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Abstract

With the gradual accession of some Central Eastern European Countries (CEECs) to the EU, international trade between EU and CEECs and the related environmental problems will definitely change because of the free trade and the mobility of production factors (labor and capital) within the EU. This paper investigates the consequences of the enlargement of the EU on trade and environment by general equilibrium modeling. A general equilibrium model with the sequential joint maximization method is developed to examine the impacts under different environmental regimes. For illustrative purposes, the model is applied in a numerical example with two regions (EU and CEECs) and two goods (pollution intensive good A and clean good B). The model is also run for some important environmental policies. The result show that the 'coordinated policy in EU and CEECs' could be efficient to restrict the total emission level for uniformly mixing pollutants.

JEL classification: C68; D58; F18

Keywords: trade and environment, environmental policy, AGE models, sequential joint maximization, Negishi-format.

1. Introduction

With the gradual accession of some Central Eastern European Countries (CEECs) to the EU, international trade between EU and CEECs and the related environmental problems will definitely change because of the special policies within the EU. The accession of CEECs to the EU has all sorts of far reaching economic implications for both CEECS and the EU. The enlargement of the EU has impacts on trade and the environment for both regions due to the EU environmental policies and the mobility of production factors (labor and capital) within the EU.

For a long time, international trade has been recognized as the engine of economic growth of nations. In many respects, trade promotes more efficient use of natural resources, reducing wasteful patterns of production and consumption, but it also results in environmental damages. Promoting policy coherence and compatibility between trade and the environment was the principal objective agreed upon at the United Nation Conference on Environment and Development and laid down in the Rio Declaration and Agenda 21(Dohlman, 1997). An important question is how to promote international trade and at the same time improve the quality of the environment? What is the effect of international trade and environmental policy on welfare and environmental quality? Considerable efforts have been devoted by a large number of researchers (e.g. Soete and Ziesemer, 1997; Xu, 1999 and 2000, and Scollay, 2000) on quantifying the likely effects of such issues. The use of computable general equilibrium (CGE) methods has proved to be the most useful in this task (Scollay, 2000).

Existing literature, however, does not give a full description about the relationship between international trade and the environment in the perspective of the enlargement of the EU. This paper investigates the consequences of the enlargement of the EU on trade and environment by general equilibrium modeling. The paper develops a general equilibrium model with the sequential joint maximization method to examine impacts on trade and the environment of the enlargement of the EU under different environmental regimes. The model is capable of analyzing the effects of accession to the EU on the markets (prices of the goods) and the environment in both acceding regions and the EU. For the illustrative purpose, the model is applied for EU and CEECs with the characteristics of partial equilibrium models as taking the rest of the world not affected. The GE model explores the implications of several important systems of environmental policy coordination. Moreover, the model includes emissions from production and consumption and from transportation related to international trade. The model is applied in a numerical example for two-regions (EU and CEECs) and two-goods (pollution intensive good A and clean good B). By assuming that the both regions produce and consume two goods A and B, and good A is an environmental-intensive good and good B is a cleaner good, the model can show some fundamental environmental economic mechanisms that might occur as a result of the EU enlargement. By assuming differences in factor endowments, consumers' preference and production technology in both regions, the model can give the results of trade effects under free trade with immobile factors before the accession of CEECs to the EU and the trade effects with the mobile factors on the base of the accession of CEECs to the EU. Therefore some fundamental implications of the enlargement of the EU on trade and the environment can be captured.

We have applied the model to analyze a number of environmental policies. Considering the common environmental policies within the EU, e.g. the commitment of the emission abatement of EU in Kyoto protocol, the model is also run for the some scenarios of different environmental policies to check the effectiveness of these policies. The results of various scenarios show that the 'unilateral environmental policy in EU' under free trade is not efficient for uniformly mixing pollutants, because emission leakage may occur in the CEECs. The 'uncoordinated environmental policy in EU and CEECs' is not efficient either, because specialization in production is hampered when environmental constraints are imposed upon both regions. The 'coordinated policy in EU and CEECs' could be efficient to restrict the total emission level for uniformly mixing pollutants, because it brings maximum economic welfare for both regions under the given emission ceiling. The paper highlights the importance of the coordination of environmental policies in the EU and CEECs.

The paper is organized as follows. Section 2 contains the description of the model in the perspective of the enlargement of EU with the accession of the CEECs. In section 3 the model is applied to illustrate the trade change with the accession of CEECs to EU and under different environment policies. Section 4 gives the interpretation of the results. Section 5 gives our main conclusions.

2. The CGE model for trade and environment

2.1 Theoretical structure

The relationship between international trade and the environment has been investigated in the framework of several international trade models of environmental pollution. The Ricardian trade model has been used by Pethig (1976), the Heckscher-Ohlin model has been used in different ways by Pethig (1976), McGuire (1982) and Merrified (1988) and the Chamberlin-Krugman model has been applied by Soete and Ziesemer (1997).

The Heckscher-Ohlin model stresses the differences in factor endowments as the cause of trade; more precisely, its basic proposition is that each country exports the commodity which uses the country's more abundant factor more intensively (Gandolfo, 1998). To analyze the relations between environment and the international trade we apply a theoretical model, based on the theory of Heckscher-Ohlin model but some assumptions of the original model are released for the generality. We now assume: 1) both regions have different production functions for goods A and B; 2) the structure of demand differs in both regions and independent of the level of income. In addition we will also include emission factors in our model to calculate the environmental impacts of production and transportation, because international trade needs transport, which results in pollution from energy use. On the basis of these characteristics a general equilibrium model can be constructed to explore the relationship between international trade and the environment. In this paper we use an AGE model to examine the behavior of international trade between two regions, because they have different factor endowments and different production technologies as well as different preferences. We use the model to examine the implications of different environmental policies in the international context.

There are five alternative formats of AGE models according to (Ginsburgh and Keyzer, 1997), namely, the excess demand format, Negishi format, full format, open economy format and CGE format.

- The excess demand format is the natural point of reference whenever micro-foundations are considered desirable. In particular, one might want to identify the signals to the individual agents that are needed for decentralization of a specific welfare optimum.
- The Negishi format provides a direct link to welfare analysis and makes it possible to use weaker assumptions on the production technology. Sometimes (e.g. with externalities or nonconvexities) it is easier to formulate a centralized welfare program (the Negishi format) than to specify its decentralized counterpart (the excess demand format or CGE format).
- The full format is an extension of the Negishi format, thus it possesses the same advantages.
- The open economy format exploits duality. It can accommodates forms that are well suited for econometric estimation.
- The CGE format is the easiest for applications, but its assumptions are more restrictive. CGE's may be considered as the descendants of input-output and activity analysis that incorporate price-dependent input-output coefficients and final demand.

For the general equilibrium of the whole economy, an aggregate utility function or global welfare function, which depends on the utility of each region, is needed. To check the consequences of the enlargement of the EU, we choose the Negishi-format for the general equilibrium model. The reason that Negishi-format is chosen is that for each type of externality the discussion starts with a welfare program, which is subsequently decentralized through commodity and agent-specific signals (e.g., prices). Since these signals will be derived from the welfare optimum, the resulting equilibrium is necessarily Pareto-efficient and describes first-best policies. The equilibrium is then said to provide signals that internalize the externalities within the decisions of the individual agent (Ginsburgh and Keyzer,1997).

2.2 Mathematical expression

The Negishi format is:

$$W(\alpha) = \underset{x_i \geq 0, all\, i, y_j\, all\, j}{Max} \sum_i \alpha_i u_i(x_i) \tag{1}$$

subject to,

$$\sum_i x_i - \sum_j y_j \leq \sum_i \omega_i \qquad (p) \tag{2}$$

$$y_j \in Y_j, \tag{3}$$

with welfare weights α, such that

$$px_i = p\omega_i + \sum_j \theta_{ij} \prod_j (p) \tag{4}$$

To get the equilibrium solution to this maximization problem, we can use the Sequential Joint Maximization (SJM) method (Rutherford, 1995 and Ermoliev, 1996).The SJM algorithm solves a sequence of "partial equilibrium relaxation's" of the underlying general equilibrium model. The convergence involved at most five SJM iterations. The SJM algorithm is demonstrated by the range of real models for which the procedure has been successfully applied (Rutherford, 1995).The convergence of the SJM method for searching economic equilibria is studied in the case of Cobb-Douglas utility functions by Ermoliev (1996). He proved that the SJM converges to the equilibria when Negishi weight is chosen as the share of income under the Cobb-Douglas utility function. In this model we follow the Rutherford-Ermoliev procedure to approximate the equilibrium solution.

We assume that each region *i* (*i*=1, …, *n*) has exogenous and different factor endowments, production technologies and preferences for consumption of good *j* (*j*=1, …, *m*) (see the production functions and utility functions below).

We use the Cobb-Douglas utility functional form for each region:

$$U_i(C_i) = C_{i1}^{\beta_{i1}} \times C_{i2}^{\beta_{i2}} \times \cdots \times C_{im}^{\beta_{im}} = \prod_{j=1}^{m} C_{ij}^{\beta_{ij}}, \sum_{j=1}^{m} \beta_{ij} = 1, 0 \leq \beta_{ij} \leq 1, \tag{5}$$

where *i* refers to each region, C_i is the consumption vector in region *i*.

According to Ermoliev, $\alpha_i = \dfrac{t_i}{\beta_i}$

$$W = \sum_{i=1}^{n} \alpha_i Log(U)_i \tag{6}$$

where $\alpha_i = \frac{t_i}{\beta_i}$ is the Negishi weights for region *I*, which is decided by the income t_i of region *i* and degree of homogeneity of the utility function β_i. For Cobb-Douglas utility function, β_i =1[1]. Then the global welfare is:

$$W = \sum_{i=1}^{n} t_i Log(U_i), \tag{7}$$

Since t_i is an arbitrary nonnegative vector, according to Rutherford (1995) and Ermoliev (1996), *t* is the income share of each region in the whole economy. That is:

$$\alpha_i = t_i \tag{8}$$

$$\therefore \sum_{i=1}^{n} \alpha_i = 1$$

The Negishi format can be specified as follows:

Equation (3) as the production functions can be specified for good *j* in region *i*, each with a Cobb-Douglas production function:

$$Q_{ij} = A_{ij} * K_{ij}^{\alpha_{ij}} \cdot L_{ij}^{\gamma_{ij}} \tag{9}$$

where A_{ij} is the technological parameters, Q_{ij} is the production quantity of good *j* in region *i* and K_{ij} and L_{ij} are production factors of capital and labor for good *j* in region *i*.

For equation (2), the following relations constrain the model because of the material balance:

$$X_{ij} = Q_{ij} - C_{ij} \tag{10}$$

$$\sum_{i=1}^{n} X_{ij} = 0 \tag{11}$$

For factors, if factors are immobile then the used factors in each region should be constrained by its total endowments:

$$\sum_{j=1}^{m} L_{ij} = \overline{L_i} \tag{12}$$

$$\sum_{j=1}^{m} K_{ij} = \overline{K_i} \tag{13}$$

[1] The proof:

$$U_i(rC_i) = (rC_{i1})^{\beta_{i1}} \times (rC_{i2})^{\beta_{i2}} \times \cdots \times (rC_{im})^{\beta_{im}} = r^{\beta_{i1}+\beta_{i2}+\cdots+\beta_{im}} \bullet ((C_{i1})^{\beta_{i1}} \times \cdots \times (C_{im})^{\beta_{im}})$$

$$= r^{\sum_{j=1}^{m}\beta_{ij}} \bullet U_i = r^{\beta_i} \bullet U_i = r^1 \bullet U_i$$

For mobile factors, the total factors used for production should be constrained by the total endowments:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} L_{ij} = \sum_{i=1}^{n} \overline{L}_i \qquad (12)^+$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} K_{ij} = \sum_{i=1}^{n} \overline{K}_i \qquad (13)^+$$

where X_{ij} is the net export, C_{ij} is the consumption of good j in region i, $\overline{L}_i$ and $\overline{K}_i$ are respectively the initial exogenous endowments of labor and capital in region i.

On the income side, the income in region i, I_i, comes from production Q_{ij} :

$$I_i = \sum_{j=1}^{m} p_j * Q_{ij} \qquad (14)$$

To consider the environmental issue in the model, we can expand the model to include emissions of pollutants. The emissions result from the production activities and transport, if there exists international trade. We assume that the emissions are from the production of goods and also from the international trade of the goods, that is:

$$E_{i,j} = \sigma_{i,j} * Q_{i,j} + \delta_{i,j} * X_{i,j} \qquad (15)$$

where $\sigma_{i,j}$ is the emission rate from production and $\delta_{i,j}$ is the emission rate from international transportation.

Then we can also implement several environmental policies in the model, for example, unilateral environmental policy is implemented in EU, a restriction is added to the model to restrict emissions to the exogenous specified level $\overline{E}_1$.

$$E_1 = E_{1A} + E_{1B} \leq \overline{E}_1 . \qquad (16)$$

Other equations for different environmental policies or upper bounds for the emissions can also be added into the model in the same way.

An important issue is the definition of prices. They are defined as the marginal value of the balance equation[2]. Equation (2) indicates that the shadow price is the Lagrange multipliers of the balance equation.

[2] The marginal value of an equation is the amount by which the objective function would change if the RHS of the equation were changed by one unit (Brooke, 1997, p.91).

2.3 Numerical example

To solve the model consisting of equations (1) to (4), we must first specify the equations and parameters of the model. In this way equation system (7)-(16) constitute a general equilibrium model. This optimization problem is the reduced form of the general equilibrium model for utility maximization of consumers and profit maximization of producers in the economy. This model is solved by the sequential joint maximization (SJM) algorithm (Rutherford,1995 and Ermoliev,1996)[3].

We apply this model to the numerical example of the two-region (EU and CEECs) and two-good (good A and B) case. We assume some exogenous variables (resources) for the numerical example: K_1=500, $L_1=220$, K_2=200 and L_2=580. The subscript 1 indicates EU and 2 CEECs. If we choose wage in CEECs (w_2) as the numeraire, then we can get the relative prices for two commodities, capital in both regions and labor in EU relative to this numeraire.

For the numerical application we use the following functional forms for the two-region model:

$$W = \sum_{i=1}^{n} \alpha_i Log(U_i)$$

$$U_1 = C_{A1}^{0.45} \cdot C_{B1}^{0.55}$$

$$U_2 = C_{A2}^{0.4} \cdot C_{B2}^{0.6}$$

$$Q_{A1} = 1.0 * K_{A1}^{0.6} \cdot L_{A1}^{0.4}$$

$$Q_{B1} = 1.0 * K_{B1}^{0.4} \cdot L_{B1}^{0.6}$$

$$Q_{A2} = 0.75 * K_{A2}^{0.2} \cdot L_{A2}^{0.8}$$

$$Q_{B2} = 0.75 * K_{B2}^{0.25} \cdot L_{B2}^{0.75}$$

$$X_{A1} = Q_{A1} - C_{A1}$$

$$X_{B1} = Q_{B1} - C_{B1}$$

$$X_{A2} = Q_{A2} - C_{A2}$$

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[3] The sequential joint maximization is solved by identifying the optimal Lagrange multiplier and consumption vectors. An optimal vector of Lagrange vector multiplier is the price vector p* , which has the form:

$$p_j^* = \frac{1}{W_j + G_j(y)} \sum_{i=1}^{n} NWT_i \beta_{ij}$$

Optimal consumption vector C_{ij}^* is calculated as follows: $C_{ij}^* = \frac{NWT_i \beta_{ij}}{p_j *}, \quad j = 1, ..., m.$

This algorithm is based on a sequence of convex nonlinear programming problems. Typically this sequence will converge to the equilibrium prices and quantities of a competitive market economy (Rutherford, 1995). Ermoliev has analyzed some convergence properties of this SJM method and concluded that for the homogenous utility functions, SJM is converged without requiring the gross substitutability. The SJM iteration typically converges within 5 major iterations to a satisfactory tolerance, and this convergence normally involves at about 5 iterations (Rutherford, 1995).

$$X_{B2} = Q_{B2} - C_{B2}$$

$$X_{1A} + X_{2A} = 0$$

$$X_{1B} + X_{2B} = 0$$

Immobile factors:

$$K_{1A} + K_{1B} = \overline{K}_1$$

$$K_{2A} + K_{2B} = \overline{K}_2$$

$$L_{1A} + L_{1B} = \overline{L}_1$$

$$L_{2A} + L_{2B} = \overline{L}_2$$

Mobile factors:

$$K_{1A} + K_{1B} + K_{2A} + K_{2B} = \overline{K}_1 + \overline{K}_2$$

$$L_{1A} + L_{1B} + L_{2A} + L_{2B} = \overline{L}_1 + \overline{L}_2$$

$$I_1 = p_A * C_{A1} + p_B * C_{B1} + p_A * X_{A1} + p_B * X_{B1} = p_A * Q_{A1} + p_B * Q_{B1}$$

$$I_2 = p_A * C_{A2} + p_B * C_{B2} + p_A * X_{A2} + p_B * X_{B2} = p_A * Q_{B1} + p_B * Q_{B2}$$

$$\alpha_i = \frac{I_i}{\sum I_i}$$

$$p_A \cdot C_{A1} + p_B \cdot C_{A2} \le I_1$$

$$p_A \cdot C_{B1} + p_B \cdot C_{B2} \le I_2$$

$$E_{A1} = 10 * Q_{A1} + 0.5 * X_{A1}$$

$$E_{B1} = 5 * Q_{B1} + 0.5 * X_{B1}$$

$$E_{A2} = 15 * Q_{A2} + 0.5 * X_{A2}$$

$$E_{B2} = 5 * Q_{B2} + 0.5 * X_{B2}.$$

3. Scenarios for trade and environment

We have applied the model to analyze a variety of scenarios for free trade before and after the accession of CEECs to EU as well as a number of environmental policies. We have analyzed the following:

- Baseline: no trade between EU and CEECs

  Part 1: Transition period (Free trade with immobile factors)

- Scenario 1: Free trade between EU and CEECs with immobile factors
- Scenario 2: Free trade, unilateral environmental policy in EU with immobile factors
- Scenario 3: Free trade, uncoordinated environmental policy in EU and CEECs with immobile factors
- Scenario 4: Free trade, coordinated environmental policy in EU and CEECs with immobile factors.

Part 2:Totally accession (free trade with mobile factors)

- Scenario 5: Free trade between EU and CEECs with mobile factors
- Scenario 6: Free trade between EU and CEECs with mobile factors; coordinated environmental policy

At first we model the case when there is no free trade between EU and CEECs. This case is the baseline of our next scenarios. The study includes two parts: the first part is the case that free trade starts but factors are immobile reflecting the transition period of the accession to EU and the second part is about the case of total accession when the factors (mainly labor) are mobile. In Scenario 1, we investigate the trade and the environment under free trade before the accession of CEECs to EU. The factors are immobile between two regions because free trade is the first stage of the accession of CEECs to EU. Environmental constraints are imposed in the model in various ways. In Scenario 2, restrictions can be imposed on emissions in EU, reflecting "unilateral environmental policies" in EU before the accession of CEECs to EU. In Scenario 3, emissions in both regions can be restricted to pre-specified levels, reflecting emission ceilings for both regions individually. We indicate this case as the "uncoordinated environmental policy". Finally, we investigate the impacts of one environmental policy both in EU and CEECs. In case of uniformly mixing pollutants, like the greenhouse gas CO_2, the total level of emissions can be restricted, without individual restrictions for the regions. We refer to this case as "coordinated environmental policy". As long as the sum of the emissions remains below the ceiling, the world standard is reached. The comparison of Scenario 3 and 4 shows the efficiency of the environmental policy of larger EU for the transboudary pollution.

In part 2, we design Scenarios 5 and 6, which consider the mobile factors, mainly labor as a characteristics of a larger EU. In Scenario 5 we consider mobile labor but without environmental restriction. We investigate the trade and the environment if the CEECs accede to EU with mobile labor. Labor is mobile because a single market is established after the accession. The comparison of this scenario with the baseline can show us the impacts of the accession of CEECs to the EU on trade and the environment. The comparison of this scenario with Scenario 1 also shows some important implication of the total accession of CEECs and transition. Scenario 6 is the case with mobile labor and an environmental policy implemented in the larger EU. The comparison of Scenario 6 and 4 can help us to check the effects of the accession of CEECs to the EU on the trade and welfare under the same environmental constraints.

4. Analysis of results

The model can be solved for different scenarios in GAMS (see annex). This section reports the simulation results for each scenario and their interpretations. Table 1 reports the results of EU and CEECs under autarky. Please note that the model so far is used as a hypothetical example and thus the parameters of the model have not been calibrated. Both regions produce good A and B and no international trade occurs. Given our assumption of factor endowments, production functions and utility functions, the sum of utility is 343 under autarky, with a slightly larger share of CEECs. Emissions are respectively 2514 for EU and 3116 for CEECs. Table 1 also shows the relative prices of goods A and B, labor and capital in EU and CEECs. In our example, wages in EU are 1.75 times higher than in CEECs as a result of relatively small supply, in combination with high productivity. Given the factor endowments, the production functions and the utility functions, the price of capital in EU is a bit cheaper than the price of capital in CEECs because they are more abundant in EU. For EU, good B is more expensive than good A because good B needs more labor for production, which is relatively scarce in EU; and consumer gives higher preference to Good B. In CEECs good B is a bit more expensive than good A because people prefer good B (higher marginal utility of good B). The autarky scenario is considered as the baseline. The results of the other scenarios will be compared with those of the baseline or other relevant scenarios. The comparison will show how international trade and several environmental policy regimes are related.

Table 1 Baseline Production and Consumption, Utility, Emissions and Relative Prices

	Production		Consumption		Net exports		Utility	Emission
	Good A	Good B	Good A	Good B	Good A	Good B		
EU	166	171	166	171	0	0	169	2514
CEECs	141	200	141	200	0	0	174	3116
Total	307	371	307	371	0	0	5.14[a)]	5630

Relative Prices of Commodities, Capital and Labor

	Good A	Good B	Capital	Labor
EU	2.04	2.43	0.74	1.75
CEECs	2.14	2.26	0.87	1.00

a). Note that the global welfare is calculated as a weighted sum of logarithm utility as specified in equation 6. This also holds for Table 2-6.

4.1 Scenario 1: Free trade without environmental policy

Table 1 reports the results under free trade between EU and CEECs as the first period of CEECs accession to the EU and no environmental restriction. An interesting result is the fact that emissions in CEECs are reduced considerably, as a result of specialization in a relatively clean commodity (good B), while emissions in EU are increased. Total emissions in the world are lower than under autarky. The emissions under free trade without environmental policy change, because the two regions have different production technologies and different emission rates from production. Total emissions in EU will increase as we assume that EU emits more in producing good A than good B (emission factors are respectively 10 and 5) and it also specializes in good A. For CEECs, good B is cleaner than good A (emission factors is 15 for Good A and 5 for good B) and it specializes in good B. Therefore its emissions will go down significantly. Although there are emissions from transport under free trade, the international transport emissions are low in our model (we assume only 0.5 per unit of export). Since EU has a cleaner production technology for good A than CEECs (emission factors are 10 and 15, respectively), international trade will decrease the emissions from the production of good A because good A would be produced in EU. Therefore the total world emissions are lower under free trade than under autarky. Because of the specialization effects, some regions may specialize in the production of pollution-intensive goods and this tends to increase environmental disruption there. But, if the specialization of each country under free trade is on producing clean products and if international transport emissions are low, then total world emissions can be expected to decrease under free trade, even in the absence of any environmental policy.

Table 2 Scenario 1 Production and Consumption, Utility, Emissions and Relative Prices

	Production		Consumption		Net exports		Utility	Emission
	Good A	Good B	Good A	Good B	Good A	Good B		
EU	310	45	162	178	148	-133	171	3405
CEECs	0	333	148	200	-148	133	178	1733
Total	310	378	310	378	0	0	5.16	5138
Relative Prices of Commodities, Capital and Labor								
	Good A		Good B		Capital		Labor	
EU	2.09		2.32		0.90		1.54	
CEECs	2.09		2.32		0.97		1.00	

Table 2 also gives the relative prices of the goods, labor and capital in both regions with respect to the numeraire. Under free trade the price of each good is the same in EU and CEECs as shown in Table 2. This meets the law of one price. The price ratio of two goods (pA/pB) also lies between the two internal equilibrium price ratios (see Table 1 and 2: 2.04/2.43 < 2.09/2.32 < 2.14/2.26). This is the condition for international trade. The production of good A in EU needs more capital than that of good

B while EU is capital-abundant with respect to CEECs. So good A is cheaper than good B in EU under autarky. The relative price of good A to good B (pA/pB=2.14/2.26) in CEECS is higher than in EU (pA/pB=2.04/2.43). Therefore EU will produce more of good A (specialize in producing good A) and export good A to CEECs. CEECs specializes in producing good B and export it to EU because good B is relatively expensive in EU (2.43>2.26) to make profit. Since each region is driven to utilize its comparative advantage and to produce what it can produce most efficiently, the global output is increased and gains from trade accrue to all countries.

4.2 Scenario 2: Free trade with unilateral environmental policy in EU

Under Scenario 2 a constraint is introduced to limit emissions in EU to a maximum of 2500. The results are reported in Table 3. If we compare Tables 2 and 3, we find that total production and consumption of good A will decrease (from 310 to 298) while the total production and consumption of good B will be almost unchanged (from 378 to 379). This is caused by the fact that good A is more polluting in both regions than good B. If an emission ceiling is given to EU, it will restrict the production of good A and it will turn to production of good B which is less polluting than good A. Because good B shows no comparative advantages in EU so the consumption of good B in EU will not increase a lot with the limit resources. As a result of the change in the production and consumption pattern, the utility of EU will decline from 171 to 169 as compared to Scenario 1. For CEECs its utility will also decline from 178 to 174 because EU does not export the cheaper good A to CEECs.

For CEECs, there is no emission restriction. It will produce more of good A and less of good B if emission restriction in EU is implemented, because EU will almost stop exporting good A to CEECs. The consumption of good A in CEECs will decrease (from 148 to 141) compared to Scenario 1, because the relative price of good A to good B is higher than under Scenario 1 (2.14/2.26 > 2.09/2.32). For CEECs its utility will also decline from 178 to 174 because EU does not export cheaper good A to them, but it utility remains at the same level as in the baseline (174).

Table 3 Scenario 2 Production and Consumption, Utility, Emissions and Relative Prices

	Production		Consumption		Net exports		Utility	Emission
	Good A	Good B	Good A	Good B	Good A	Good B		
EU	163	173	156	179	7	-6	169	2500
CEECs	135	206	141	200	-7	6	174	3052
Total	298	379	298	379	0	0	5.14	5553

Relative Prices of Commodities, Capital and Labor				
	Good A	Good B	Capital	Labor
EU	2.14	2.26	0.63	1.50
CEECs	2.14	2.26	0.87	1.00

Total emissions under Scenario 2 are even higher than under Scenario 1, because of "emission leakage". EU has to decrease its production of good A and stops exporting good A. Because the emission limit only applies to EU, CEECs will produce more of the polluting good A to maximize its utility. Then the emissions in CEECs increase significantly and so do total emissions. In our example, the unilateral environmental policy in EU has negative impacts on the welfare of EU and world welfare, as well as the environment. This results from the shifting of polluting activities from EU to CEECs.

As for the prices of capital and labor in EU, the capital price will decrease under Scenario 2 as compared to Scenario 1, because EU will produce the cleaner product good B, which needs less capital but more labor. That means capital is less scarce in this case. As for the price of labor, it is scarce in EU as compared to CEECs, so it is more expensive in EU.

4.3 Scenario 3: Free trade with uncoordinated environmental policy

Under Scenario 3, emissions in *both* regions are restricted to the maximum level of 2500. The results are shown in Table 4. As compared to Scenario 1, the global welfare will decrease as a result of the environmental policy. The production of good A in both regions will decrease, because good A pollutes more than good B. Good A will become relatively more expensive in both regions. The emission ceilings restrict the production possibilities in EU and CEECs, and less specialization takes place as compared to Scenario 1. This restricts international trade compared to Scenario 1 but more trade than Scenario 2 because EU can make profit by trading if the strict emission ceiling is also given in CEECs. The utility in EU does not decrease because it has more advantages in emission (lower emission factors) than CEECs. For CEECs the restriction of emission reduces its utility as compared to Scenario 1 and 2.

Table 4 Scenario 3 Production and Consumption, Utility, Emissions and Relative Prices

	Production		Consumption		Net exports		Utility	Emission
	Good A	Good B	Good A	Good B	Good A	Good B		
EU	161	175	133	213	28	-38	172	2500
CEECs	79	259	107	221	-28	38	165	2500
Total	240	434	240	434	0	0	5.13	5000

Relative Prices of Commodities, Capital and Labor				
	Good A	Good B	Capital	Labor
EU	3.97	2.95	0.534	1.28
CEECs	3.97	2.95	0.910	1.00

The prices of good A and B are much higher than under Scenario 1, because of the constraints of emissions in both regions.

4.4 Scenario 4: Free trade with coordinated environmental policy

Under Scenario 4, environmental policy is assumed to be coordinated, which implies that only total emissions are restricted to be less than 5000. The results for this scenario are reported in Table 5. To check the effectiveness of coordinated environmental policy, this scenario will be compared with Scenario 3, where each region faces an emission ceiling of 2500. Both regional utility and global welfare under coordinated environmental policy are higher than those under the uncoordinated regional environmental policy. The coordinated environmental policy is more effective than uncoordinated environmental policy, although both result in the same level of environmental welfare at the total level. In this case international trade will increase, and more specialization will occur. More gains from the international trade will be obtained, because of the greater flexibility of this policy. It should, however, be mentioned that this flexibility is only effective for 'uniformly mixing pollutants' like CO_2 with global impacts (global warming) and not for non-uniformly mixing pollutants like SO_2 and NO_x with strong local impacts (local acidification). Because of these local impacts, non-uniformly mixing pollutants require specific emission ceilings for each region.

Table 5 Scenario 4 Production and Consumption, Utility, Emissions and Relative Prices

	Production		Consumption		Net exports		Utility	Emission
	Good A	Good B	Good A	Good B	Good A	Good B		
EU	287	66	159	198	128	-132	179	3267
CEECs	0	333	128	201	-128	132	168	1732
Total	287	399	287	399	0	0	5.16	5000

Relative Prices of Commodities, Capital and Labor				
	Good A	Good B	Capital	Labor
EU	2.74	2.66	0.84	1.51
CEECs	2.74	2.66	0.97	1.00

The prices of both goods will be lower than under Scenario 3, because this policy will induce both regions to maximize their consumption levels by specializing in production which is consistent with the policy. The greater flexibility allows for more efficient production and lower relative prices for good A and B than under Scenario 3.

4.5 Scenario 5: Free trade with mobile labor without environmental policy

Under Scenario 5, labor is mobile as an EU policy but without implementing any environmental policy. We compare the results of this scenario with those of the baseline and Scenario 1. The total production and consumption of both goods increase a lot. The mobility of labor increase the global welfare from 5.16 to 5.29 because of the more efficient production takes place in EU. The freedom of labor mobility makes 280 labor moves from CEECs to EU. The international trade decrease because the labor is easily moved. If there is no environmental restriction of emission then the emission will increase because of the higher production of both goods. The accession of CEECs to EU needs corresponding environmental policy to prevent more environmental pollution.

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Table 6 Scenario 5 Production and Consumption, Utility, Emissions, Prices and Labor Movement

	Production		Consumption		Net exports		Utility	Emission
	Good A	Good B	Good A	Good B	Good A	Good B		
EU	197	312	232	278	-35	34	256	3552
CEECs	118	88	83	122	35	-34	104	2226
Total	315	400	315	400	0	0	5.29	5778
Relative Prices Commodities, Capital and Labor					Labor movement			
	Good A	Good B	Capital	Labor	Initial labor		Present labor	
EU	1.85	1.89	0.91	1.00	220		500	
CEECs	1.85	1.89	0.43	1.00	580		300	

4.6 Scenario 6: Free trade with mobile and coordinated environmental policy

Under Scenario 6, the trade is free, labor is mobile and one coherent system of environmental policy is implemented in a larger EU at the same time. Because environmental policy is implemented at the same time, good A is totally produced in EU because it has lower emission factor than in CEECs. EU still specializes in producing good A and CEECs in good B. But the total production of good A is less than Scenario 5 and production of good B is more than Scenario 5 because of the limitation of the emission reduction. Global welfare increases from 5.16 to 5.32 compared to Scenario 4 because the mobile labor makes production more efficient. Given the free trade and one environmental policy, half of the labor (290 among 580) in CEECs will move to EU to improve the economic welfare.

Table 7 Scenario 6 Production and Consumption, Utility, Emissions, Prices and Labor Movement

	Production		Consumption		Net exports		Utility	Emission
	Good A	Good B	Good A	Good B	Good A	Good B		
EU	273	243	211	321	61	-78	266	3971
CEECs	0	198	62	120	-78	78	92	1029
Total	273	441	273	441	0	0	5.32	5000

Relative Prices Commodities, Capital and Labor				Labor mvement	
	Good A	Good B	Capital	Labor	Initial Labor	Present Labor
EU	3.31	2.61	1.05	1.00	220	510
CEECs	3.31	2.61	0.48	1.00	580	290

5. Conclusions

Our analysis with the two-region general equilibrium model provides some interesting results. First it confirms the well-known advantages of free international trade and specialisation of production. More interestingly, it illustrates that free trade may well result in a reduction of global emissions, even if no environmental policies are implemented. This result depends on whether the specialisation in international trade leads to more production of the dirty product or of the clean product, and of the emission factor related to international trade. If international trade leads to a shift to the cleaner product as compared to autarky, and if the emissions related to international trade are sufficiently small, then international trade will lead to a cleaner environment. Based on the assumption that EU specialises in production of environmental intensive good and CEECs in cleaner products, the accession of CEECs will improve the economic welfare and environment.

In addition the analysis shows that unilateral environmental policy, in our example only implemented in the EU, may lead to "pollution leakage", increasing total global emissions, instead of reducing them. This is a "pervert" effect of environmental policy, which may typically occur in the case of global warming policies, if policies are only implemented in the developed regions like EU. It is interesting to note that this phenomenon may occur, even if the factors of production are assumed to be immobile between the regions, as we assumed in the first stage of the accession (Scenario 2). If free trade takes place between EU and CEECs without implementing effective environmental policy, the reduction of emission is not possible. Again, this result depends on the specific choice of the parameters: the reduction of emissions in the EU is not necessarily always offset by a larger increase of emissions in the CEECs. If production technologies in the CEECs would be sufficiently clean given the standard technology, overall emission reduction might occur at the global level.

Under Scenario 3 we have shown that imposing exactly the same absolute emission level to both regions can be very restrictive for international trade. It may result in lower utility levels for higher emission countries. This illustrates the trade off between “economic welfare” and environmental quality. An improvement of environmental quality in this case results in a reduction of utility of CEECs based on the consumption of good A and B.

Scenario 4 shows that a coordinated policy, where the distribution of emission reduction over the regions is left to market forces, results in an efficient allocation of resources, providing the highest level of utility that can be obtained given the global emission ceiling and technologies. The example illustrates that both regions can gain from this type of international co-ordination as compared to uncoordinated regional environmental policies. The combination of free trade (accession of CEECs to EU) and coordination of environmental policy can improve the economic welfare and the environment. Close co-ordination of international trade policies and international environmental policies are therefore essential to enhance sustainable development.

Our analysis confirms that for uniformly mixing pollutants, like greenhouse gases, well-co-ordinated international policies would be more efficient. Whether both regions should contribute to emissions reduction is a matter of international policy debate, and various schemes for cooperation and compensation can be implemented, e.g. the clean development mechanism or joint implementation. For non-uniformly mixing pollutants like acidifying compounds, such as sulphurdioxide (SO_2), nitrogenoxides (NO_x) and ammonia (NH_3), region specific emission ceilings are required, depending on the local carrying capacity of the environment.

The mobile labour in the perspective of enlargement of EU will improve the economic welfare because labour will move to the area with higher production technology or efficiency. To protect the environment, suitable environmental policy is needed at the same time to reduce the negative effects. With labour moving from CEECs to EU, trade will decrease to some extent because some will now consume within the EU.

Based on the methodology of this paper, further study, like the empirical study in the perspective of enlargement of EU combining with the parameter calibration using the real data is promising.

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