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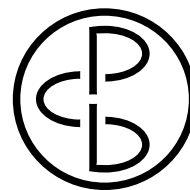
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The Interplay between Globalization and Environmental Objectives

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Abstract

This paper presents two scenarios simulated with the applied general equilibrium model WorldScan. The scenarios are constructed to study the effects of globalization on environment quality and environmental policies. WorldScan quantifies the economic content of the scenarios and the volume growth of energy and emissions between 1995 and 2020. It shows that trade as such does not affect the volume of emissions except for technology spillovers. However, trade liberalization affects significantly the carbon leakage of implementing environmental policies in the Annex-1 regions to the non Annex-1 regions.

1. Introduction¹

Globalization is an ongoing trend. Although the current economic crisis may raise some doubts on the benefits of globalization in some developing countries, globalization is still seen as a prerequisite for further development. Globalization can be interpreted as the growing economic interdependence of countries world-wide through the increasing volume and variety of cross-border transactions in goods and services and of international capital flows and also through the more rapid and widespread diffusion of technology. It affects trade patterns, capital flows and location choices of firms at a regional and global level. It could raise economic growth of developing regions substantially, leading to a drastic shift of production activities to these countries. Moreover, increasing linkages between regions could affect the dissemination of new technologies and consumer preferences.

All these effects of the globalization process could have an impact on global environmental quality. Globalization affects environmental quality by the increase in production, the shifts in the composition and location of production and consumption activities, other technology paths, and different product mixes (Jones, 1997). This paper aims to identify those elements of the globalization process which affects environmental quality, measured by CO₂ emissions, substantially.

Besides the effects on environmental quality, globalization also influences the effectiveness of environmental policy. If the industrial and transition countries (also called the Annex-1) want to pursue emission limits, their efforts would have to be more intense if economic growth is higher due to globalization. Moreover, if developing countries catch up a larger share of CO₂ will be emitted by those countries such that environmental policy of the Annex-1 countries is less effective on a global level. These policies are also less effective because energy-intensive producing firms can escape environmental legislation in the Annex-1 countries more easily by shifting their production to non Annex-1 countries in a globalizing world. The analysis of these policy effects is the second aim of this paper.

We analyse the effects of globalization on environmental quality and the sustainability of environmental objectives using two scenarios. Scenario one is characterised by globalization. Scenario two is characterised by low growth and a lack of further globalization, say a business-as-usual scenario. Both are comparable to the High and Low Growth scenario of the OECD in their study on globalization and the effects for the OECD (1997). We develop those diverging scenarios to study the impact of globalization on environment until 2020.

The quantitative effects of both scenarios are illustrated by WorldScan. This is an applied general equilibrium model for the world economy. It focusses on economic growth in the long run and trade patterns between the twelve regions in the model, see also Section 2. For that reason WorldScan is a good tool to analyse scenarios which focus on globalization. Moreover, it categorises several sectors among which are energy sectors such as oil, gas and coal, and energy-intensive and energy-extensive sectors. As a consequence, macroeconomic analyses can be combined with environmental policies.

The emphasis will be laid on the growth in energy and emissions in both scenarios. Starting from the low growth scenario, we introduce one-by-one the characteristics of globalization process mentioned above. Section 3 presents the economic outcomes of both scenarios. We compare the outcomes of these simulations in terms of emission growth. This enables us to identify the characteristics of the globalization process which contribute heavily to emission growth. Section 4 shows that trade liberalization as such does not affect CO₂ emissions drastically as is also discussed by Jones (1997) and others. However, faster productivity growth in mainly developing countries induced by among others technology spillovers affect the volume of emissions heavily. The simulations show that technology spillovers are for the greater part responsible for the increase in

¹This paper benefitted from discussions with Hans Timmer.

emissions due to globalization if these are directed at productivity growth and not at energy efficiency. Shifts in the consumption patterns from Food and Agriculture to services does nearly not affect the volume of emissions just as capital market integration has nearly no effect.

Moreover, we introduce environmental policies necessary to reach the Kyoto targets in both scenarios to study the effects of globalization on these policies. This analysis is carried out in Section 5. Whether or not globalization occurs, the economic effects of introducing environmental legislation to obtain the emission targets are about 0.5% of GDP in 2020 for the industrial countries. These effects are larger for the transition countries. The unilateral energy taxes are significantly higher in the globalization scenario. However, the effects on GDP are limited. Environmental legislation by the Annex-1 countries is less effective in a globalizing world. First of all, those countries produce a smaller share of global emissions such that the impact of legislation of global emissions is much lower. Second, the analysis shows that the shift from energy-intensive industries to the non Annex-1 countries is much larger in a globalizing world. In particular, the breakdown of import tariff contributes much to this shift. Due to these so called carbon leakage effects, environmental policy in the Annex-1 countries is much less effective. So, although trade liberalization as such does not affect the level of emissions significantly, its impact on the effectiveness of environmental policy is substantial. Section 6 elaborates on this conclusion and summarizes some of the main results.

2. WorldScan: a global applied general equilibrium model²

WorldScan has been developed to construct scenarios. To avoid extrapolation of current trends or mere reproduction of the current situation, WorldScan relies on the neoclassical theories of growth and international trade. Changes in economic growth and international specialization patterns evolve from changes in (relative) endowments. The emphasis on the long run also manifests itself in the broad definition of sectors. WorldScan distinguishes 11 sectors. This is a relatively small number compared to other AGE models. Over a long period of two decades or more the character of products and branches of industry change drastically. Current statistical definitions of products and branches of industry are likely to become irrelevant at the end of scenario period. For this reason, WorldScan uses broad aggregates.

The standard neoclassical theory of growth distinguishes three factors to explain changes in production: the accumulation of physical capital, labour, and a fixed technology trend. WorldScan augments the simple growth model in three ways. First, WorldScan allows overall technology to differ across countries. It also takes up the related idea that developing countries can catch up quickly by adopting foreign state-of-the-art technologies. Second, the model distinguishes two types of labour: high-skilled and low-skilled labour. Sectors differ according to the intensity with which they use high-skilled and low-skilled labour. Countries can raise per capita growth by schooling and training the labour force. Third, in developing countries part of the labour force works in low-productivity sectors. In these sectors workers do not have access to capital and technology. Reallocation of labour from the low-productivity sectors to the high-productivity sectors enables countries to raise per capita growth as well. In principle, all these three factors affect the performance of a region only temporarily. Catching-up, training of low-skilled workers and reallocating labour to the high-productivity sector do not raise the growth rate indefinitely. Nevertheless, they are important. Adjustments in the economies of developing regions take a great deal of time and will surely show up in the growth rates of these regions in the period under consideration.

²The model is described extensively in CPB (1999a).

Box 1 WorldScan, a global general equilibrium model

At the heart of WorldScan are the neoclassical theories of economic growth and international trade. The core of the model is extended to add realism to scenarios. In doing so, we aim at bridging the gap between academic and policy discussions. The extensions include:

- an Armington trade specification, explaining two-way trade and allowing market power to determine trade patterns in the medium run, while allowing Heckscher-Ohlin mechanisms in the long run;
- imperfect financial capital mobility;
- consumption patterns depending upon per capita income, and developing towards a universal pattern;
- a Lewis-type low-productivity sector in developing regions, from which the high-productivity sector can draw labour, enabling high growth for a long period.

The model distinguishes the following regions, sectors and productive factors (see appendix for a detailed, regional and sectoral classification):

<i>Regions</i>	<i>Sectors</i>	<i>Productive factors</i>
United States	Agriculture	<i>Primary inputs</i>
Western Europe	Services	Low-skilled labour
Japan	Trade and Transport	High-skilled labour
Rest of the OECD	Electricity	Capital
Eastern Europe	Intermediate goods	(fixed factor)
Former Soviet Union	Consumer goods	
Middle East and North Africa	Capital goods	<i>Intermediate inputs</i>
Sub-Saharan Africa	Oil	from all sectors
Latin America	Natural Gas	
China	Coal	
South-East Asia	Other Raw Materials	
South Asia & Rest		

Education and reallocation of workers not only explain the performance of developing countries, but also affect specialization patterns. Workers in the informal, low-productivity sector are predominantly low-skilled. When more workers find employment in the high-productivity sectors, the (relative) wage of low-skilled workers falls and mainly sectors that intensively employ low-skilled workers expand. These regions will specialize further in sectors which make a lot of use of the relative abundant factor: low-skilled labour. Obviously, education has an opposite effect. Low-skilled labour will become relatively more scarce and shifts production to sectors which intensively use high-skilled labour. Either effect can dominate. This is also reflected in the relative wages of high and low-skilled. In some developing countries wages of low-skilled workers lag behind the wage of high-skilled workers, whereas in other regions the skill premium decreases.

Sectors in WorldScan have different factor requirements. For a given sector these factor requirements are more or less similar across regions. This means that if a sector is relatively capital intensive in one region, it is also relatively capital intensive in other regions. Agriculture (including food processing) and Consumer Goods employ relatively few high-skilled workers, whereas Capital Goods, Electricity, Trade and Transport and Services (including the government) absorb many high-skilled workers. Sectoral restructuring can easily be linked to changes in relative endowments and changes in (region-specific) demand patterns. This also holds because in WorldScan substitution elasticities between domestic and foreign goods are believed to be high in the long run, at least much higher than in the short run. All goods are tradable, although trade in services is much lower than in manufacturing and raw materials.

Except for different factor inputs, sectors vary also in some other respects. The sectors Capital Goods and Services are the suppliers of investment goods and the sectors, Oil, Coal, Gas and other Raw Materials only produce intermediate outputs. Consumer demand for electricity also includes demand for other energy carriers. This assumption is made because nearly all demand for Raw materials is intermediary demand.

Data

WorldScan has been calibrated on the GTAP database, see Mc Dougall et al. (1998). The calibration year is 1995. From this data base we derive not only demand, production and trade patterns, but also labour and capital intensity of the various sectors. The sectoral classification according to skill intensity is broadly correct, but the precise differences could very well change, when better data become available.

The data and projections for population size and labour supply are from various sources. The United Nations (1995) provide demographic projections. The ILO (1996) provides projection rates on participation rates until 2010. We extrapolate the regional trends in participation rates between 1950 and 2010 to 2020. The data for the supply of low-skilled and high-skilled workers at a regional level have been taken from Ahuja and Filmer (1995). Workers are labelled high-skilled when they have completed secondary education or a higher level. Ahuja and Filmer provide projections for many developing countries. We lack projections for the OECD, Eastern Europe and the Former Soviet Union. Therefore we use the Barro and Lee (1996) data on education. We derive a trend between OECD and non-OECD regions between 1960 and 1990 and extrapolate this trend until 2020. The data on the size of the informal sector are obtained from the WorldBank (1995) and the ILO (1998). The IEA (1997) provides data on energy volumes and emissions for the base year, 1995.

Substitution elasticities

The results of the model depend also on the substitution possibilities in production and consumption. The production possibilities are described by a nested CES function. The upper level distinguishes between value added and intermediate goods. The elasticity between these two broad categories is 0.8. At the lower level value added is described by Cobb-Douglas function of the primary productive factors: capital, low-skilled labour and high-skilled labour. The intermediate goods are described by a nested CES function with a substitution elasticity of 0.8. The first nest is a CES function which includes energy and raw materials such as Oil, Petrol, Natural Gas, Electricity and other Raw Materials. The substitution elasticity between these inputs is 2.0. The second nest is also a CES function with again a substitution elasticity of 0.8, which includes the other intermediate inputs.³ The utility function, from which demand for different consumption categories is derived, has been given a Cobb-Douglas specification. The substitution elasticity between any pair of consumption categories therefore is unity.

Traded, foreign goods are not perfect substitutes for domestic goods, and this also affects the outcome of simulations. The substitution between goods from different origin is not perfect. WorldScan employs an Armington-type assumption. However, the price elasticities of demand considerably increase over time. The model employs different assumptions for raw materials, Agriculture, Manufacturing and Services. The long-run substitution elasticities in the benchmark case are 9, 9, 7 and 5 respectively.

³In case of the sector Electricity, the input Electricity is a part of the nest with other Intermediate inputs instead of the nest consisting of Energy and Raw materials.

3. The Low Growth and High Growth scenarios

This section presents two scenarios: a High Growth scenario and a Low Growth scenario. The former is a globalization scenario. It is optimistic on economic progress in developed and developing regions. It emphasizes globalization tendencies and market-oriented policies in the world economy. The latter is a business as usual scenario. Both are akin to the High Growth and Low Growth scenario, which CPB and OECD constructed for their collaborative study on globalization and the consequences for the OECD countries (OECD, 1997).⁴

The idea of the High Growth scenario is that when developing countries grow fast or start to grow rapidly, the linkages between the OECD and the non-OECD countries intensify. Fast development outside the OECD area and complete liberalization of goods and capital markets produce closer economic integration of rich and poor countries. More generally, the scenario extrapolates and probably exaggerates the current globalization tendencies. We compare the results of this scenario with a Low Growth scenario to consider the impact of globalization. This section presents the economic differences between both scenarios while Section 4 focusses on the effects of globalization on the environment

We introduce a globalization and a business as usual scenario because the differences between both stress the linkages between regions in particular between developed and developing regions. The ties between the regions are fairly close in the High Growth scenario. As a consequence, the spillover effects between the regions are large. These spillovers affect also the amount of carbon leakage to the non Annex-1 countries induced by the agreements in the Kyoto protocol. Carbon leakage results from emission limits in the Annex-1 countries, because energy-intensive production processes shift to the non Annex-1 countries.

We do not want to suggest that one scenario is more plausible than the other. We only use these scenarios to illustrate the impact of globalization. Because of the intensified linkages between regions in this scenario, it fits that purpose fairly well.

To attain and sustain high growth rates, developing countries should pursue sound domestic policies. Countries that do not create favourable conditions for market-based development, are likely to fail. Governments must also promote or at least not discourage (private) savings, invest in public infrastructure and human capital and at the same time try to control or even curb fiscal deficits and public debt. Finally, developing economies must open up to allow foreign goods and foreign investment. Liberalising trade of goods, services and capital allows countries to specialise, exploit economies of scale and create competition. Moreover, open markets stimulate the dissemination of modern technologies in the developing regions.

In the High Growth scenario, trade liberalization applies globally. Whereas barriers to trade in manufacturing goods are already low, agriculture is still heavily protected. Mainly developing countries benefit from liberalization in agriculture.

One of the most important driving forces for economic growth is technical progress. If the speed of technical progress is high, economies grow fast, such as in the High Growth scenario. The rate of technical progress is 0.5 to 1% per year higher than in the Low Growth scenario. The rate of innovation in the Trade and Transport sector is higher than average technical progress in the High Growth scenario. This reflects the idea that sharp falling costs in transportation and communication

⁴The Globalization scenario is also akin to the Schumpeterian scenario in our project Globalization, International Transport and the Global Environment, which focuses on the effect of globalization on the global environment induced by trade, see CPB (1999b), en Van Veen-Groot and Nijkamp (1998). The Low Growth scenario is comparable to the Ecological scenario in that project, except for the assumptions made on environmental policy in the latter scenario.

benefit trade substantially. Trade is also stimulated by the breakdown of tariff barriers. Moreover capital markets are further liberalised in the High Growth scenario.

Because per capita incomes rise in the non-OECD, the consumption patterns will change. Consumers will spend relative more money on Services and less on Agriculture, as is the case in the OECD countries. This convergence to the OECD consumption pattern is of course less pronounced in the Low Growth scenario, in which the per capita growth rate is low.

Table 3.1 Exogenous trends in all scenarios (in %)

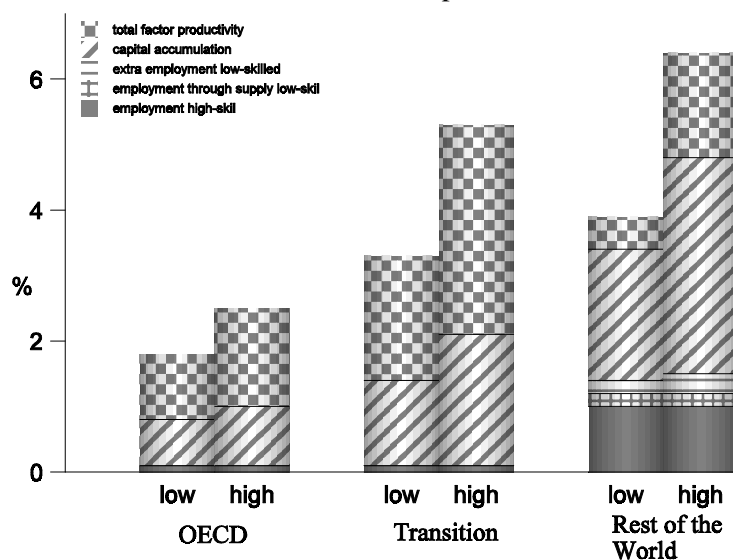
Scenario	Low Growth		High Growth	
Region	OECD	non OECD	OECD	non OECD
Technical progress (annual)	1.0	0.9	1.5	2.1
Technical progress Trade & Transport (annual)	1.1	0.8	2.1	2.7
Population growth (annual) medium scenario UN	0.3	1.4	0.3	1.4
Schooling (annual)	0.1	2.8	0.1	2.8
Trade liberalization	0%	0%	100%	100%
Degree of capital market integration	stable		increasing	
Consumer preferences convergence towards	bit to services	bit to OECD	services	to OECD

growth

In the High Growth scenario many poor countries catch up, though not completely, with rich countries. Due to education, population growth, and labour reallocation from the low-productivity to the high-productivity sectors, labour is one of the engines for growth, see Figure 3.1.

Figure 3.1 Growth accounting

annual contributions of the productive factors 1996-2020.



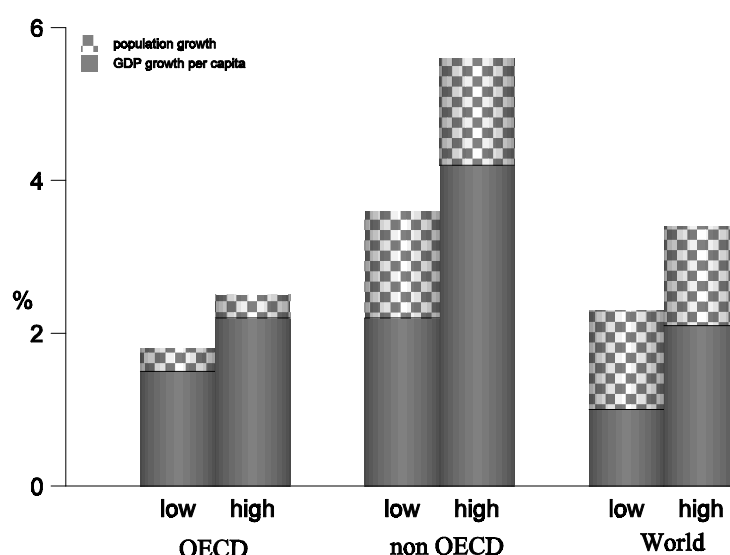
Moreover, capital accumulation is fairly important in the developing regions. The liberalization of

capital markets and the high savings rates in the Rest of the world, in particular Asia, contribute substantially to the supply of capital in the non-OECD. Because of the lack of population growth and stable schooling levels in the OECD, technology is the most important contributor to economic growth. Technology is also important for the transition countries in order to reform the inefficient production processes inherited from the communist past.

The differences in growth between both scenarios are mainly due to differences in technological progress and extra capital accumulation induced by the increase in TFP. Compared to the low growth scenario, the average growth rate of technology is about 0.5% per year larger for the OECD regions in the High Growth scenario and about 1.0% per year in for the other regions. Reallocation from labour to the high-productivity sectors is also higher in the High Growth scenario, because wages in these sectors rise faster.

Non-OECD countries grow at a per capita rate of 4.2% in the latter scenario, while OECD countries grow on average with a rate of 2.2% per capita (Figure 3.2). This is an optimistic scenario, because only a few countries have been able to maintain growth rates of about 4% per capita for two decennia or more. At a global level the increase in income per capita is lower. This is caused by the population increase in the non-OECD, where the income levels per capita are much lower than in the OECD.

Figure 3.2 Annual growth per capita



The increase in labour productivity is also apparent in Table 3.2. First, labour reallocates quickly from the low-productive sectors to the high-productivity sectors in the High Growth scenario. The size of labour reallocation in terms of labour supply is twice as large. Second, education levels will increase. The supply of high-skilled labour is much higher than average population growth (2.8% compared to 1.4%, respectively, see Table 3.1). Technical progress contributes also to economic growth in the non-OECD. The opening of goods and capital markets facilitates the dissemination of western technologies to the non-OECD countries in the High Growth scenario. Together with sound market-oriented policies and government investment, productivity rates will be pushed upwards in these countries. The high growth rate for total factor productivity in the non-OECD compared to the one in the OECD represents technological catching up.

Table 3.2 Aggregated percentage shares in 1995 and 2020 in both scenarios

year	OECD			non-OECD		
	1995	low	high	1995	low	high
informal sector (share labour supply) ¹	6.9	6.9	6.9	50.1	40.9	31.6
savings ratio (ratio nat. income)	20.6	16.7	17.6	24.2	23.5	32.7
ratio of value of trade to GDP ²	11.0	12.4	21.7	24.8	22.9	39.0
share of food in total consumption	9.6	7.9	7.6	26.0	19.7	16.3
share of services in total consumption	74.3	75.6	75.8	54.0	61.4	65.3
share in world GDP	77.1	68.3	61.0	22.9	31.7	39.0

¹For the OECD countries, this is the unemployment rate.

² This includes intra-regional trade.

High productivity growth rates match rapidly increasing demand from the non-OECD countries. The reduction and elimination of trade barriers contributes to this process. International specialization becomes more and more pronounced during the scenario period in response to the liberalization of goods markets and lower transport costs. International trade flourishes as is indicated by the substantial increase in the trade to GDP ratio in the High Growth scenario. The OECD specializes relatively more in high-skilled labour-intensive goods such as Capital goods and Services. Non-OECD countries specialize in Consumer goods which are low-skilled labour intensive.

The specialization pattern is a bit hidden by the general trend towards the production of high-skilled labour-intensive goods. In particular, consumers in the non-OECD countries change their consumption patterns from Agriculture and Food towards Services. In the OECD this trend also continues, but to a moderate extent. This implies that in spite of specialization the non-OECD countries produce also much more Services now. The non-OECD share in world production increases drastically in both scenarios. In the High Growth scenarios it nearly reach 40%. This is amazing, but still far away from their share in total population. All these trends are much more pronounced in the Globalization scenario than in the Business as usual scenario. However, in general the trends in both scenarios point in the same direction.

specialization patterns

Figure 3.3 presents the differences in the export (net of intra trade) to production ratio between 1995 and 2020 for both scenarios at a sectoral level. The ratio of exports to production is an indicator for the linkages between regions. The sectors Oil, Natural Gas, Coal and Other Raw Materials are aggregated to Raw Materials. Because of limited trade in the sectors Services, Electricity and Trade and Transport, these sectors are not represented in Figure 3.3. It shows that the OECD regions export a larger share of production, while the non-OECD regions export relatively less in the Low Growth scenario. In particular, OECD regions export relatively more Raw Materials and Capital Goods, while the decrease in exports for these goods is the highest for all sectors in the non-OECD regions.

In the High Growth scenario including trade liberalization this picture changes. Trade in all sectors increase substantially in the scenario period. The elimination of the high trade barriers in agriculture is a big stimulus for trade in that market. In particular, United States, Australia and Canada benefit from open markets. Trade in Consumer Goods and Capital Goods is also heavily stimulated by the breakdown of the tariffs. The OECD has more possibilities to export Capital Goods and the non-OECD to export Consumer Goods.

The increase in trade in the High Growth scenario does not necessarily lead to further specialization. The numbers in Figure 3.3 could represent only intra-industry trade. To account for specialization, we present Figure 3.4. This Figure shows the changes in the ratio of net exports to production for both scenarios. In the Low Growth scenario the OECD regions specialize in Agriculture, Raw Materials and Intermediate, while the non-OECD specialize relatively in Consumer Goods, and Capital Goods. Trade liberalization as it takes place in the High Growth scenario,

emphasizes this picture for some sectors but weakens it for others. Specialization does not increase in Agriculture. The increase in trade thus mainly intra-industry trade. That is also the case for Raw Materials. The OECD does specialize in Intermediate Goods and also net trade in Capital Goods increases to some extent. The non-OECD regions specialize in consumer Goods and trade liberalization strengthens their competitiveness in that sector.

Figure 3.3 Differences in export to production ratio in both scenarios 1995 - 2020

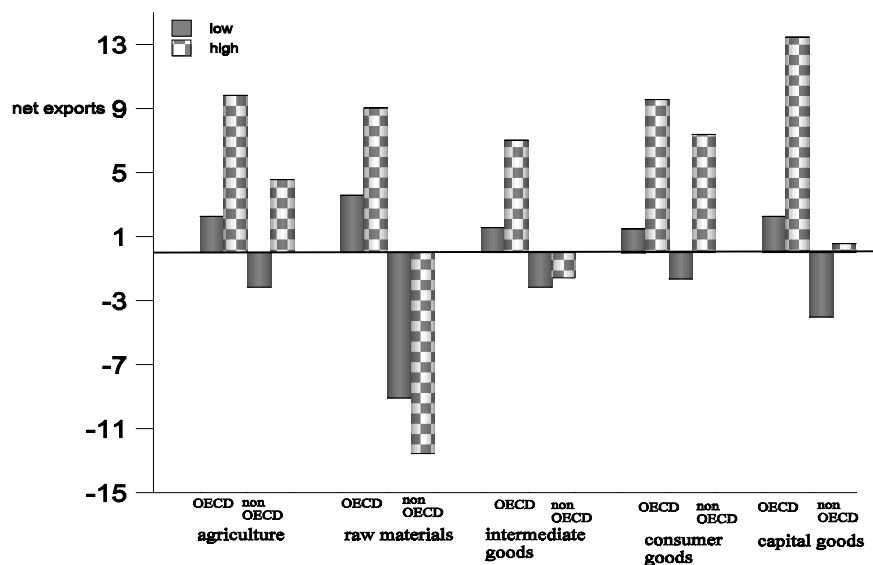
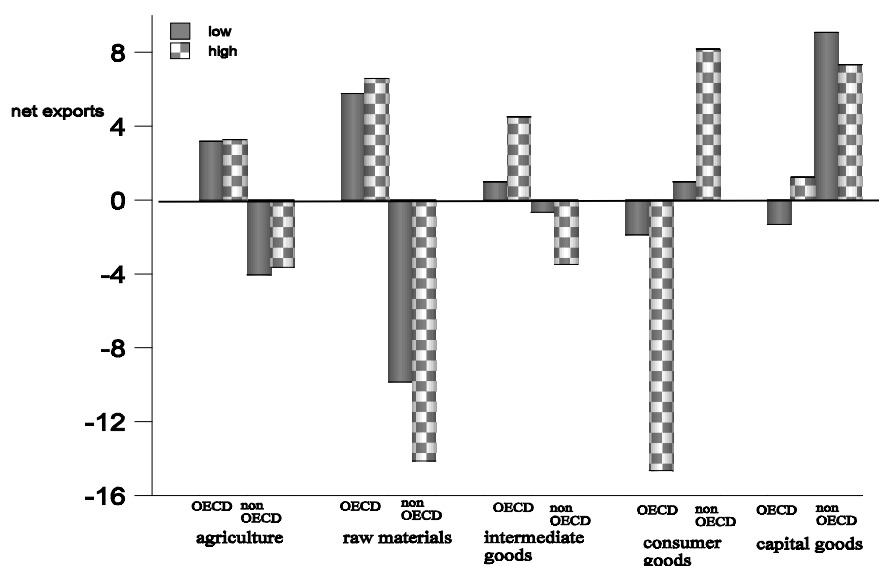


Figure 3.4 Differences in net export to production ratio in both scenarios 1995 - 2020



4. Emissions

This section focusses on CO₂ emissions in both scenarios and the causes of the different emission volumes. First, we present the volume of emissions in 2020 in both scenarios. Second, we show the energy intensiveness of the various sectors in WorldScan. Third, we discuss the contribution of globalization to CO₂ emissions. Section 5 will introduce emissions limits in both scenarios according to the Kyoto protocol. That Section concentrates on the implications of globalization for the efforts in reaching these targets and on the volume of carbon leakage.

Both the Low and High Growth scenario show a drastic increase in the volume of emissions between 1995 and 2020. These increases which is even dramatic in the High Growth scenario, are possible because both scenarios do not assume any effort in limiting the increase of emissions. There are not any energy-saving technologies, consumers do not save energy, and regions do not introduce environmental legislation. Section 5 will discuss the introduction of environmental legislation. Table 4.1 shows that global emission rise by about 70% in the Low Growth scenario. The rise in the Annex-1 regions (=OECD and transition regions) is much lower. However, CO₂ emissions double in the Rest of the World. The reason is that production grows also faster in the non Annex-1 regions, and correspondingly the demand for energy will increase drastically.

This pattern is even stronger in the High Growth scenario. Abundant economic growth in the non-OECD regions increases demand for energy significantly. Emissions will rise by about 250%. The shift from oil and natural gas to coal in the energy mix does also contribute to the increase in emissions, because coal is relatively more carbon intensive than the other two energy carriers. Notice, that the emission patterns are comparable to those in OECD (1997).

Table 4.1 Emissions in both scenarios

Emissions in 2020	1995.0	low growth	high growth
Annex-1	3.8	5.5	6.4
non Annex-1	2.2	5.1	8.0
World	6.0	10.6	14.4

In WorldScan, CO₂ is only emitted in production processes. Energy is only used as intermediary input in production. The share of household consumption is very low, so we assume that consumers only use electricity as energy source. Table 4.2 shows that the Intermediate sectors is the most energy-intensive sector. It is responsible for 40% of the total emissions, while its production share is only 8%. Per unit of production Electricity is even more polluting. It produces 30% of all emissions while its share in total output is only 2%. Agriculture, Capital Goods and Services (including Trade and Transport) are the most energy-extensive sectors in terms of output. The emission output ratio varies between 1 to 10 and 1 to 5. These numbers are also valid for other years and for the Low Growth scenario.

Table 4.2 Global emissions and production shares by sectors

sector	Agriculture	Raw Materials	Electricity
emissions	0.6	7.0	30.9
output value	8.1	2.2	2.1

sector	Intermediate	Consumption	Capital Goods	Services
emissions	41.9	7.1	1.7	10.8
output value	8.3	8.7	15.2	55.3

The sector Raw Materials consists of Oil, Natural Gas, Coal and other Raw Materials. The sector Services consists of Services and Trade & Transport. These results are derive from the High Growth scenario in 2020. These ratio's on emissions do not change significantly for other years or for the other scenario.

The knowledge on the energy-intensiveness of the various sectors is useful is discussing the differences in the volume of emissions in both scenarios. The analyses of these differences is helpful in discussing the effects of globalization on the environment in Section 5. As is shown by Table 4.1 the emissions are about 3.8 million kilo ton C higher in the High Growth scenarios. This is an increase of about a third, mainly due to the non Annex-1 regions. Here we want to disentangle the increase in emissions according to the various elements of the globalization process. This answers also the question whether trade has significant environmental effects.

Table 4.3 disentangles these effects for the OECD, non-OECD (including transition regions) and the world. It shows clearly that technical progress and thereby economic growth is the main cause of the increase in emissions. Trade liberalization as such has nearly no effect. The extra shift in consumption expenditures from agriculture to services, see Table 3.3 has nearly no effect on the volume of emissions. Table 4.2 has already shown that both sectors are energy-extensive. The contribution of extra labour reallocation is caused by higher productivity leading to a higher demand for low-skilled labour. This reallocation effect exerts a downward pressure on wages for low-skilled. This stimulates further productivity. The further liberalization on capital markets has a small positive effect on pollution. The interest rates at the capital markets in the non-OECD will adapt downwards to OECD levels. The inputs for production will shift from energy to capital in the non-OECD.

The increase in total factor productivity and the accompanied increase in capital accumulation stimulate production in the non-OECD substantially leading to a larger demand for energy. Notice that the increase in technology in the non-OECD reflects market and outward oriented policies which also includes a quick dissemination of technologies from the OECD. Trade as such does not contribute much to pollution. In this sense is does not make much difference whether goods are produced in the OECD or the non-OECD, in spite of the fact that production technologies in the non-OECD are more energy-intensive than in other regions. However nowadays it is often claimed that trade induces the spillovers of technology, see Coe et al. (1997). If trade indeed contributes to catching up and consequently higher productivity levels in the non-OECD, trade liberalization policies have probably also bigger effects on the environment. These effects which are now ascribed to technical progress in Table 4.3. This table thus shows that globalization as such has much effect on the level pollution, in particular if technology transfers are incorporated in the concept of globalization. Trade policies as such have nearly no effect on pollution, as long as it does not lead to higher productivity levels in the non-OECD.

Table 4.3 Causes from globalization elements on emissions

country	OECD	non OECD	global
low growth scenario	3.97	6.66	10.63
technical progress	0.24	2.84	3.08
lower transport costs	0.06	0.25	0.31
trade liberalization	0.03	0.01	0.04
more capital mobility	0.00	0.01	0.01
more labour reallocation	-0.02	0.37	0.35
change consumption patterns	0.01	-0.04	-0.03
high growth scenario	4.29	10.10	14.39

5. Kyoto

Section 4 has shown that emissions in both scenarios increase dramatically until 2020. This section analyses whether the introduction of emission limits agreed upon in the Kyoto protocol will slow down this increase. We will analyse whether globalization has similar effects on the level of pollution in the presence of environmental legislation. We also analyse the effects of globalization on the volume of carbon leakage. OECD (1999) and others have shown that the introduction of emissions targets in the Annex-1 regions will lead to an increase in emissions in the non Annex-1 regions compared to the case that environmental legislation does not exist. We will show the carbon leakage will increase due to the intensified spillovers in a globalization scenario.

The Annex-1 regions will succeed in reaching their emission targets agreed upon in the Kyoto protocol in 2010. For the period 2010 to 2020 we assume that the same emission ceilings. The non Annex-1 regions are not confronted with emission ceilings. We assume that the Annex -1 regions introduce unilateral environmental taxes as policy instruments to obtain the targets from 1996 onwards.⁵ Regions levy environmental taxes on the used volumes of Gas, Oil and Coal. Given the emission target and energy use, the tax rate depends on the carbon content of each of the energy carriers.

Table 5.1 presents the effect of introducing environmental taxes on the emission levels, GDP and the tax rate in 2020 for both scenarios. Emissions are reduced by 24 to 35% in the Low and high Growth scenario, respectively. Due to leakage, emissions in the non Annex-1 regions increase. The effects on cumulated GDP in 2020 are modest, at most 0.8 % of GDP. The introduction of energy taxes do not harm the OECD regions very much. Moreover, the economic effects are not significantly larger in a globalization scenario, while in that scenario economic growth and CO₂ emissions are much higher than in the low growth scenario. The energy taxes nearly double in the former scenario. In spite of higher energy taxes, the non Annex-1 regions do not benefit significantly from these taxes in the High Growth scenario

⁵In the follow up of this paper we will carry out the same analysis with emission trading.

Table 5.1 **Effects of unilateral energy taxes in the Annex-1 regions in 2020**

levels/quotes	low growth		high growth	
region	Annex-1	non Annex-1	Annex-1	non Annex-1
emissions	-23.8	4.4	-34.6	5.6
GDP	-0.5	0.4	-0.8	0.2
energy tax	31.1	0.0	56.2	0.0

This table depicts the differences between a scenario with energy taxes and without energy taxes for the low and high growth scenario. The numbers on emissions and GDP are relative cumulative deviations in 2020 from the scenarios without energy taxes. The energy tax is measured in US dollar per ton C (energy).

sectoral effects

Table 5.2 shows the effects of environmental legislation on the shifts in production from the Annex-1 regions to the non Annex-1 regions. The shares in global production of the Annex-1 regions without environmental legislation are of course lower in the High Growth scenario than in the Low Growth scenario. Due to legislation a larger share of Intermediate Goods, and energy are produced in the non Annex-1 regions. The Annex-1 regions demand a large share of Electricity and other Raw Materials. due to the substitution from the taxed energy carriers Oil, Natural Gas and Coal to the former energy carriers. As a result, the production of Electricity and Raw Materials will increase in the Annex-1 regions. The production of Electricity uses also a lot of Oil, Gas and Coal, but the price increase is lower than for the energy carriers which are taxes directly.

The production shifts of Oil, Coal and Natural Gas to the non-OECD are substantially higher in the High Growth scenario. The increase in the production shift result from two opposite forces. First, the increase in relative productivity in the non-OECD enlarges the production shifts. To some extent this shift is compensated by the second effect: the elimination of tariffs. On average, the OECD producers face higher tariffs than those in the non-OECD. As a consequence, the OECD producers benefit more from the breakdown of tariffs.

Table 5.2 **Sectoral effects of environmental legislation**
absolute changes in share of global production for Annex-1 in 2020

changes in global production shares	Low Growth scenario		High Growth scenario	
base (2020) & change	baseline	change	baseline	change
Agriculture	58.3	0.0	53.6	0.1
Consumption Goods	60.9	-0.3	46.1	-0.4
Intermediate Goods	63.2	-0.6	56.3	-1.2
Capital Goods	68.2	-0.1	58.4	-0.1
Services	78.5	-0.1	71.2	-0.2
Trade & Transport	72.0	0.0	64.9	-0.1
Electricity	60.7	0.5	52.3	0.6
Coal	49.7	-7.1	45.7	-8.9
Oil	26.7	-3.8	21.3	-4.3
Natural Gas	72.1	-1.9	68.4	-3.9
Other Raw Materials	47.4	1.2	37.2	1.5
all goods	70.3	-0.2	62.2	-0.3

baseline is defined as the scenario without environmental legislation. change is de difference between the scenarios with and without environmental legislation.

The location shift of the production of Intermediate Goods is not surprising given its energy intensity, see Table 4.2. The production of Consumer Goods is also energy intensive compared to Agriculture, Capital Goods and Services. In the Globalization scenario the elimination of substantial tariffs increases the spillovers in both sectors. For that reason the shifts in production for those sectors are substantially larger in the globalization scenario than in the Low Growth scenario. These shifts contribute to the increase in carbon leakage effects as will be motivated in more detail below. The shifts in many others sectors are relatively smaller. These are induced by the change in the specialization pattern. If the Annex-1 regions spend less endowments in the production in Intermediate and Consumer Goods they will produce relatively more Agriculture, Services and Capital Goods.

leakage

Although Table 5.1 shows that globalization does not affect environmental policy in the sense that the effects of environmental taxes on GDP are significantly higher, globalization as such has effects on environmental policy. Due to the intensified linkages between the regions, the spillovers are much larger now. As a result, the increase in emissions in the non Annex-1 regions induced by environmental legislation in the Annex-1 regions is much larger in the globalization scenario than in the business as usual scenario. The emissions increase by 0.4 million kilo ton C instead of 0.2 million kiloton C. These are the leakages effects of emission reduction in Annex-1 to the other regions. The emission reduction in the High Growth scenario is also larger, but the relative leakage effects do increase. Table 5.3 shows the leakage ratios for both scenarios. The leakage rate is 13.7% in the Low Growth scenario and 20% in the High Growth scenario. These rates are comparable to Bollen et al. (1999), but somewhat higher than those of the AGE model GREEN, see OECD (1999).

Table 5.3 Leakage effects in 2020 for both scenarios

Emissions in 2020	Low Growth		High Growth	
	baseline	difference with Kyoto	baseline	difference with Kyoto
Annex-1	5.5	-1.3	6.4	-2.2
non Annex-1	5.1	0.2	8.0	0.4
World	10.6	-1.1	14.4	2.0
leakage rate	none	13.7	none	20.0

Interestingly, the increase in the leakage ratio can be ascribed to the larger extent to trade liberalization. While the increase in emissions in the globalization scenario is to the main extent due to the increase in technological progress and not to trade liberalization this is not the case for the leakage ratio. Table 5.4 shows the contribution of the various elements of globalization to the carbon leakage ratio. It shows that larger productivity increases due to a faster dissemination of new technologies leads to a larger reduction in emissions in the Annex -1 regions in order to fulfill the emission targets agree upon in the Kyoto protocol. This also induces more carbon leakage. Trade liberalization increases the linkages between the regions and stimulates a further shift from the production of Consumer and Intermediate Goods to the non Annex-1 regions. Besides the shift of these energy-intensive production technologies the elimination of tariffs at the oil, gas and coal markets induces non Annex-1 regions to use more energy. Energy becomes relatively less expensive compared to other inputs in production - in particular energy produced in the OECD regions. This substitution in production inputs raises the leakage rate significantly. Half of the increase in the volume leakage can be explained in this way. In total trade liberalization as such contributes for

about 50% to the increase in the carbon leakage ratio.

The integration of capital markets stimulates production in the non Annex-1 regions due to lower costs for capital accumulation, and more labour reallocation stimulates production by lower labour costs. However, both effects are very modest.

Table 5.4 Causes from globalization elements to leakage

country	Annex-1	non Annex-1	leakage ratio
Low Growth scenario	-1.32	0.18	13.65
technical progress	-0.78	0.15	1.86
lower transport costs	-0.11	0.03	0.61
trade liberalization	-0.08	0.03	0.61
trade liberalization energy	0.02	0.05	2.55
more capital mobility	0.00	0.00	0.10
more labour reallocation	0.03	0.01	0.54
change consumption patterns	0.02	0.00	0.08
High Growth scenario	2.22	0.45	20.40

Tables 5.3 and 5.4 thus show that globalization has substantial effects on the volume of carbon leakage induced by environmental agreements in the Annex-1 regions. In absolute terms the leakage volume doubles and the leakage ratio increases by 50%. Globalization thus weakens the effectiveness of environmental legislation by the Annex-1 regions. In general, the size of the leakage effects depends on the substitution possibilities within the production technologies and in demand, see also Bollen et al. (1999). Some sensitivity analysis shows indeed that low substitution possibilities in production and demand lower the leakage ratio. However, the change in leakage due to globalization remains significant.

6. Conclusions

This paper has presented the effects of globalization on environmental quality and environmental policy. By comparing a business as usual scenario and a globalization scenario simulated by WorldScan we were able to show the effects of globalization on the emission levels in Annex-1 and non Annex-1 regions and the effects on environmental policies aimed by the targets according to the Kyoto protocol. Although globalization can have substantial effects on production levels, production methods, location of production and the product and consumption mix, the emission levels are mainly affected by the increase in output. Changes in consumption patterns or trade liberalization as such did not have much effect.

These results can be affected by removing two assumptions, both we plan to do in the near future. The first is that technology spillovers from OECD to non-OECD regions is exogenous. In spirit of the recent literature on R&D and spillovers (eg Coe et al. (1997)), we want to endogenize technology spillovers by the amount of trade. Then, trade liberalization will have a large impact on output and the volume of emissions. The second is closely related to the first one. At this moment technology spillovers are directed to increases in total factor productivity levels. Non-OECD regions do not shift more energy-efficient technologies copied from the OECD. In that case, high growth in the non-OECD regions would be accompanied by a lower increase in emission volumes.

Trade liberalization does have much effect on the effectiveness of environmental policy in

the Annex-1 regions. The breakdown of trade barriers for energy-intensive goods will lead to a shift in activities if these sectors face the burden of environmental legislation. Moreover, the downward pressure on energy prices due the elimination of trade barriers at these markets, stimulates non Annex-1 regions to use more energy. The carbon leakage ratio is significantly higher in the globalization scenario. Furthermore, the share of global emissions which is restricted is much lower. For both reasons the effectiveness of environmental policies by the Annex-1 countries is seriously hampered. The environmental taxes are also higher in the globalization scenario, but the GDP effects of the Annex-1 countries are very modest. From this perspective globalization does not affect the costs of legislation.

There are several solutions to the carbon leakage problem. One is the possibility of technology transfers regarding more energy-efficient technologies. In that case energy-intensive production technologies will still shift to regions without environmental legislation, The energy-intensiveness is however lower, than in the case that they use the old production technologies in these countries. This point is closely related to the technology spillovers mentioned above. A second possibility is the (re)introduction of import tariffs on energy-intensive products by the Annex-1 countries. The combination of environmental legislation and import tariffs is already analysed for Western Europe by Tang et al. (1998). They show that import tariffs and export subsidies can be used to restore competitiveness and to alleviate the problems of carbon leakage induced by unilateral energy taxes in Western Europe. The combination with these trade policies can also analysed in this framework, assuming that the WTO framework permits such policies in order to protect the environment.

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Appendix Regional and sectoral concordances for WorldScan

1	United States	1	Agriculture and food production
2	Japan		Paddy rice, Wheat, Grains, Cereal Grains, Non grain crops, Vegetables, Oil seeds, Sugar cane Plant-based fibres, Crops, Bovine cattle, Animal products, Raw milk., Wool, Forestry, Fisheries, Processed rice, Meat products, Vegetable Oils, Dairy products, Sugar, Other food products, Beverages and tobacco
3	Western Europe		
	United Kingdom, Germany, Denmark, Sweden, Finland, Rest of European Union, EFTA		
4	Remaining OECD	2	Consumption goods
	Australia, New Zealand, Canada		Textiles, Wearing apparels, Leather etc, Wood products, Chemical, rubbers and plastics
5	Eastern Europe	3	Intermediate goods
6	Former Soviet Union		Pulp paper, Petroleum and coal, Nonmetallic minerals, Ferrous metals, Nonferrous metals
7	Middle East and North Africa	4	Capital goods
	Turkey, Rest of Middle East, Morocco, Rest of North Africa		Fabricated metal products, Transport industries Machinery and equipment, Electronic equipment Motor vehicles and parts, Rest of manufacturing
8	Sub-Saharan Africa	5	Services
	South African Customs Union, Rest of Southern Africa, Rest of Sub-Saharan Africa		Gas manufacture and distribution, Water, Construction, Financial, business and recreational services, Public administration, education and health, Dwellings
9	Latin America	6	Trade and Transport
	Central America and Caribbean, Mexico, Argentina, Brazil, Chile, Uruguay, Venezuela, Colombia, Rest of South America	7	Electricity
10	China	8	Oil
	China, Hong Kong	9	Natural Gas
11	South East Asia	10	Coal
	Republic of Korea, Indonesia, Malaysia, Philippines, Singapore, Thailand, Taiwan, Vietnam	11	Other Raw Materials
12	South Asia & Rest		Minerals
	India, Sri Lanka, Rest of South Asia, Rest of the World		