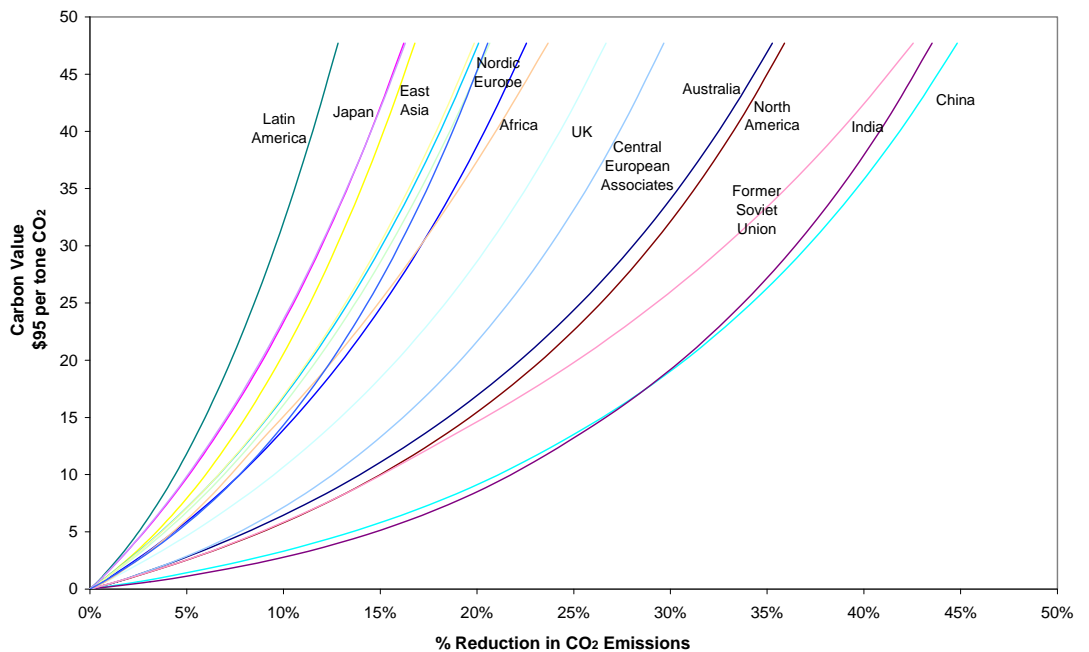


In Figure 12 the absolute reduction of emissions is shown on the horizontal axis and the carbon value on the vertical axis. This presentation assists mainly in the evaluation of the distribution of emissions abatement by region. The absolute quantity of emissions abatement depends to a great extent on the magnitude of the production activity of a region. Based on this criterion, the significant emissions abatement potentials existing in regions such as the North America can be explained. However, the magnitude of the production activity is not

sufficient to provide a satisfactory explanation for the relative position of the MACC of each region in Figure 12. North America, for instance, with GDP seven times as much as the one of China, has lower emissions abatement potential for all carbon values. The same observation can be made for Japan, which, having one of the highest GDPs in the world, has low emissions abatement potentials in absolute terms.

An alternative presentation would be to show the percentage reduction in emissions compared to the baseline on the horizontal axis (Figure 13). This depiction provides even further insights on the relative abatement potential of various regions. The potential according to which a country is capable of reducing emissions at a certain point in time mainly depends on the intensity and the composition of energy products used in production and consumption. A country that uses energy inputs relatively more intensively in its production process has a higher abatement potential compared to other countries. Under the assumption that there exist two countries with the same composition of energy inputs (coal, oil, gas), which differ in terms of production and consumption intensity of these energy inputs, the marginal product of energy inputs and, therefore, their price in the more energy-intensive country is lower than the less energy-intensive country. Something similar occurs in consumption due to declining marginal utility. When two countries face the same carbon value then the price of fossil fuels in the energy-intensive country will increase relatively more, resulting in more extensive substitution of energy inputs and, thus, a bigger reduction in emissions.

Figure 13: Reduction of emissions in percentage terms by region (2030)



The average ratios of energy inputs to output by region in the business-as-usual scenario are presented in Table 21. According to Table 21, China uses coal with significantly higher intensity than the rest of the countries, with a coal to output ratio three times as much as India, and twenty three times higher than North America. Oil is also used with great intensity.

India and the Former Soviet Union are among the regions with high energy intensity but with a composition of energy products different to that of China. The relatively high emissions reduction potential of these regions is due to the high intensities primarily in oil and secondarily in natural gas.

Table 21: Energy to output ratio in baseline projections (2030)

	Coal	Oil	Gas
Australia	0.0020	0.0172	0.0063
Japan	0.0003	0.0064	0.0039
East Asia	0.0017	0.0340	0.0073
China	0.0212	0.0296	0.0016
India	0.0087	0.0501	0.0130
North America	0.0009	0.0106	0.0055
Latin America	0.0009	0.0382	0.0097
Nordic Europe	0.0008	0.0099	0.0018
Germany	0.0017	0.0024	0.0018
UK	0.0010	0.0106	0.0047
Rest of Europe	0.0005	0.0070	0.0020
Other Europe	0.0012	0.0118	0.0065
Central European Associates	0.0032	0.0194	0.0068
Former Soviet Union	0.0031	0.0321	0.0271
North Africa	0.0003	0.0605	0.0060
Africa	0.0019	0.1115	0.0106
Rest of the World	0.0072	0.0191	0.0137
WORLD	0.0022	0.0182	0.0055
North	0.0008	0.0082	0.0040
South	0.0051	0.0390	0.0085

The relative position of the MACC for North America in Figure 13 can be explained by both the magnitude of economic activity and the substantial energy intensities in this region compared to the rest of the developed countries.

Among developed countries, Australia has a relatively high abatement potential because it has the highest coal to output ratio among countries of the North as well as high intensities for the other two fuels, while Japan and the European countries have relative low abatement potentials due to their low intensity in energy inputs.

A significant observation that can be noticed from Figure 12 and Figure 13 is that in some cases the MACCs of two countries intersect. This means that up to a certain level of carbon value, one country has higher emissions reduction potential compared to another country while the opposite is true thereafter. This, for instance, occurs in terms of the relative abatement potentials between China and India; for a carbon value less than €₉₉ 20, India has higher emissions abatement potential than China while for a price of permits higher than €₉₉ 20, China is the one with the higher emissions abatement potential. This inversion is due to the fact that China is relatively more carbon intensive than India and is able to substitute coal for other energy inputs with lower emission factors. On the other hand, India, due to the relatively lower carbon intensity, will be forced to substitute beyond a certain level relatively more quantities of oil, which offers lower emissions abatement potential because it has a lower emission factor than coal. Nevertheless, in terms of absolute levels as it is shown in Figure 12, China has higher emissions abatement potential than India for all levels of carbon value because of the bigger size of the production activity in this country. This characteristic is likely to affect the results of different emissions trading schemes.

2.2.3. World Emissions Profile

Under the assumptions made, which are provided in section 2.2.1, the global restriction for the Kyoto period (up to 2010) results in a carbon value of €₉₉ 14.25 at the end of the implementation period. The reduction in global emissions is 2% compared to the business-as-usual scenario.

In 2015 most of the non-Annex B regions are provided with emission rights that represent more emissions than they have in the baseline. The emission rights of Annex B countries stand at substantially lower levels than their baseline emissions. Given the availability of cheaper abatement options in non-Annex B countries, this enlargement of the permit market results in a reduction of the carbon value in 2015 compared to 2010 to €₉₉ 4.82.

Table 22: % Change of emissions compared to baseline in the “soft-landing” scenario

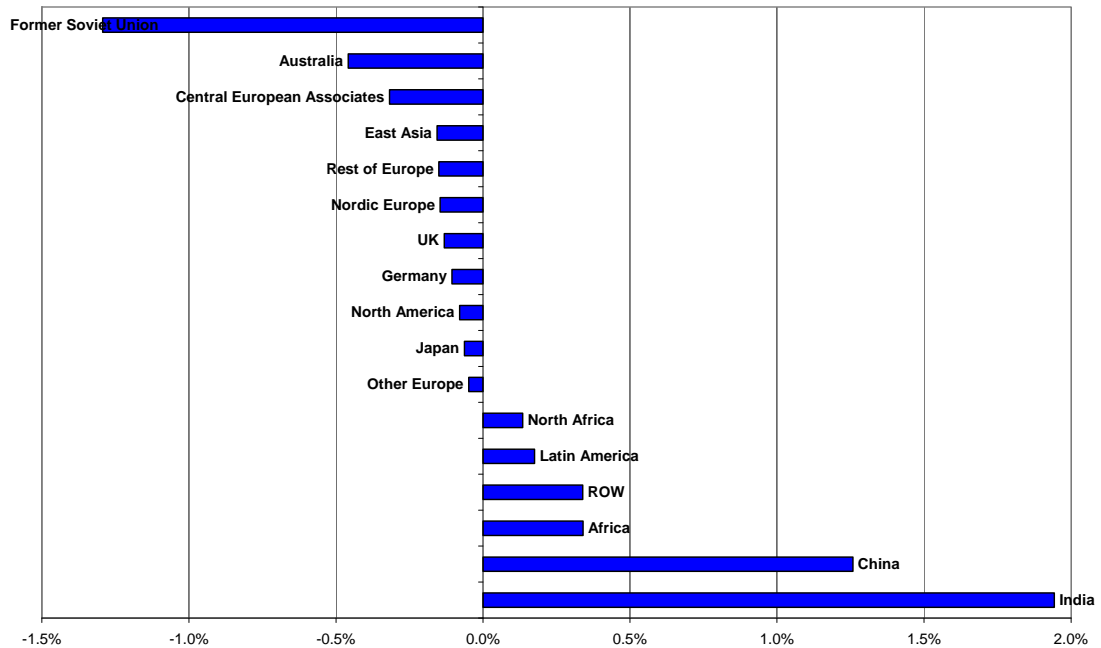
	2015	2020	2025	2030
Australia & New Zealand	-21.0	-31.9	-42.3	-53.3
Japan	-18.4	-25.3	-32.4	-38.8
East Asia	-2.0	-6.3	-14.0	-19.9
China	2.4	2.6	-2.7	-12.6
India	2.6	3.8	2.7	-0.3
North America	-10.5	-18.0	-24.6	-31.4
Latin America	13.2	19.0	16.8	7.3
Nordic Europe	-24.0	-32.7	-39.4	-43.7
Germany	-21.7	-29.3	-35.4	-39.2
UK	-15.7	-23.4	-30.4	-36.4
Rest of Europe	-20.1	-27.7	-33.9	-38.7
Other Europe	-0.2	-3.3	-9.6	-19.1
Central European Associates	-19.4	-23.4	-27.1	-31.6
Former Soviet Union	-28.0	-37.9	-45.1	-50.1
North Africa	6.4	9.3	6.5	-3.0
Africa	3.6	6.7	2.2	-2.6
Rest of the World	6.0	8.8	9.9	13.0

In 2020 the permit allocations to the Annex B countries become increasingly tight and the amount of excess emission rights (“hot air”) provided to the non-Annex B countries is increased only marginally. The higher demand for permits cannot be compensated from the slightly increased supply of permits, thus the resulting carbon value increases. Given that the restriction of emissions becomes tighter towards the end of the implementation period, the permit price for 2030 reaches €₉₉ 19.44.

The overall restriction in emissions in the “soft landing” scenario results in a reduction of 19.7% compared to the baseline in 2030.

Among developed countries, which are net importers of permits in 2030, Australia registers the most significant loss of income. According to the construction of the “soft landing” scenario, given that Australia has high ratios of GDP per capita and emissions per capita, the permit allocation for this country is lowest compared to the baseline among all regions. The rest of the developed countries, due to the amount of the emission rights they are supplied, spend no more than 0.15% of their GDP on purchases of internationally traded permits.

Figure 14: “Soft landing” scenario: net exports of permits as % of GDP (2030)



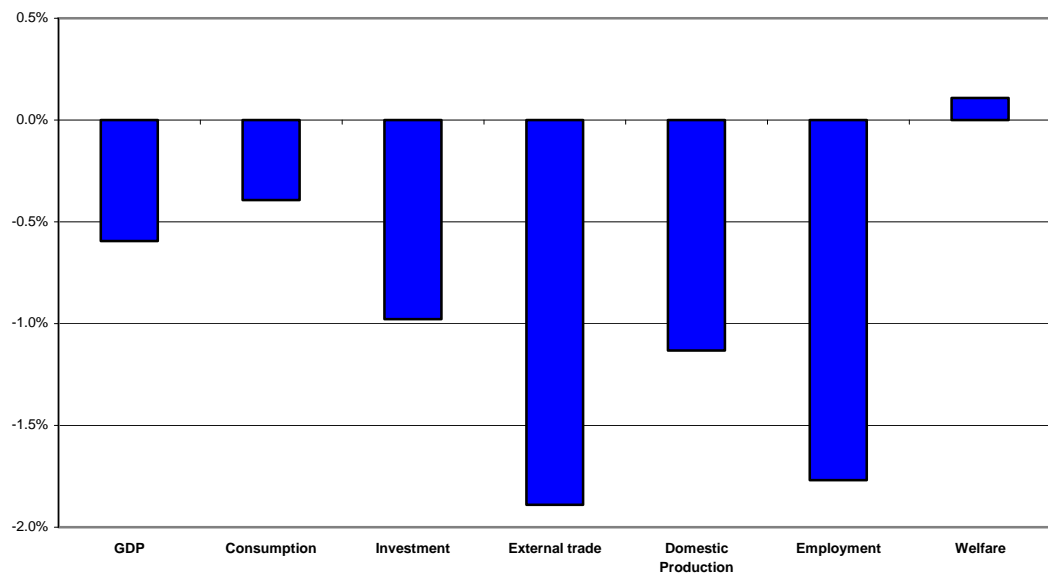
The scenario assumes that, although the Former Soviet Union is provided with permits covering its baseline emissions for the Kyoto period, the emission rights it is given for the post-Kyoto period represent substantially fewer emissions than in the baseline; this explains why their spending on permit imports reaches 1.3% of their GDP in 2030.

Among the rest of the developing countries, the Central European Associates and East Asia are the only regions that are net importers of permits. The rest of the developing countries are net sellers of permits; in the case of India and China the income flow represents 1.9% and 1.2% respectively. This is due to the fact that, as it is shown in Table 22, the permits provided to these countries do not correspond to substantially fewer emissions than in the baseline. In addition, following the discussion in section 2.2.2.3, the relative cost of abatement for these countries displayed in Figure 12 and Figure 13 is the lowest among all regions. Thus the profits for these countries from the sales of permits, as it is explained in Figure 14, are relatively high.

2.2.4. Macroeconomic Results

The macroeconomic results generated by the simulation of the “soft landing” scenario at the world level are displayed in Figure 15. As is explained previously, referring to the supply-side, the imposition of the same carbon value in all regions generates different increases in the energy cost in each country, with the low energy cost users facing the highest consequences. The income inflow from the sales of emission rights increases the demand for goods and services of the net exporters for permits while the opposite occurs for the net importers of permits.

Figure 15: The macroeconomic results of the “soft landing” scenario (% changes from baseline in 2030)



At the world level the impact of the first factor is reflected on the reductions of GDP, international trade, and employment. The burden on the price of fossil fuels increases the general price level, reducing disposable income of households and resulting in the reduction of production activity and employment. In parallel, it generates a reduction in the level of total productivity by distorting the distribution of resources both geographically and sectorally. The second factor acts towards the redistribution of world income from the developed to the developing countries. Given the higher propensity of the lower income households to consume, this redistribution of income increases the demand for consumption goods in developing regions. It also lowers the savings of most developed countries in a way that, at the world scale, a shift from investment towards consumption goods is observed. A considerable part of global activity takes place in sectors that are severely affected by the increased cost of energy inputs but, on the other hand, are not significantly involved in international trade. Such sectors are the production of electricity, domestic transport, market services, and construction. The expenditures made for the products of these sectors are largely inelastic, thus the reduction in the income spent on purchases of goods with higher elasticity is relatively bigger. This results in the more significant reduction in the demand for products with higher elasticities that are also involved in international trade. At the world level this trend is expressed through the bigger reduction of international trade than GDP.

At the regional level, the macroeconomic results of the “soft landing” scenario are displayed in Table 23. The reduction of production activity observed at the world level is also present at the regional level but with substantial deviations in the distribution of the magnitude of the reduction in each country. Based on the argumentation developed previously, the bigger reductions occur in countries that are specialized in the production and exports of energy and energy-intensive products due to the inexpensive energy inputs in the business-as-usual scenario, a situation that is radically altered by the imposition of the carbon value.

Table 23: The macroeconomic results of the “soft landing” scenario at the regional level (% changes from baseline in 2030)

	GDP	Exports	Imports	Domestic Production	Employment	Wage	Return on Capital	Welfare
Australia	-0.6	1.5	-2.6	-1.18	-0.02	-1.00	-2.76	-0.42
Japan	0.1	0.6	-1.1	-0.06	-0.06	1.67	1.75	0.00
East Asia	-0.4	0.0	-1.6	-0.89	-0.25	-0.71	-0.87	-0.19
China	-3.5	-10.1	-0.6	-5.37	-2.56	-8.60	-12.48	0.70
India	-3.5	-24.8	1.5	-6.23	-2.96	-5.23	-2.12	1.35
North America	-0.5	-1.6	-2.2	-0.96	-0.17	0.78	-0.41	-0.06
Latin America	-0.3	-3.5	-0.1	-0.64	-0.41	1.88	0.49	0.07
Nordic Europe	0.0	0.2	-1.0	-0.24	-0.07	1.11	0.95	-0.11
Germany	0.1	0.4	-1.1	-0.12	-0.08	1.06	0.87	-0.04
UK	-0.2	0.1	-1.2	-0.52	-0.12	0.80	0.20	-0.08
Rest of Europe	0.1	0.4	-1.4	-0.23	-0.09	0.88	0.69	-0.07
Other Europe	-0.1	0.0	-0.2	-0.32	-0.23	1.85	0.88	0.01
Central European Associates	-1.5	-2.3	-2.6	-2.05	-0.51	-1.08	-3.38	-0.21
Former Soviet Union	-6.1	-4.3	-11.9	-7.74	-2.20	-8.22	-15.20	0.19
North Africa	-0.9	-2.2	0.0	-1.33	-0.88	0.95	-1.84	0.10
Africa	-2.1	-5.4	-2.2	-3.54	-1.56	-3.20	-5.09	0.22
ROW	-0.1	-4.7	0.8	-0.48	-0.99	0.00	1.19	0.32

On the supply-side, the significant reduction of production inevitably lowers the demand for labor and capital, and leads to a reduction of wages and returns on capital, which are translated into lower value added and GDP. Since the reduction of emissions is achieved by substituting energy and energy-intensive inputs for less energy-intensive inputs, labor, and capital, intermediate consumption is reduced more than value added. Given that domestic production is the sum of intermediate consumption and value added, the reduction in GDP is smaller than the reduction in domestic production.

On the demand-side, the results are diversified depending on the net position of each country in the market for permits. In the case of regions such as China, India, the Rest of the World, North Africa-Middle East, Africa, and Latin America, which are net exporters of permits, the relatively higher increase of the cost of production in these countries is expressed through the lower demand for domestically produced goods both in domestic and in the foreign markets, resulting in the reduction of imports at a rate smaller than that of the reduction of exports. The income inflow from the sales of permits widens the deficit in the balance of trade even further because it initiates the increase of consumption that is covered with imports due to the substantial reduction in domestic production. In some cases, such as that of India and the Rest of the World, the income effect from the sales of permits in consumption is so big that imports actually increase. On the other hand, in regions such as the Former Soviet Union, the Central European Associates, and East Asia, which are net importers of permits, the adjustment on the demand-side follows a different path. The trade in the permit markets worsens the current account of these countries. In order to meet the restriction of the current account, imports must be reduced at a rate bigger than that of the reduction of exports. This is achieved with adjustments both on the demand- and on the supply-side. The adjustment on the demand-side is induced in the following way: the disposable income of households is reduced not only due to the reduction of the quantities of primary factors of production (labor and capital) employed and their returns but also due to the expenditures for the purchase of emission rights. This generates a reduction in the demand both for domestically produced goods and for imported goods. The lower demand for domestically produced goods reduces their prices; this reduction in some product categories is such that it compensates for the comparative disadvantage stemming from the relatively higher cost of energy. On the supply-side, the adjustment will take place in the specialization in labor-intensive goods, which are

avored due to the surplus of labor created by the lower production of fossil fuels. Sectors the production process of which gains a comparative advantage in this way experience increased exports. The final result is that the rate of increase of exports in these countries is higher than the rate of increase of imports. In the case of East Asia, which is traditionally specialized in the production of labor-intensive goods, exports are marginally increased.

The significant reductions in the returns on capital cause a redistribution of demand from investment goods to consumption goods. This impact, in combination to the increase of the disposable income of households from the sales of permits and the higher propensity to consume of the lower income households, results in an increase of consumption in developing countries.

The production activity of developed countries is reduced with rates considerably lower than those of the developing regions. This occurs because of the following reasons:

- A. The increase in the unit cost of energy in these countries is smaller, as it follows from the discussion above.
- B. Their more modern technologies allow for an easier substitution of energy inputs for other “cleaner” inputs.
- C. Their production structure is more diversified and less dependent on energy and energy-intensive activities, as it is in the case in developing countries.

The relatively smaller increase in the cost of production in these countries leads to a gain of comparative advantage in the domestic as well as in the foreign markets. This leads to an increase of exports and the reduction of imports for all developed countries but North America. The improvement in the balance of trade in North America is brought about by a reduction of imports bigger than the reduction of exports. The increased revenues from international trade compensate to a great extent the payments for the purchase of permits.

The reduction in domestic production of fossil fuels releases labor and capital that are directed towards energy-intensive sectors, in which developed countries have increased their comparative advantage. Since these sectors are more labor- and capital-intensive than the energy sectors, the marginal products of labor and capital increase, resulting in the increase of their returns. This outcome is observed in all developed countries except for Australia, the coal sector of which has a substantial reduction in production and is more capital-intensive than the energy-intensive sectors. The relatively big quantities of labor and capital released from this sector in Australia exert high pressure on the corresponding markets, leading to the reduction of wages and returns on capital. In developing countries, the increased rent on capital favors relatively investment expenditures, which decline less than consumption.

From the analysis above, two flows of income between developed and developing countries can be distinguished. These flows have the opposite direction and generate different results. The first flow of income starts from developing countries and is expressed by the deficit of their balance of trade that contributes to the reduction of their GDP. The recipients of this income are the developed countries, which direct this income towards investments due to the increased rents on capital; thus the reduction in their GDP is smaller than that of the developing countries. The second flow of income starts from the developed countries in the form of purchases of permits from the developing countries. Due to the decreased return on capital in developing countries, this income is directed towards consumption. When imports increase, the level of welfare of the households increases but GDP decreases. Thus welfare is a more appropriate measure for the impacts of the abatement effort to the consumer than the activity level, which to a large extent reflects the increased effort undertaken by a net purchaser of permits towards increased exports in order to finance this spending.

Examining the impact of the abatement effort on welfare, there is a clear pattern between the net position of a country in the market for permits and the welfare impacts on this country: the higher the sales (expenditures) the higher the gains (losses) in welfare (Figure 16). The only region that deviates from this pattern is

the Former Soviet Union. This is due to the fact that the Former Soviet Union, as well as the Central European Associates and East Asia, do not follow the pattern of flows of income of investment and consumption as described above. These countries have an improved balance of trade and purchase permits, thus have the same pattern of flows of income with the developed countries. However, due to the reduction in the return on capital, final expenditure in these countries is directed towards consumption, as in the developing countries. In the case of the Former Soviet Union, the considerable improvement in the balance of trade and the significant decrease in the rent of capital lead to an increase in consumption and welfare. On the other hand, the limited impact of the above factors in the Central European Associates and East Asia lead to the reduction of consumption at a rate smaller than that of investment, resulting in the reduction of the level of welfare.

Figure 16: The impact of sales/purchases of permits on welfare (2030)



2.2.5. Sectoral and country results

This section deals with the simulated redistribution of world activity among countries and sectors. The initial disturbance refers to the sectors of primary fuels, thus the quantitative effects on these are the most pronounced. Given that the expectations for the direction of the changes in these sectors are met, the results of the GEM-E3 model do not differ in substance from the outcomes of other partial or general equilibrium models. Given that primary fuels are a significant input in the production process, the initial disturbance is diffused to the rest of the sectors of production generating a partial re-structuring in production and external trade. The magnitude of the secondary effects, apart from the magnitude of the initial disturbance, also depends on the intensity of utilization of various inputs in the production of goods, as well as the relative position of each country in the production at the world level. These two factors are affected to a great extent by the hypotheses that have been embodied in the baseline scenario.

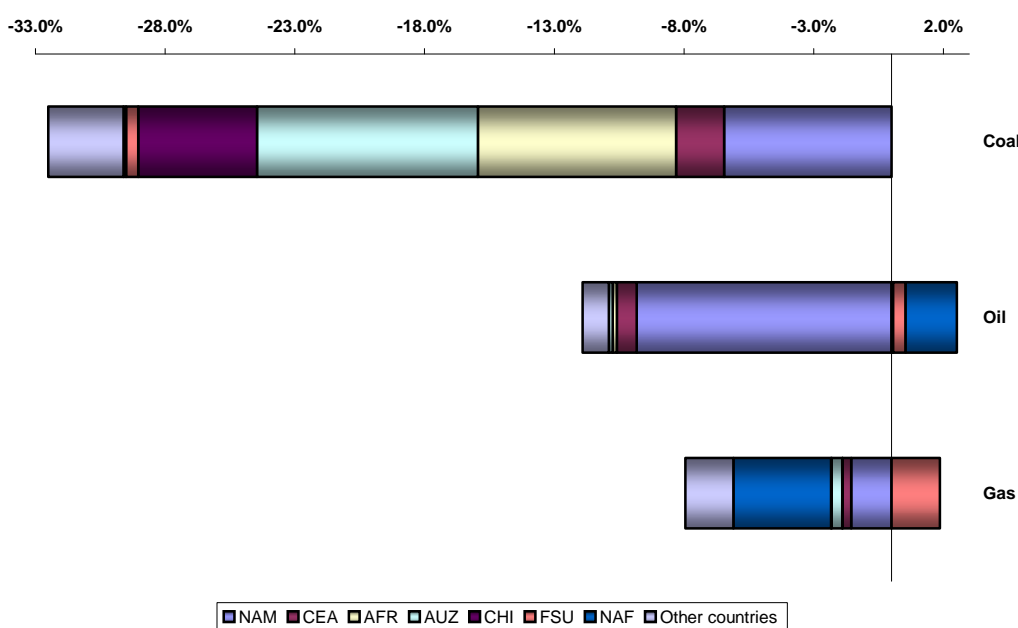
2.2.5.1. Energy products⁶

Energy products carry the main weight of the emissions restriction policy and, as expected, the demand for and production of these products are reduced.

The most significant reduction is observed in the production of coal, which has the highest emission factor among all primary fuels. Significant, although of a smaller magnitude, are the reductions in the level of production of the other two primary fuels.

The most significant reductions in the production of coal and gas take place in countries that are the major producers of these products, as is the case for China, North America, and India for coal, and North America and Former Soviet Union for gas. Coal and gas in these countries is mainly consumed domestically, thus the reduction of production is primarily driven by the reduction in domestic demand. On the other hand, the production of oil in North Africa-Middle East, which is one of the major producers of these products, is reduced with relatively low percentages. This is due to the fact that they produce oil with a lower cost than their main competitors, and gain a share in world market for oil, resulting in a small reduction of domestic production (Figure 17).

Figure 17: Decomposition⁷ of the changes in the world level of exports of energy products (2030)



A relatively big reduction in the world production is observed in the electricity sector due to the intensive use of primary fuels. The burden on the price of electricity, together with the following reduction in the demand, is heavier in countries such as China, North America, and India, where the production is made based mainly on the use of coal.

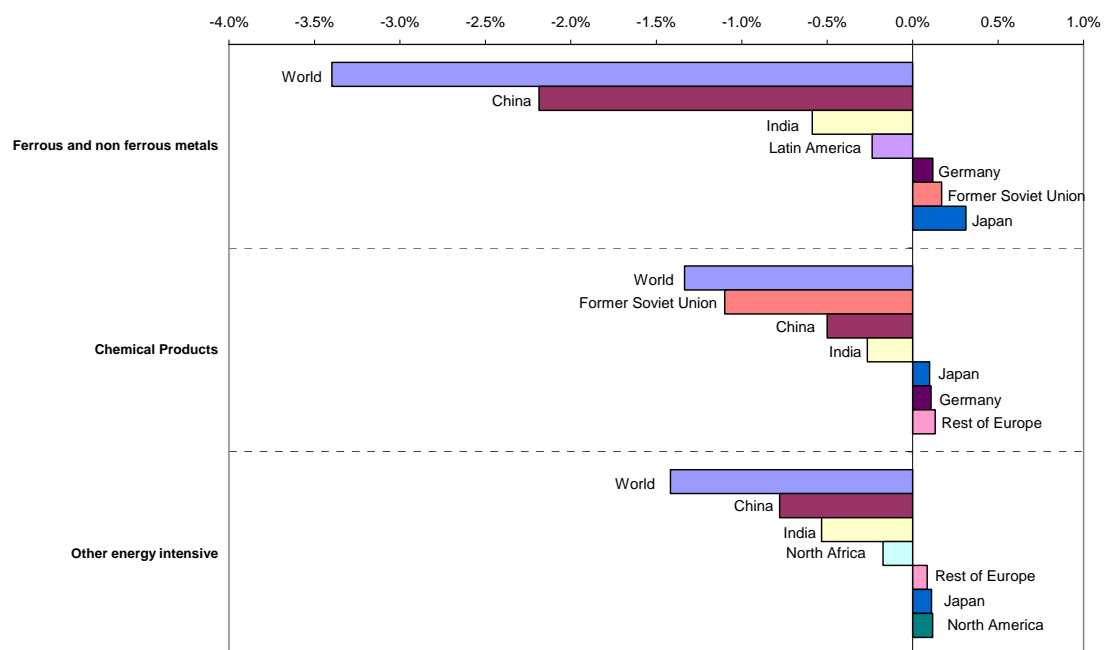
⁶ It has to be noted that, according to the aggregation adopted in the model, there is no distinction made between crude and distilled oil, thus each unit of the "oil" product in the model includes a mix of both of these products in the same ratio with in the base year (1995). The same note can be made for gas.

⁷ Idem 7.

2.2.5.2. Energy-intensive sectors

The prices of energy-intensive products, due to their dependence on fossil fuels inputs, increase more than the prices of all other non-energy sectors of the economy. The increases in the price levels are differentiated by good and country depending on its composition and the prices of energy inputs of each product. In all countries but the Former Soviet Union, ferrous and non-ferrous metals exhibit the highest increases in prices compared to the rest of energy-intensive products due to the relatively higher consumption of coal inputs in their production process. Gas is used more intensively than coal in the production of ferrous and non-ferrous metals in the Former Soviet Union. Given that chemical products in the Former Soviet Union are more gas-intensive than ferrous and non-ferrous metals, the price of the former increases more than that of the latter. The most significant increases in the prices of energy-intensive products are observed in countries with low cost of production such as China, India, Latin America, and North Africa-Middle East. These countries increase their share in world production over time in the baseline scenario due to their low prices of primary fuels. The relatively higher burden on these countries due to the imposition of a common carbon value results in the partial substitution of these products both in the domestic and the international markets.

Figure 18: Decomposition⁸ of the changes in the world production of energy-intensive products (2030).



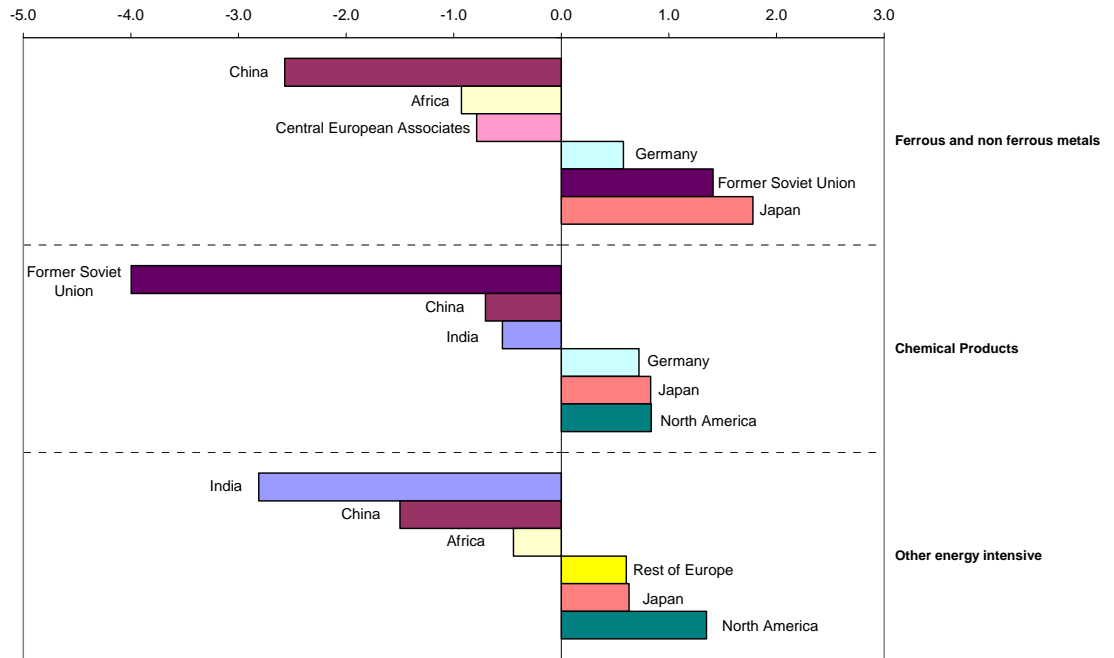
The exception to this tendency is the Former Soviet Union, which registers an increase in the production and exports of ferrous and non-ferrous metals. This is due, on the one hand to the intensive use of cheap gas (as opposed to heavily penalized coal), and on the other to the significant reduction of non-energy costs of production (substantial reductions of wages and returns on capital).

An additional reason for the lower demand for energy-intensive products in developing countries is the lower demand for investment goods. Ferrous and non-ferrous metals and chemical products are significant inputs for equipment goods (electronic, transport, other), and cement (included in the other energy intensive goods sector) is a significant input for the construction sector. For the opposite reasons developed countries such as Japan, Germany, and North

⁸ Each bar represents the contribution of each region in the change in world production.

America, which are the major producers of energy-intensive products, increase their production and gain a share in the world export markets of these products.

Figure 19: Decomposition⁹ of the changes in the world exports of energy-intensive products (2030).



2.2.5.3. Investment goods – durables

Noticeable reduction in the world production and international trade is observed in the sectors producing investment goods. In the case of transport equipment and other equipment goods, the reductions in production both at the regional and at the world levels are bigger than the reductions in the production of some energy-intensive products such as chemicals. This is due to the fact that the assumptions of the “soft landing” scenario have both direct and indirect impacts on the factors affecting demand and supply of these products.

On the supply-side, the impacts are indirect: these products, being more energy-intensive than the economy as a whole, face more intensively the considerably higher cost of the energy and energy-intensive inputs. Low-cost energy producers have the most severe consequences in this case.

On the demand-side, impacts are both direct and indirect: the direct impact refers to the increase in the price of consumption of durable goods (electronic equipment, transport equipment, other equipment goods), which, according to the hypotheses of the model, depends on the prices of fuels. Indirectly, the demand for investment goods is affected by the redistribution between consumption and savings caused by the transfers of income from permit sales and purchases. For durable goods, the combination of higher cost of production and consumption results in the reduction of production in all countries. This reduction is bigger for the low-cost energy producers due to their increasing comparative disadvantage both in the domestic and the international markets.

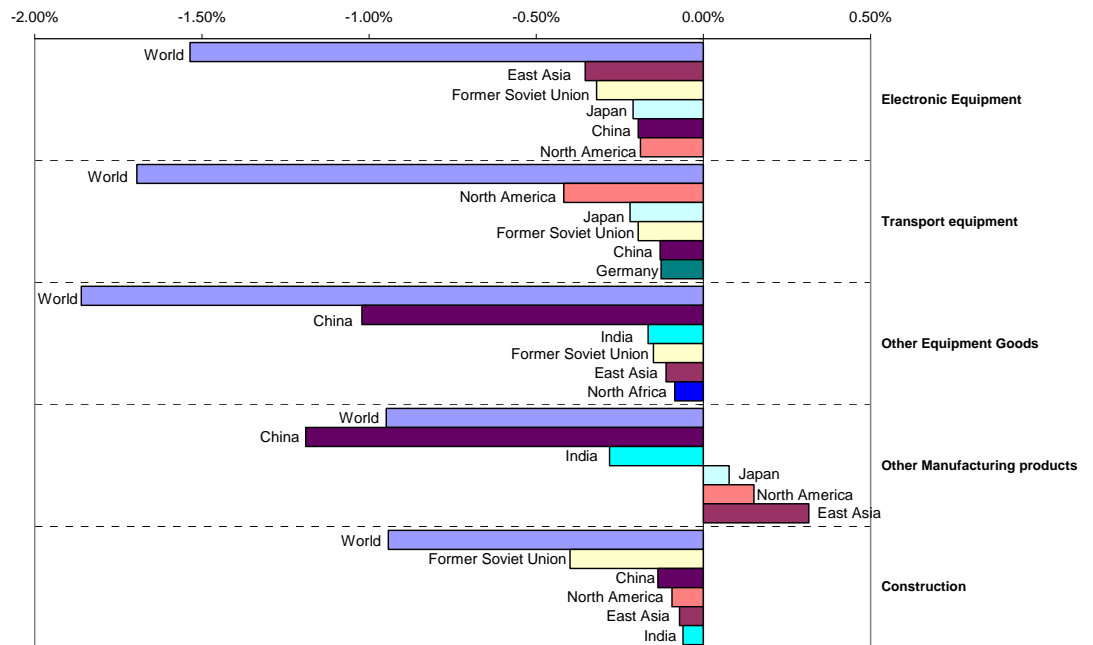
The Former Soviet Union, the exports of durable goods of which increase substantially, is the exception of this rule for two reasons: the first is the significant reduction in wages and returns on capital that compensate for the

⁹ Idem 9.

increased cost of energy and energy-intensive inputs. The second reason is the significant reduction of domestic demand (mainly intermediate consumption and investments), thus more output becomes available for exports.

In developed countries the reductions in production and exports of these goods are only marginal. In some cases such as North America and Australia, exports increase as a result of the combination of increasing comparative advantage and the confinement of domestic consumption expenditures. The production in the construction sector is reduced in all countries due to the lower investment expenditures in all countries. This reduction is bigger in developing countries due to the redistribution of expenditures towards higher consumption. The sector of other manufacturing products is affected only indirectly in this simulation. The comparative advantage of developing countries, in combination to the bigger reduction of their investment expenditures, results in the reduction of production and exports. Developed countries increase their production in order to meet the higher domestic demand for investments as well as the increased demand for imports from developing countries.

Figure 20: Decomposition¹⁰ of the changes in the world production of investment products (2030).



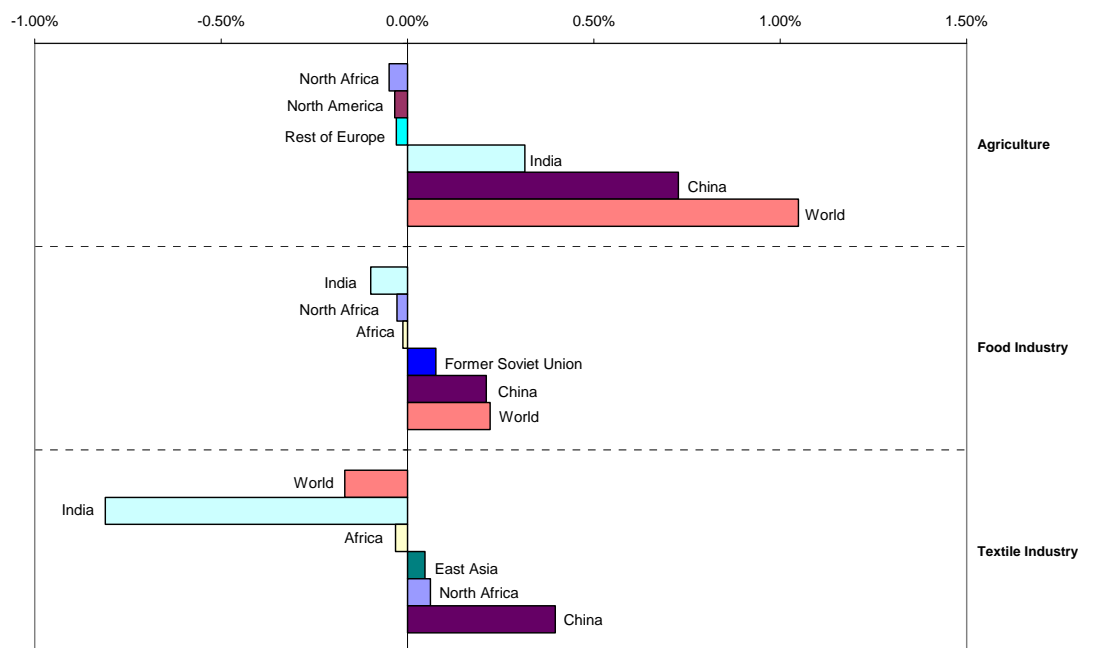
2.2.5.4. Traditional consumption goods

On the supply-side, consumption goods face the lightest burden from the higher prices of energy inputs compared to the rest of the sectors in the economy because of the low intensity with which these inputs are used. On the other hand, given that traditional goods are primarily labor-intensive and secondarily capital-intensive products, their costs of production are significantly affected by the changes in wages and returns on capital. The most noticeable reductions of wages, combined with the relatively higher labor-intensity of consumption goods in developing countries, results in the bigger reduction of the cost of production in these countries. Excluding the food and textile industries in India, the reduction of wages compensates for the higher prices of energy inputs, leading to a lower cost of production of traditional consumption goods.

¹⁰ Idem 9.

On the demand-side, these products are favored by the redistribution of expenditures towards higher consumption levels, while the opposite occurs in developed countries. The result of these adjustments is the increase of production of traditional goods in developing countries and a corresponding decrease in the developed countries. At the world level this is translated into the increase in the production of agricultural and food products, and a marginal reduction in the production of textiles mainly due to the substantial reduction in the production of these goods in India. The highest increases in production take place in China and the Former Soviet Union, where the biggest reductions in wages occur. These two countries have the highest increase in exports of traditional consumption products. On the other hand, in the majority of developed countries the exports of these goods decrease.

Figure 21: Decomposition of the changes in the world production of traditional consumption products (2030).



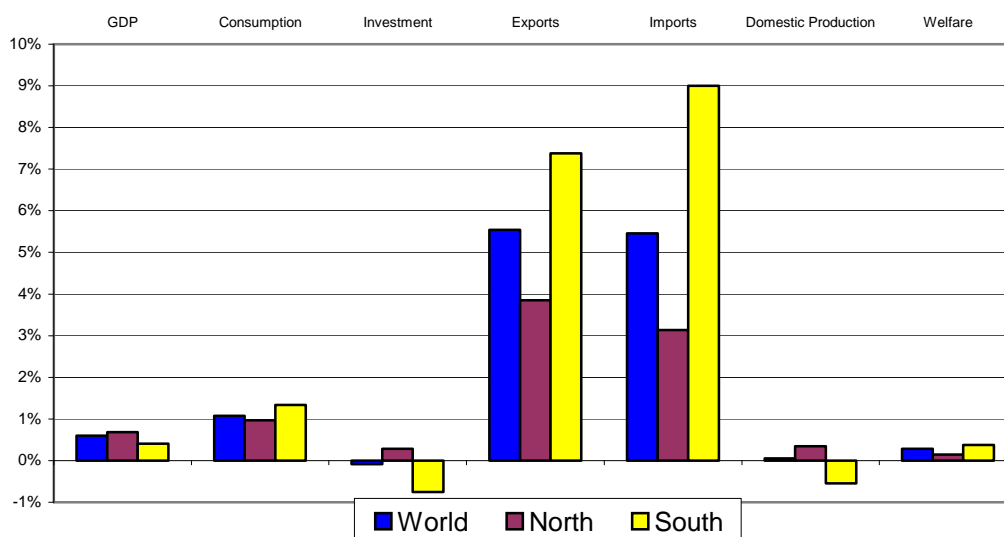
2.3. The Effects of Free Trade in Emissions Abatement: “Trade Liberalization & Soft Landing” Scenario

In this part of the book we will examine the impact on the results of the model of a combination of shocks: the elimination of tariff and non-tariff barriers and the imposition of the emissions restriction policy. The main question that is addressed is whether the abolition of tariffs facilitates the abatement effort or not. A similar question is brought up in the literature regarding the discussions over the “Double Dividend” hypothesis. These discussions examine if the level of welfare of a country increases in the case that the revenues from the imposition of a carbon tax are used for the reduction of other taxes. In this study, such a direct correlation between the reduction of tariffs and revenues from the sales of permits is not possible due to the design of the scenarios. The financing of the reduction of tariffs is an issue of the public sector while the transactions regarding permits take place among private sector agents (firms and households). Furthermore, the “full liberalization” scenario requires that tariff and non-tariff barriers are totally eliminated and not reduced up to the point that the loss in tariff revenues is equal to the gain from the revenues from permit sales. Nevertheless, the results of the simulated scenario from the GEM-E3 model provide useful insights for the impact of tariff abolition on the abatement effort of each country.

2.3.1. Macroeconomic results

The macroeconomic results stemming from the simulation of the “Trade Liberalization & Soft Landing” scenario (FL&SF) are, as expected, a synthesis of the results of the “Trade Liberalization” and “Soft Landing” scenarios (Figure 22).

Figure 22: Results of the “FT&SL” scenario at the macroeconomic level (2030)



The elimination of tariffs results in the increase of world production of all goods, and specially of the traditional consumption goods (agriculture, food industry, textiles) due to the tariff peaks existing in these sectors. The significant differences existing in the tariff burden between countries of the North and the countries of the South result in the higher increase in the production of these goods in developing countries. The imposition of the restriction on emissions reduces significantly the economic activity at the world level, with the burden placed mainly on energy and energy-intensive sectors. On the country level, the

imposition of the same carbon value in all countries has the most significant impact on the low energy-cost producers, the majority of which belong to the developing countries. The higher burden on the prices of developing countries is translated in a reduction of their relative advantage and their shares in world exports in the international markets. The transfers of income in the form of purchases and sales of emission permits, in combination to the restriction on the current account of developing countries, redistribute expenditures of countries towards consumption goods in developing countries and towards investment goods in developed countries, with the corresponding adjustments in welfare. The favorable impact of the tariff abolition on the level of prices and the increase in consumption expenditures create an increased demand for the goods of traditional consumption sectors in developing countries. However, given that the sectors that are negatively affected from the increased cost of energy constitute the largest portion of economic activity of these countries, total domestic production is reduced and their trade balance becomes negative. This results in the increase of GDP in developed countries with rates higher than those of developing countries.

2.3.2. Sectoral results

The elimination of the relatively low tariffs imposed on primary fuels is not enough to compensate for the significant burden on their prices from the imposition of the carbon value, thus the demand for and production of primary fuels is reduced significantly both at the regional and global levels. The reduction in the production of coal is bigger in the South mainly due to the size of Chinese production. In international markets, given that Australia is the major exporter of coal, the reduction in the exports of coal in the North is bigger than that of the South. The significant shares of North Africa-Middle East and the Former Soviet Union in the world exports of oil explain, following the argumentation of the “soft landing” scenario, the increase in the exports of oil in the South. The significant dependence of the electricity sector on coal mainly in developing countries (China, India, and the Former Soviet Union) overrides the increase in the demand for electricity coming from the increased economic activity due to tariff abolition, resulting in the reduction in the production of electricity at the world level.

The production of energy-intensive products at the world level is reduced or increased only marginally. The contribution of developing countries to this evolution is significant; in these countries demand decreases for two reasons: the first is that the higher burden on energy inputs in the countries of the South creates a comparative disadvantage in the production of energy-intensive products, resulting in the reduction in the demand for exports of energy-intensive products. The second reason is the reduction of investments, which are the main source of domestic demand for energy-intensive products.

The adjustments in the case of investment goods are more complex: the demand for investments increases in developed countries while it is reduced in the countries of the South. Moreover, the prices of durable goods (transport and other equipment goods) intended for consumption purposes increase due to the higher prices of primary fuels, reducing the demand for these products in all countries. Therefore domestic demand for durable goods intended either for consumption or investment purposes decreases in the countries of the South. The elimination of the relatively high tariffs imposed on the transactions among countries of the South increases the demand for exports but not enough to compensate for the reduction in domestic demand. The result of these adjustments is the reduction of domestic production of durable goods in developing countries. In developed countries the increase in the demand for durable goods for investment purposes as well as the increase in the demand for exports are enough to offset the reduction of demand for consumption purposes, resulting in a higher level of domestic production for these goods.

Table 24: % Changes from baseline in domestic production (2030)

	Full Liberalisation			Soft Landing			Soft Landing & Full Liberalisation		
	World	North	South	World	North	South	World	North	South
Agriculture	1.9	1.8	2.0	1.0	-0.2	1.9	3.1	1.4	4.2
Coal	1.5	-0.4	2.2	-36.3	-32.4	-37.6	-36.3	-33.2	-37.3
Oil	1.5	1.2	1.7	-9.6	-16.6	-5.2	-8.5	-15.8	-4.0
Gas	1.0	0.7	1.3	-11.4	-11.8	-10.9	-10.7	-11.3	-10.0
Electricity	1.2	0.8	1.7	-6.0	-3.0	-10.3	-5.1	-2.2	-9.1
Ferrous and non ferrous metals	1.3	0.9	1.8	-3.4	1.0	-8.3	-2.2	2.1	-7.0
Chemical Products	1.6	1.0	2.7	-1.3	0.7	-4.8	0.2	1.8	-2.5
Other energy intensive	1.2	0.5	2.4	-1.4	0.7	-5.2	-0.3	1.3	-3.2
Electronic Equipment	1.4	0.1	3.8	-1.5	-0.7	-3.0	-0.3	-0.8	0.5
Transport equipment	0.9	1.7	-1.3	-1.7	-1.3	-2.9	-0.9	0.3	-4.2
Other Equipment Goods	1.2	0.7	2.0	-1.9	-0.2	-4.8	-0.7	0.6	-3.0
Other Manufacturing products	1.5	-0.3	4.3	-0.9	0.6	-3.4	0.5	0.4	0.5
Construction	0.8	0.5	1.6	-0.9	-0.3	-2.3	-0.2	0.2	-0.9
Food Industry	2.3	2.1	2.6	0.2	0.0	0.6	2.6	2.3	3.2
Trade and Transport	1.2	0.8	2.0	-0.8	-0.5	-1.6	0.4	0.4	0.3
Textile Industry	3.3	0.6	5.5	-0.2	0.1	-0.4	3.2	0.8	5.2
Other Market Services	0.8	0.8	0.9	-0.1	-0.2	0.2	0.8	0.7	1.1
Non Market Services	0.1	0.4	-0.6	0.1	0.0	0.4	0.7	0.4	1.4

Table 25: % Changes from baseline in exports (2030)

	Full Liberalisation			Soft Landing			Soft Landing & Full Liberalisation		
	World	North	South	World	North	South	World	North	South
Agriculture	26.1	25.1	27.2	0.0	-1.0	1.1	27.0	23.0	31.5
Coal	1.8	-2.1	6.4	-32.5	-30.5	-34.9	-32.2	-32.8	-31.5
Oil	2.9	2.7	3.0	-9.4	-22.0	2.2	-7.0	-19.9	4.8
Gas	1.5	-1.6	2.3	-6.1	-14.8	-3.7	-4.5	-16.2	-1.3
Ferrous and non ferrous metals	7.7	4.2	10.6	-1.2	6.8	-7.9	6.3	12.2	1.3
Chemical Products	8.2	4.0	13.3	-2.5	3.7	-10.2	5.3	8.1	1.9
Other energy intensive	7.4	2.0	12.6	-2.2	6.1	-10.2	4.7	8.7	0.7
Electronic Equipment	6.6	2.1	9.7	-1.8	-1.3	-2.1	4.6	0.5	7.4
Transport equipment	9.9	6.7	21.4	-1.8	-1.6	-2.5	7.7	4.8	18.6
Other Equipment Goods	7.6	3.8	13.2	-2.0	0.3	-5.3	5.3	4.0	7.1
Other Manufacturing products	11.5	2.0	16.2	-2.7	3.3	-5.8	7.9	5.6	9.1
Food Industry	11.9	6.9	17.7	-0.3	1.2	-2.0	11.7	8.1	15.7
Textile Industry	9.9	2.1	12.6	-0.4	0.9	-0.8	9.6	2.9	11.9

At the world level the production of durable goods is reduced due to the significant decrease of production in the countries of the South. An increase in the production and exports of electronic equipment in developing countries and a reduction in the production and exports of these goods in developed countries is observed; this is due to the fact that countries such as China and East Asia have gained a comparative advantage in the production of these goods at the expense of Japan and North America. The significant reduction of wages caused by the reduction of production activity in China and East Asia reduce significantly the cost of production of electronic equipment, which is labor-intensive in these countries. The production in the construction sector, the product of which is almost exclusively used for investment purposes, drops in the countries of the South and increases in developed countries, following the course of investments in these regions.

2.3.3. The effects of trade liberalization on the abatement effort.

The increase in production activity caused by the tariff abolition results in a greater use of coal, crude oil, and gas as intermediate inputs for the production of goods and as final goods for household consumption, therefore more emissions are produced both in regional and world levels. More specifically, world emissions are increased by 1.6%. As is shown in Table 26, about 60% of the increase in emissions comes from China and India while only 10% from European regions. This is due to the relatively higher increase in activity in China and India as a consequence of trade liberalization.

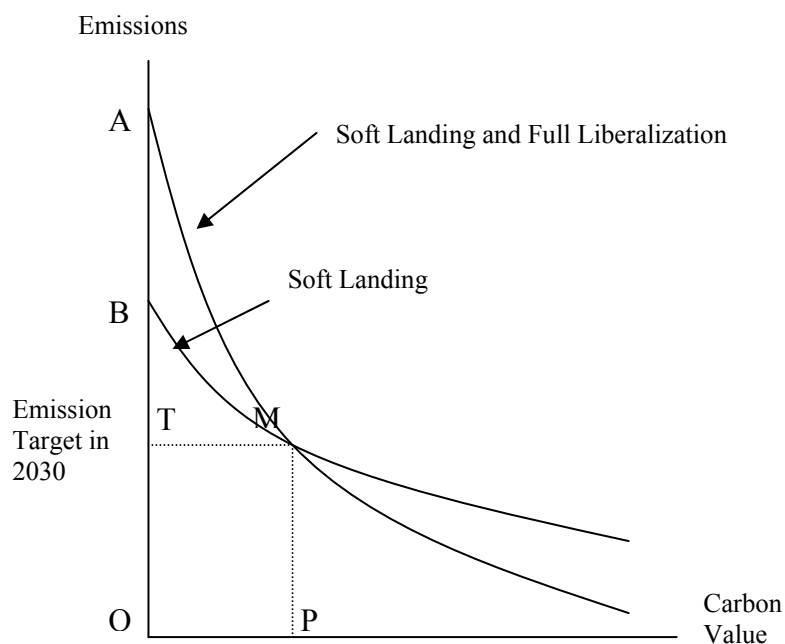
Table 26: Changes in regional emissions in the “full liberalization” scenario compared to baseline (2030)

	Changes from Baseline (%)	Contribution to Total Increase from Baseline (%)
Australia	1.1	0.9
Japan	1.4	2.3
East Asia	1.5	8.3
China	2.1	27.9
India	4.5	28.8
North America	0.5	5.7
Latin America	1.0	2.9
Nordic Europe	0.9	0.3
Germany	0.7	0.9
UK	1.0	0.9
Rest of Europe	1.2	3.4
Other Europe	1.4	1.1
Central European Associates	1.6	2.4
Former Soviet Union	0.7	3.8
North Africa	1.1	4.1
Africa	1.9	4.9
Rest of the World	2.0	1.4

The increase in emissions notwithstanding facilitates the abatement effort through a more efficient allocation of resources. As shown in Table 27, tariffs on primary fuels are substantially lower than on non-fuels, thus the prices of non-fuels face a bigger reduction. This means that the substitution towards non-fuel goods is more pronounced. The increased production activity also favors the increase of investments for the entire 2010-2030 period, thus capital inputs are higher in the “FL&SL” scenario, increasing the substitution ability of primary fuel inputs.

The changes induced by trade liberalization are in a way equivalent to a change in the shape of the implicit Marginal Abatement Cost Curve. For illustration purposes, a comparison of the abatement effort between the “Soft landing” and the “FL&SL” scenarios is shown in Figure 23. Point B shows the quantity of emissions in the baseline, which, according to the projections used for the simulations, reaches 44.4 billion tones of CO₂. Point T shows the target quantity of emissions in the “Soft Landing” scenario, which is 35.6 billion tones of CO₂. In the “Soft Landing” scenario the carbon value is gradually increased up to the point P (€₉₉ 19.4) in order to reduce emissions so that the target is met. Diagrammatically, this gradual adjustment takes place along the curve BM. The tariff abolition results in the increase of emissions compared to baseline represented by the distance BA. The quantity of emissions in the “full liberalization” scenario (point A) is 45 billion tones of CO₂.

Figure 23: A comparison of the abatement effort between the “soft landing” and “FL&SL” scenarios



In the “FL&SL” scenario the target quantity of emissions is assumed to remain the same as in the “Soft Landing” scenario, thus the reduction achieved in the “FL&SL” scenario is bigger. Nevertheless, this reduction is obtained with almost the same carbon value (€₉₉ 19.5) as in the “Soft Landing” scenario. The fact that in the “FL&SL” scenario a bigger emission reduction is achieved at almost the same marginal cost is a measure of the positive impact of tariff abolition on the global emission abatement effort.

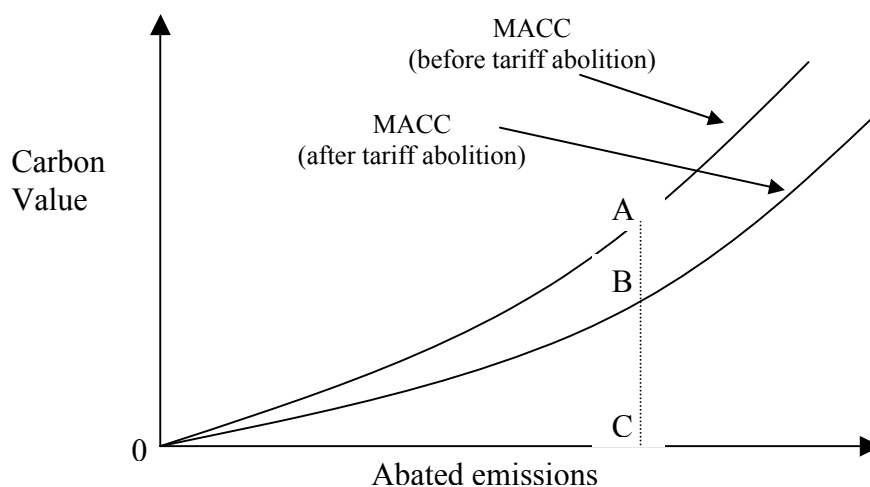
At the regional level, the measurement of the increase in the effectiveness in emission reduction can be illustrated with the use of country-specific MACCs. An increase in the effectiveness in emission reduction means that the same quantity of abated emissions is achieved with a lower carbon value or that the MACC of each country moves to the right (Figure 24). In order to measure the improvement of the ability to abate, the MACCs are re-estimated for the case that the emissions restriction policy is combined with the full liberalization of international trade (see Appendix).

The comparison of the two sets of MACCs shows that the curves have moved to the right for each country. The measurement of this shift for each country is made based on the percentage reduction on the carbon value resulting from the replacement of the abated quantities of emissions in 2030 with the ones of the “soft landing” scenario¹¹.

¹¹ The distance AC is equal to the common carbon value for all countries resulting from the “soft landing” scenario in 2030 and the distance OC is equal to the abated emissions of the corresponding country. Thus the percentage reduction we refer to is equal to the rate

$$100 \cdot \left(\frac{AB}{AC} - 1 \right).$$

Figure 24: The impact of trade liberalization on MACCs



The results of this exercise are displayed in the third column of Table 27. According to the data of Table 27 and the argumentation above, the highest gains in terms of effectiveness in the reduction of emissions is found in countries with the highest tariff rates in the baseline. The size of tariffs is a measure of the distortion in the allocation of resources and also of the extent of adjustments that take place due to the trade liberalization. In India and the Rest of the World, which have high tariff rates in the baseline, the same emission reduction is achieved with lower carbon values due to tariff abolition. On the other hand, the adjustments in European countries are almost negligible due to the low tariffs they impose on their imports.

Table 27: The impact of trade liberalization on the abatement effort (2030)

	Primary Fuels Average Tariff (%)	Non-Fuels Average Tariff (%)	% Change in Carbon Value due to Tariff Abolition
Australia	0.1	6.1	-2.0
Japan	0.6	8.6	-2.8
East Asia	4.9	8.1	-4.1
China	3.5	18.8	-5.9
India	16.9	30.1	-20.6
North America	1.4	3.0	-2.2
Latin America	10.2	8.1	-5.8
Nordic Europe	0.1	1.2	-2.6
Germany	0.1	1.5	-1.6
UK	0.1	2.1	-1.9
Rest of Europe	0.2	2.1	-3.3
Other Europe	4.2	4.6	-4.0
Central European Associates	2.2	6.6	-6.4
Former Soviet Union	0.0	1.2	-2.3
North Africa	5.3	6.4	-3.6
Africa	1.3	6.0	-4.8
Rest of the World	20.4	25.1	-11.8

3. CONCLUSIONS

The main result obtained from the analysis of the scenario involving the full liberalization of international trade is that the total elimination of tariffs leads to an increase in world GDP and welfare level. This corresponds with expectations derived from trade theory. However the pace of trade liberalization in recent decades (which has been extended into the Baseline Scenario) has raised questions as to further potential for gains and our analysis points to the conclusion that they still exist. Furthermore most of the potential benefits from full liberalization of international trade seem to be concentrated on developing countries where most of the doubts concerning its desirability have been expressed.

According to this scenario's results most of the increase in trade (both imports and exports) in developing countries is due to an increase in exchanges among these countries that increase faster than other bilateral transactions. The increase in total exports of developed countries is mainly due to increased exports to developing countries and less to the increase in the trade among developed countries.

The biggest increases in investments take place in the countries that have the highest tariff rates, enabling a positive response of domestic production to the increased demand generated by the elimination of tariffs. This ability to expand capital inputs together with the more effective allocation of resources resulting from the removal of distortions eventually leads to a positive correlation between the relative percentage of tariffs to GDP and the rate of increase of GDP.

The observation that international trade increases at a higher rate than GDP is strongly supported by the results of GEM-E3. It can be mainly attributed to the "love of variety" property incorporated in the model. Due to the existence of tariffs, imported varieties comprise a smaller percentage of the domestic demand than the domestic varieties, thus consumers spend the additional income generated by the elimination of tariffs to buy more of the imported varieties.

At the sectoral level, the elimination of the substantial tariff burden imposed on imports of goods from traditional sectors (agricultural, textiles and food products) results in a substantial increase of international trade in these products.

Concerning Climate Change policies for the Kyoto horizon a number of cases have been examined. They involve alternative configurations for participation in Clubs of abating regions with a common target corresponding to Kyoto commitments for the respective regions. Abatement is paradigmatically assumed to take place under a regime of a full tradable permit market involving all abating agents within the Club, benefits from permit sales accruing to the consumers in the respective regions. Since the model used is a computable general equilibrium model, the costs and benefits include abatement costs, costs and benefits from purchases/sales of permits as well as secondary impacts, notably those arising from changes in the terms of trade and re-allocation of economic activity in different sectors and countries.

In all cases examined where Developing countries do not participate in an abating Club and therefore incur no direct costs they end up with diminished welfare due to secondary effects in the form of reduced prices and volumes of their energy and energy intensive exports.

A withdrawal of the United States from the Kyoto process apart from reducing the environmental impact of the process and endangering the whole process (55% clause) signifies a considerable increase (2.5 to 4 times) of the average cost to the EU per ton of CO₂ avoided worldwide. This result is to a large extent due to carbon leakage effects (lower fossil fuel prices and higher polluting activity in non-participating regions).

Inclusion of the Former Soviet Union naturally blunts the environmental impact because of the so called "hot air" effects but at the same time enhances the efficiency of the abatement effort in the EU (the average cost to the EU per ton of

CO₂ avoided worldwide falling to between a half and two thirds of their levels when the Former Soviet Union did not participate). Such reductions are less important if the Former Soviet Union does not bring into the market the totality of its excess permits.

The Former Soviet Union stands to gain overall from inclusion in the Club of abating countries. Such gains are very substantial in cases when the USA is also participating but remain non-negligible for other configurations especially when the Former Soviet Union does not trade all its excess permits.

When not participating in a Club the Former Soviet Union experiences losses in economic terms compared to the zero worldwide abatement reference case. These losses result from the fact that the Former Soviet Union is a major energy and energy-intensive product exporter and suffers from lower export prices and higher import prices (worsening of terms of trade) without the benefit of net permit sales. In this sense non-inclusion for the Former Soviet Union is a worse case even than the complete collapse of the Kyoto process and considerably worse than inclusion in an abating Club.

Were the EU to attempt meeting its Kyoto commitments alone with its Central European Associates the prospect of inclusion of the Former Soviet Union would render the exercise meaningless since it is very likely that the sum of the targets will be above reference (no abatement) levels. Former Soviet Union participation in such a Club can only be envisaged in the context of limitations to Former Soviet Union excess permits used. Such a scenario would bring considerable economic benefits (compared to the EU/CEA alone case) to both the EU and the Former Soviet Union. It would however be accompanied by a corresponding reduction in environmental effectiveness.

A number of cases were examined where the Former Soviet Union was assumed to participate in a Club acting as a monopolist in restricting the supply of excess permits in order to maximize its benefits. It was found that the restriction that maximized the value of permit sales did not correspond to the point of maximum welfare. In most cases the latter represented a less restrictive stance where some loss in net sales was compensated by gains in welfare arising from trade effects. In general such imperfect competition in the permits market was found to increase the cost of abatement at the world level although such increases were small when the abating Club was large (involving the whole of Annex B).

For the post-Kyoto period an abatement scenario of the "soft landing" type has been considered. Such scenarios take into account current emission patterns and increasingly tighten individual country emission budgets depending on income and emissions per capita. The aim has been to extend the climate change policy analysis beyond the Kyoto commitment period when it can be reasonably assumed that developing countries participate in the abatement effort. Again free trade in permits without transaction costs was assumed generating a unique carbon value for the world. Two major factors contribute to differentiation of impacts across regions: a) though unique this carbon value generates differential impacts on energy costs in the different regions, depending on carbon intensity but also on differential energy prices incorporated in the Baseline scenario, and b) the income inflow from the sales of emission rights increases the demand for goods and services of the net exporters of permits while the opposite occurs for the net importers of permits.

At the world level the impact of the first factor is reflected on the reductions of GDP, international trade, and employment. The burden on the price of fossil fuels increases the general price level, reducing disposable income of households and resulting in the reduction of the production activity and employment. In parallel, it generates a reduction in the level of total productivity by distorting the distribution of resources both geographically and sectorally. The second factor acts towards the redistribution of world income from the developed to the developing countries. Given the higher propensity to consume of the lower income households, this redistribution of income increases the demand for consumption goods in developing countries, lowers the savings of most developed countries in a way

that, at the world scale, a shift from investment towards consumption goods is observed.

Two flows of income having the opposite direction and generating different results between developed and developing countries can be distinguished. The first flow of income starts from developing countries and is expressed by the deficit of their balance of trade that contributes to the reduction of their GDP. The recipients of this income are the developed countries, which direct it towards investments due to the increased rents on capital; thus the reduction in their GDP is smaller than that of the developing countries. The second flow of income starts from the developed countries in the form of purchases of permits from the developing countries. Due to the decreased return on capital in developing countries, it is directed towards consumption. When imports increase, the level of welfare of the households increases but GDP decreases.

The energy products carry the main weight of the emissions restriction policy and, as expected, the demand for and production of these products are reduced both at the regional and global levels. Similar impacts are obtained for energy intensive sectors.

On the supply-side it is consumption goods that face the lightest burden from the higher prices of energy inputs. On the other hand, given that traditional goods though not energy-intensive are labor-intensive and to a lesser extent capital-intensive products, their costs of production are significantly affected by the changes in wages and returns on capital. The most noticeable reductions of wages, combined with the relatively higher labor-intensity of consumption goods in developing countries, results in the bigger reduction of the cost of production in these countries. On the demand-side, these products are favored by the redistribution of expenditures towards higher consumption levels, while the opposite occurs in developed countries. The result of these adjustments is the increase of production of traditional goods in developing countries and a corresponding decrease in the developed countries.

In order to examine possible impacts of trade liberalization in view of climate change policy a scenario was constructed combining tariff abolition with the post-Kyoto global constraint scenario discussed above.

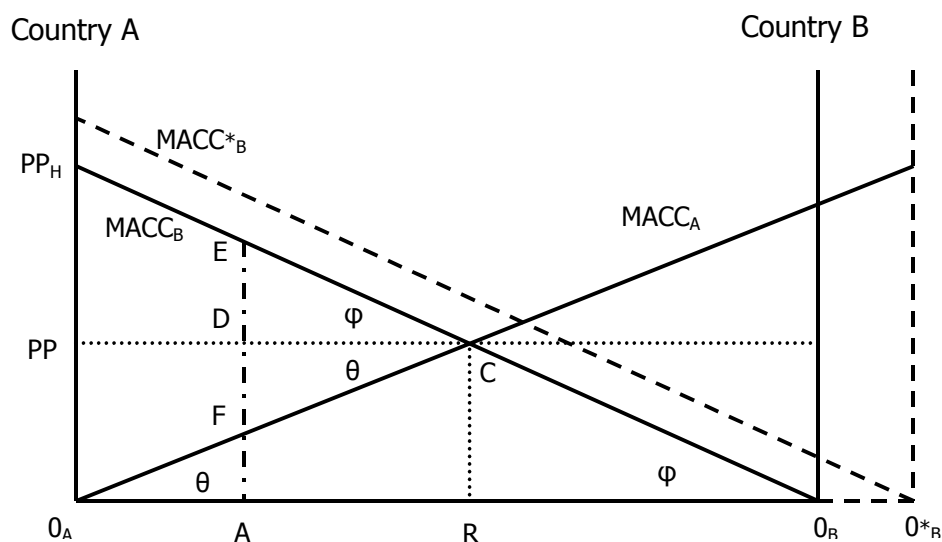
As was mentioned earlier, tariff abolition leads to increased productive activity worldwide which would result in a greater use of coal, crude oil, and gas as intermediate inputs for the production of goods and as final goods for household consumption. This means that emissions in the liberalization scenario stood at a level 1.5% higher than the Baseline. About 60% of the increase occurs in China and India while only 10% from European regions corresponding to the relatively higher increase in the production activity in China and India. Imposing the emission constraint therefore implies that reductions at the world level must be deeper. However, the carbon value obtained is substantially the same as in the abatement case without trade liberalization. This is mainly due to important side effects of liberalization that permits an increase in investment in developing countries and a more efficient allocation of resources worldwide. Such changes are equivalent to a rightward shift of the implicit marginal abatement cost curves. The highest profits in terms of effectiveness in the reduction of emissions are found in countries with the highest tariff rates.

4. APPENDIX: MARGINAL ABATEMENT COST CURVES

In a simulation of a market for emission permits of a computable general equilibrium model, there are two factors playing a crucial role for the resulting outcome: the determination of the total abated quantity of emissions and the distribution of emission rights to the participating countries. With the assistance of the MACCs the ways through which these factors affect the outcome are explained.

Let there be a permit market with two participating countries (A and B) as it is shown in Figure 25. The total quantity abated is represented by the distance $0_A 0_B$ on the horizontal axis of the diagram. The starting point of the axes for country A is 0_A and the abated emissions increase to the right. In the same way, the starting point of the axes for country B is 0_B and the abated emissions increase to the left. $MACC_A$ and $MACC_B$ stand for the MACCs for countries A and B respectively. For the sake of the presentation, emission rights are expressed as the difference of the amount of emissions according to the allocation of permits in the scenario and baseline emissions. From Figure 25 it can be inferred that country A has the right to produce $0_A A$ less emissions than in the baseline (the same stands for the distance $0_B A$ for country B).

Figure 25: MACCs and the mechanism of emissions abatement



The least-cost combination of the reductions of emissions in the two countries as it is defined in a computable general equilibrium model is achieved at the point of intersection of the two MACCs. At this point the marginal abatement costs of the two countries are equal by definition, meaning that country A will reduce its emissions by $0_A R$ and country B by $0_B R$. The common carbon value for the two countries resulting from the model is equal to PP . Under the technological conditions existing in each country and expressed by the MACCs, the main factor affecting the carbon value and the distribution of emissions in a permit market is the total quantity of emissions from the overall restriction. An increase in the overall restriction on emissions is equal in this example to a shift of the starting

point of the axis for country B from the point O_B to the point O^*_B and a parallel shift of $MACC_B$ to $MACC^*_B$. As it is expected this tighter constraint will generate an increase in the carbon value. It is also expected that in the least-cost combination of the reduction of emissions, the most significant emission abatement will be made by the country with the MACC that has the higher elasticity; in terms of Figure 25 this is the country with the steepest MACC. This can be proved diagrammatically in the following way: Supposing that the two countries have the same MACCs, both countries would reach the same reduction in emissions which would be equal to half of the total quantity of emissions according to the overall restriction¹². If we assume that the slope of $MACC_B$ is reduced, meaning that it rotates counterclockwise around the point O_B then at the new equilibrium country A reaches a bigger reduction of emissions compared to country B.

Given the least-cost allocation of the reduction of emissions the initial distribution of emission rights to the participating countries, shown by point A, determines the sales and purchases of emission permits among countries. In Figure 25 it can be observed that country A, for the given distribution of emission rights, is a net exporter of permits. The quantity of permits sold by country A to country B is equal to the distance AR. For this sale country A receives the amount represented by the area ADCR, while the total cost of abatement for the same quantity is provided by the area AFCR. Therefore the profit for country A from the sales of permits is represented by the area of the triangle DFC. In a similar way, country B pays for the purchase of AR emission rights the amount represented by the area ADCR while the cost of abatement for this country if it had been abating alone would be the area of the trapezoid AECR. The profit for country B is represented by the area of the triangle CDE. It can be proved that the country that has the flattest MACC (indicating higher abatement potentials) has the highest profit¹³ from this transaction. In the case that country A is provided with emission rights enough to cover its emissions in the baseline, then the line EA in Figure 25 shifts to the position $O_A P P_H$.

In order to construct a MACC in the framework of the current study, several simulations under alternative hypotheses as for the restriction on emissions of each country were examined using the GEM-E3 model. With the resulting carbon values and abated emissions, the existing relationship between these two variables in each country was estimated econometrically. The functions have been approximated by 2nd and 3rd degree polynomials of the form:

$$PP = \alpha_3 \cdot \Delta E^3 + \alpha_2 \cdot \Delta E^2 + \alpha_1 \cdot \Delta E$$

where PP : Carbon value
 ΔE : Abated CO₂ emissions (in billion tons)

¹² The triangle $O_A C O_B$ is isosceles and therefore its height is also its median.

¹³ In terms of Figure 25 this means that triangle DFC has a bigger area than the triangle DCE if the angle ϑ is bigger than the angle φ . It is true that

$$DF = CD \cdot \tan(\vartheta) > DE = CD \cdot \tan(\varphi), \text{ thus}$$

$$\frac{1}{2} \cdot DF \cdot CD = \frac{1}{2} \cdot CD^2 \cdot \tan(\vartheta) > \frac{1}{2} \cdot DE \cdot CD = \frac{1}{2} \cdot CD^2 \cdot \tan(\varphi)$$

Table 28: Estimates for MACCs by region in the “soft landing” scenario (2030)

	α_3	α_2	α_1	R^2
Australia	2674.4000	73.3550	95.6120	0.9999
Japan	0.0000	670.6600	125.1100	0.9998
East Asia	0.0000	66.6230	24.8580	0.9998
China	0.4756	-0.2090	3.4105	0.9999
India	4.8397	-0.8302	5.7284	0.9998
North America	0.9644	-0.1694	6.0689	0.9999
Latin America	0.0000	419.5700	73.8660	0.9999
Nordic Europe	0.0000	11494.0000	375.3600	0.9995
Germany	0.0000	866.3600	118.2700	0.9996
UK	0.0000	930.5600	89.0670	0.9999
Rest of Europe	0.0000	168.2600	50.5620	0.9998
Other Europe	0.0000	2057.1100	176.1100	0.9997
Central European Associates	0.0000	373.0300	17.6120	0.9982
Former Soviet Union	3.5469	4.3654	13.9270	0.9999
North Africa	0.0000	116.1900	55.8480	0.9999
Africa	-54.4840	149.7100	55.3330	0.9998
Rest of the World	0.0000	3270.6000	129.6700	0.9991

Table 29: Estimates for MACCs by region in the “FT&SL” scenario (2030)

	a_3	a_2	a_1	R^2
Australia	2561.8000	77.3120	93.9740	0.9999
Japan	0.0000	649.7300	121.9100	0.9998
East Asia	0.0000	63.6610	23.9490	0.9998
China	0.4508	-0.2218	3.2537	0.9999
India	4.0970	-1.4132	5.0986	0.9998
North America	0.9400	-0.1760	5.9641	0.9999
Latin America	0.0000	398.9300	70.2510	0.9999
Nordic Europe	0.0000	11270.0000	363.9100	0.9995
Germany	0.0000	851.5900	116.5700	0.9996
UK	0.0000	908.5100	87.9210	0.9990
Rest of Europe	0.0000	163.1900	48.7690	0.9998
Other Europe	0.0000	1967.4000	169.5600	0.9997
Central European Associates	0.0000	352.0300	16.0810	0.9981
Former Soviet Union	3.2631	4.7041	13.3730	0.9998
North Africa	0.0000	112.4100	53.7900	0.9999
Africa	-57.9800	149.9200	51.2810	0.9998
Rest of the World	0.0000	2958.5000	110.6400	0.9990

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