ECONOMIC REPERCUSSIONS OF ENVIRONMENTAL REGULATIONS IN POLAND: THE CASE OF THE SECOND SULFUR PROTOCOL

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Abstract

In this paper economywide effects of SO_2 emission reduction in Poland are studied. In order to fulfill the commitments required by the Second Sulfur Protocol (*SSP*), Poland needs to achieve roughly a 50% reduction of SO_2 emission in relation to 1992 no later than in 2010. A 16% reduction was already achieved after two years of the Protocol signature, in 1996, and it keeps progressing. Nevertheless the Polish Government did not ratify the SSP yet, because it is afraid of potential negative consequences for the economy.

A Computable General Equilibrium (*CGE*) model was applied to simulate the likely impact of the SSP policy on the Polish economy. The model was adapted from an earlier one developed by Swedish, Dutch and Polish research teams. For present project the model was modified further in order to let it be capable of simulating the effects of environmental and energy policies implemented in the form of energy input taxes and emission taxes. The model was calibrated for the year 1992.

Simulation results show fulfilling by Poland the commitments resulting from the SSP will have a modest impact on economic indicators. Over the period of 18 years GDP may be lower by up to 2 percentage points than under a policy without an emission limit. Compared to other shocks that affect the economy in the transition period, the economic hardships caused by the SSP for the whole economy seem to be negligible.

Background

In 1990 the transition period from a centrally planned economy into a market oriented economy started in Poland. Social and economic changes connected with this transformation process began when the long economic stagnation was accompanied by hyper inflation (718% in 1990). During 1989-1992 GDP dropped by more than 18%. It was a drastic period for the Polish economy.

On the other hand, a substantial decrease of energy consumption could be noticed in Poland after 1989. This means that power plants, the main source of sulfur dioxide emission in Poland (Table 1), had also decreased their emissions. It is especially important that coal consumption, which has a dominant position in the energy balance of the country, was reduced by 12% during 1989-1996. Still its share in the primary energy consumption is higher than 75%.

Table 1. Total sulfur dioxide emission [kt] in Poland

Specification	*1990*	*1992*	*1996*
Utilities (electricity + heat)	1570	1310	1195
Industrial power generation	500	420	406
Industrial technologies	270	250	200
Other stationary sources	760	750	521
Mobile sources	110	90	46
TOTAL	**3210**	**2820**	**2368**

Source: GUS 1996, 1998c

Poland is one of the main air polluters in Europe. Some parts of the country are known to be among the world's most polluted areas. Also the country has a great impact on European sulfur dioxide depositions. The Polish Government has decided to sign the SSP but did not ratify it yet, because it is afraid of the negative consequences for the economy.

In order to fulfill by Poland the first commitment required by the Protocol - to decrease SO_2 emission no later than 2000 to 2583 kt (Table 2) - it is necessary to achieve a 37% reduction in relation to 1980. Already in 1996, the emission was 2368 kt (Table 1) and it is still decreasing. However, any future emission reductions will be more difficult to achieve, because the production continues to increase from 1992 after the crisis. This implies that pollution emission level is likely to increase as well, unless serious mitigation measures are taken. It is possible to conclude that while in the case of Poland meeting the first two targets of the Protocol (for 2000 and 2005) will not involve major difficulties, the next emission level - for 2010 - will be much harder to comply with.

Table 2. Sulfur dioxide emission limits for Poland in the Second Sulfur Protocol

Years	*2000*	*2005*	*2010*
Emission limits [kt SO_2]	2583	2173	1397
Emission reduction [%] in relation to 1980	37	47	66

Source: Ministry 1994

To meet these obligations it is necessary to achieve pollution emission reduction from many different sectors of the economy. The polluters protest emphasizing the emission reduction costs to be borne by them. In fact, meeting tough environmental requirements may have wide economic repercussions. For this reason it is important for environmental policies to take into account their economic consequences.

As economic approaches require long-run strategies for pollution problems, I have chosen a Computable General Equilibrium model to analyze economic repercussions of alternative scenarios for meeting by Poland the SSP requirements. Such a model covers interlinkages among sectors, between agents' incomes and expenditures, among factor markets and thus also reflects feed-back effects of a policy. The main reason to use a CGE model is to provide a quantitative evaluation of the effects of government policies. While qualitative results are nice and useful, we typically want to know more than simply whether a particular exogenous shock mattered a lot or a little. The use of a general equilibrium model is required when an environmental policy exerts economy-wide impacts and it is the distribution of impacts across the economy that matters.

Outline and modifications of the model

A starting point for the Polish CGE model was the Bergman general equilibrium model [Bergman 1991]. Bergman constructed his model for the Swedish economy to investigate to what extent emission reduction policies are likely to have general equilibrium effects.

This model was later adapted for Poland in the course of cooperation between the Polish Academy of Sciences (PAN) and the Netherlands Energy Research Foundation (ECN) [Hille 1993]. The Polish model differs from the Bergman model in several respects. The most important differences are the sector classification, the energy breakdown by fuels, and the treatment of capital.

Further development of the Polish model's structure and reestimation of its parameters was done by Peszko [Peszko 1997]. Simultaneously, Leeuwen together with a group of researchers from the PAN, has modified the model in a somewhat different manner [SEO 1997]. This model was extended by deeper sector disaggregation, changing the base year, introduction of VAT and subsidies, splitting the representative consumer into households and the government, explicitly introducing labor demand and supply (and the difference between them i.e. unemployment), and splitting the labor force into high educated and low educated.

For this particular project the model was developed even further in order to let it be capable of simulating the effects of environmental and energy policies in the form of energy input taxes and emission taxes. Additionally sector classification was changed and households were broken down into 'rich' and 'poor'. Below I present the main modifications I made for the present Polish CGE model. As a starting point I chose the SEO 1997 model (further called the 'original model'), as it reflects deeper interactions between the energy sectors, the rest of the economy and the environment in Poland than the other models mentioned. The AIMMS software package was used to develop this model.

Classification

Sector classification is based on an input-output (*i/o*) table for Poland. The 38 economic branches of the original input-output table were aggregated in fewer broad categories according to economic characteristics such as: the market power, protection, and the tradability of products.

However, such a classification is not intended to account for environmental impacts exerted by sectors. For this purpose the data should be additionally broken down to sector level according to emission volume or the availability of a treatment technology. In this paper I followed the first approach, so all sectors were additionally characterized as 'emitting' or 'non-emitting' ones like in Table 3. Energy sectors were separated as well, because they are the largest source of SO_2 emissions.

Finally, the economy was aggregated into 13 production and 4 energy sectors. The model uses the information from the 1992 input-output table for Poland. This was dictated by the fact, that the latest available official i/o table is the one for that year. The original model used a 1994 predicted i/o table based on the 1990 one.

Table 3. Sector classification of the model

sectors	*symbol*	*emitting sectors*	*non-emitting sectors*	*share in Gross Product 1992*
		(according to SO_2 intensity of production)		
PRODUCING	T1	Ferrous and Non-ferrous metallurgy, Metal products		5.6%
	T4	Mineral industry (quarry, building materials, ceramic, glass)		2.1%
	T5		Wood industry, Paper industry, Other industries	3.3%
	M1		Electro-engineering	9.3%
	M2		Light industry (textiles, clothing, leather, wool)	3.9%
	M3		Food industry, Cigarettes, other	11.9%
	M4	Chemical base and products industry		5.6%
	M5		Construction	7.4%
	M6		Agriculture, Horticulture, Forestry, Fishing	9.1%
	M7	Transport		5.5%
	M8		Commercial services (finance, communication, trade, hotels and restaurants, architecture, etc.)	12.5%
	Ne /N	Municipal service activities	Non-commercial services	12.2%
ENERGY	E1	Coal industry		2.4%
	E2e /E2	Coal cokery and Oil refinery products	Fuel and Gas industry	4.5%
	E3	Electricity and Heating, Gas production, Water treatment and distribution		4.6%

Sources: Leeuwen 1997, GUS 1998a, own calculations

Production

According to my modification of the sector classification, the production function in the model was modified respectively. The model uses a combined Leontief with fixed technological coefficients and nested-CES production structure. Factors substitution is modeled in five (instead of four as in the original model) successive steps using a nested-CES production function structure. This is due to the change in the number of energy sectors form three (in the original model) to four.

Demand

The domestic demand is described by a Linear Expenditure System (*LES*). The LES system is used to distribute total aggregate disposable income (measured as value added) over the various domestic final demand categories. In the original model the demand is represented by a representative household and the government.

To analyze social consequences of an environmental policy, its impact on income distribution is investigated in this study. For this purpose the households were additionally divided into two groups: 'the rich' and 'the poor'. These households have different levels of disposable income and the basis for dividing is their income per month per capita [GUS 1993]. Based on consumer expenditures data, the difference between rich and poor consumers was estimated with respect to the percentage share of expenditures on the commodities from different sectors. Therefore now the model is capable of showing how economic impacts of different policy options affect richer and poorer parts of the society.

Welfare functions are not explicitly defined in the original model. That is why I have used the Laspeyres and Paasche quantity indices to verify the welfare changes due to the new choice of goods bundles.

Labor market

A mixed system is used in the original model with respect to labor: in the high educated segment the endowment is exogenously given and the price is determined endogenously, while in the low educated segment the price is exogenously given and the demand is determined within the model. The difference between labor supply and demand is defined as unemployment. Even though all markets are supposed to clear in a CGE model, it is not inferred that there must be no unemployment. It is possible that the labor market will be at an equilibrium with certain amount of voluntary or/and involuntary unemployment in the benchmark. A computational algorithm finds an equilibrium where all other markets clear.

I have introduced the same algorithm for this study. Taking into account that the data of labor cost for high educated and low educated labor per sectors are not available in Poland, I have split the labor force into manual and non-manual workers. Additionally, during the equations verification I have found that the labor force, employment, labor cost, tax and social security contributions were not correctly (in my opinion) introduced in the original model. After modifications, the relevant equations were changed in the following way:

$$E_i^m = \frac{LD_i^m(1+s^m)}{v_i^m(1+\rho^m)^t} \quad and \quad E_i^n = \frac{LD_i^n}{v_i^n P^n}$$

where E_i^m and E_i^n are the employment of manual and non-manual workers respectively per sector *i*, *LD* represents endogenous labor demand in monetary terms, *s* is the subsidy rate paid by the government, *v* is gross wage in base year, ρ represents the annual growth rate of labor price, *t* is time, and *P* is endogenous labor price. For all variables, superscripts *m* and *n* stand for manual and non-manual workers, respectively.

$$L^m = (1+\rho^m)^t IO(L^m) = \sum_i LD_i^m$$

where L^m is labor cost for manual workers and $IO(L^m)$ is total labor cost for manual workers in the input-output table.

$$T_i = LD_i \gamma_i$$

where T_i is income tax (or social security contribution) on labor cost and γ is income tax (or social security) share in the total labor cost. The same equation applies both for manual and non-manual workers.

$$LF^m = EL^m(1+\varphi^m)^t + \mu^m(LF - LF^n)$$

$$LF^n = EL^n(1+\varphi^n)^t + \mu^n\left(LF^n\mu^n + \frac{IO(L^n)(1+\varphi^n)^t}{v^n}\right)$$

where *LF* is the total labor force, LF^m and LF^n represent the labor force of manual and non-manual workers, respectively, *EL* is total employment in the base year, φ is employment growth rate, and μ is unemployment rate. As before, superscripts *m* and *n* stand for manual and non-manual workers, respectively.

<u>Environment</u>

In order to fulfill the SSP it will be necessary to apply different instruments of environmental policy such as: taxes, charges, fines, standards, tradable permits, deposit refund systems, and damage compensation. The original model used standards, subsidies and tradable permits for this purpose.

The model calculates the total SO_2 emission by summing up pollution resulting from combustion of fossil fuels and pollution from industrial processes. These two sources of pollution for each polluter are assumed to be proportional to the amount of energy used and to the sectoral production level respectively. For this purpose the so called emission coefficients were used in the original model. In this project such coefficients were used too, but data were reestimated. These coefficients could be changed overtime as a result of adopting new standards.

In the model a maximum emission level can also be imposed. The model can be used for simulating the results of environmental policies that consist in lowering these levels. For this purpose the concept of tradable emission permits is used. The cost of environmental policies affect then the marginal costs and prices through the impact of abatement costs (expressed in the price of an emission permit). This was the idea of the original model. In my project taxes were additionally introduced: an emission tax and an excise tax.

The idea of an emission tax (t_e) is simple in the model. This tax just increases the price of an emission permit (P_e) and it is identical for each polluter. It is reflected in the equations which describe the marginal cost of production and the price of fossil fuels. However, there are some complications related to this tax for the base year. The emission tax was exogenously introduced in the model and its rate for sulfur dioxide was 0.11 PLN/kg SO_2 in 1992. However this tax was already included in the original model in the i/o table together with all other dues existing for that year. So the additional introduction of a t_e greater than zero for the base year means that model double counts the emission tax. This implies that the model would not calibrate. To solve this problem I used rescaling, the original rate of emission tax of 0.11 to 0.00. Such rescaling does not distort the model, because an additive modification was used:

$$P_e k \rightarrow (P_e + t_e)k$$

where k is emission coefficient. Let us denote (P_e+t_e) as X. If the emission tax increases from 0.11 PLN/kg SO_2 to, say, 0.30 PLN/kg SO_2 in the future, we need to add just 0.19 in the model, instead of 0.30, to receive a proper result:

$$P_e + t_e + 0.19 = X + 0.19$$

The explanation of this fact is as follows. The model assumes that the price of fuels and the marginal cost of production already included the initial emission tax rate of 0.11 for the base year (even though a zero tax rate was introduced explicitly in the model). The model demonstrates only relative prices. Thus, a new value of the tax rate for some future year which we can introduce to the model will be always the difference between the new and previous real values of the tax rate. We can treat this tax rate just as a new tax, that was not introduced into the model previously.

The excise tax (t_f) is introduced in the model as an ad valorem tax, which increases price of fuels (P_f) in sectors E1, E2 and E2e from Table 3:

$$P_f \rightarrow P_f(1+t_f)$$

The same complication is related to this tax for the base year as for the emission tax. Hence a similar idea was applied to solve this problem. Therefore the price of fuels paid by consumers reads as follows:

$$P_{fc} = \left(\frac{P_f(1+t_f)}{(1+s_f)} + k_{fc}(P_e + t_e) \right)(1+VAT)$$

where P_{fc} is a consumer price of fuel, s_f is an exogenous subsidy on fuel inputs, k_{fc} is a fuel emission coefficient in the household sector, and VAT is a value added tax (introduced in Poland in 1993). For the base year this equation could be reduced just to the form:

$$P_{fc} = P_f$$

because all exogenous dues are equal zero. The same price equation, but without a value added tax, is introduced for producers, who generate an intermediate demand for these fuels.

Revenues collected from the emission and energy taxes increase the capital resources available to economy (implicitly in the general budget).

Environmental and Energy Policies

To calculate the consequences of the SSP commitments in this project, computations for one of the three periods indicated by the Protocol for Poland were carried out. This means that the model was solved for the year 2010 starting from the initial calibration for 1992. In Table 2, the emission limits for Poland in the SSP are presented. The initial official emission level for 1992 was 2820 kt SO_2, but in the model 3641 kt SO_2 is introduced instead. The reason for such a difference is that the model computes the total emission level using actual emission coefficients by sectors. These data are available from three different institutes in Poland: Energy Computing Center, the Main Statistical Authority and the Institute of Environmental Protection. The first one has a complete data on emissions from fuels combustion, but not for households [Energy 1994]. The second institute has only incomplete data of emissions from technological processes [GUS 1998b]. The last one has complete data that are used officially in the Polish statistics, but these data are available in the aggregated form only [Institute 1993]. I decided to use the sectoral data from the first two institutes and households data from the last institute.

The model was run twice:

- first time - with unlimited emissions
- second time - with emission limits.

The two runs allowed us to see how the structure of the sectors production and demand has changed after introducing the emission limits. At the same time it was assumed that taxes would stay at their 1998 level: the emission tax would be 0.30 PLN/kg SO_2, tax on use of coal (E1) and crude fuels (E2) would be null as for the base year, and excise tax for the other energy carriers (E2e) would be 41%[1].

In both cases the same scenario is used. It assumes that the world market prices increase 2% per year. The import growth is 1.5% per year under 1.5% zloty depreciation per year. The autonomous export growth oscillates, for various sectors, between 0 and 2% per year and export demand elasticity in 2010 will be 25% higher than in 1992 as international trade becomes more competitive.

One of the most important factors that determine growth in our CGE model is the yearly change in the availability of production factors: 3% growth of capital (K), 1.5% growth of labor (manual - L^m and non-manual - L^n), 2.5% growth of electricity production (E3), 0.5% reduction of coal extraction (E1), and 1% growth of products of refinery and cokery processes (E2e). The other factor inputs - the intermediate demand and the use of crude oil and gas (E2) - are endogenously determined by the model and therefore have no direct impact on the growth rate. In addition the scenario assumes that investments in human capital are expected to stimulate productivity and they will result in an increase in the amount of non-manual workers. The yearly growth

[1] based on own calculations

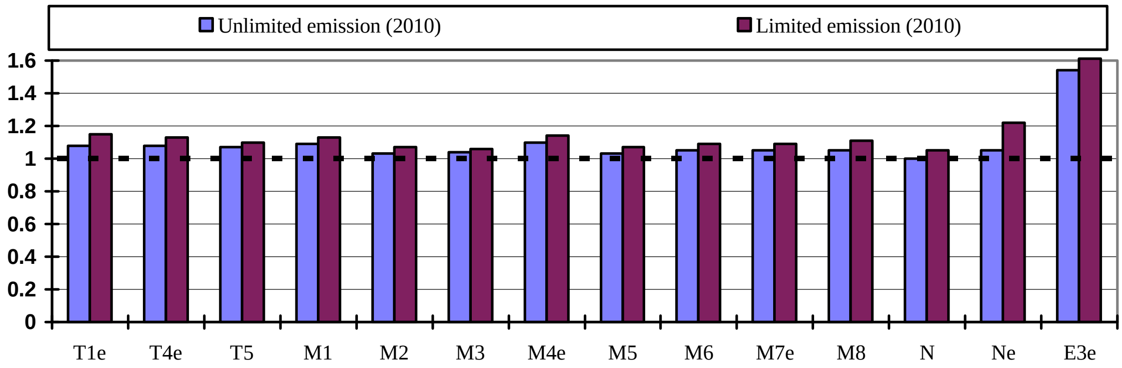
rate of price for E2 (2%) and L^m (1%) are also introduced exogenously. Other factor prices are determined on the factor markets.

All forecasts of the growth rates were calculated by the author based on the data taken from the documents of the Polish government.

Simulation results

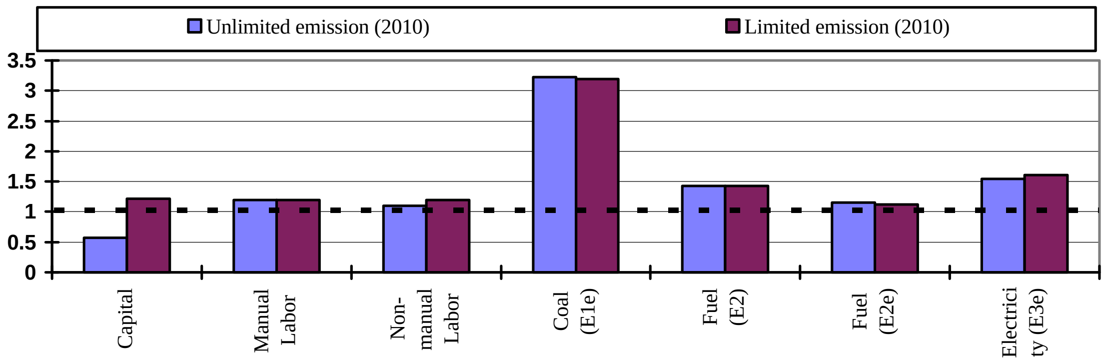
The results of computations are presented in relative terms, i.e. as percentage difference in 2010 with respect to the corresponding result in the base year (1992). We can see on the Chart 1 that marginal costs are quite similar for both scenarios. Compared to the base year, where marginal costs equal 1.0 for all sectors, these costs have increased in virtually all sectors.

Chart 1. Marginal cost per sector [at 1992 level]



As we can see on the Chart 1, even considerable emission reduction probably will not have a dramatic influence on the marginal costs in most branches of the economy. However, some branches (like Metallurgy, Municipal service and Electricity) may have marginal cost higher by more than 5%. Especially in the case of Municipal services this cost is very high in the second scenario. No unexpected effects are observable in this case.

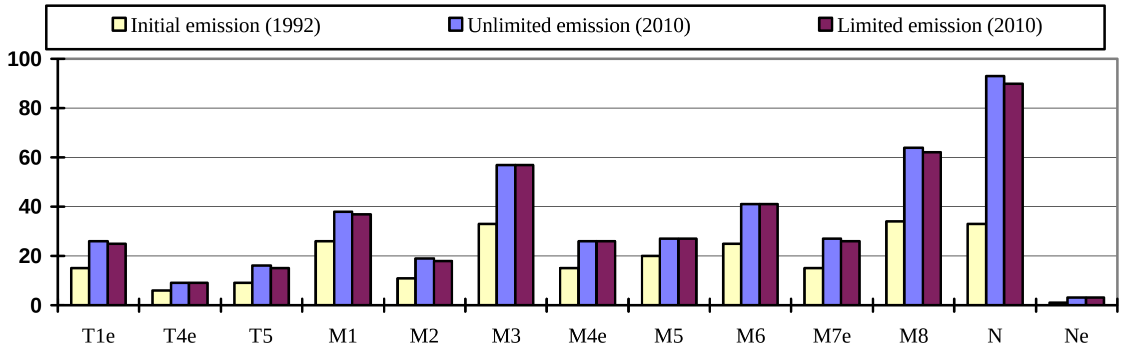
Chart 2. Price of production factors [at 1992 level]



Next Chart 2 presents how the price of production factors will be changed after introduction of an SSP policy (unity level is introduced for the base year). The substantial limitation of the total country's emissions causes that industries should change their composition of production factors. They decrease their use of factors with high sulfur content, especially coal. This ensue an accelerated decrease of coal demand, and consequently it is provide to price decrease. It is could be the explanation why price of coal and fuel (E2e) may decrease after the SSP introduction.

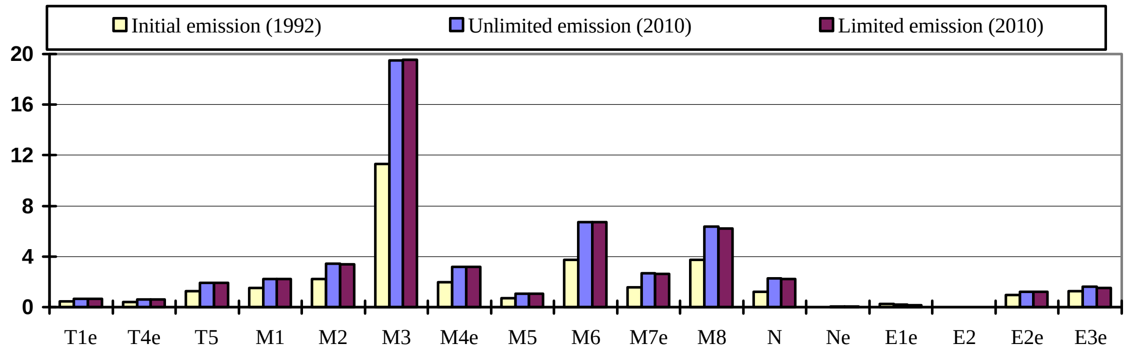
The prices of two factors (manual labor and crude fuels in sector E2) remain constant for both scenarios as we exogenously introduced them to the model. Chart 3 presented below shows the impact of SSP on production of different sectors. This impact could be slightly negative (no more than 3% output reduction). In the case of energy sectors, we are not able to observe this impact because they are exogenous in the model.

Chart 3. Output per sector [bln PLN]



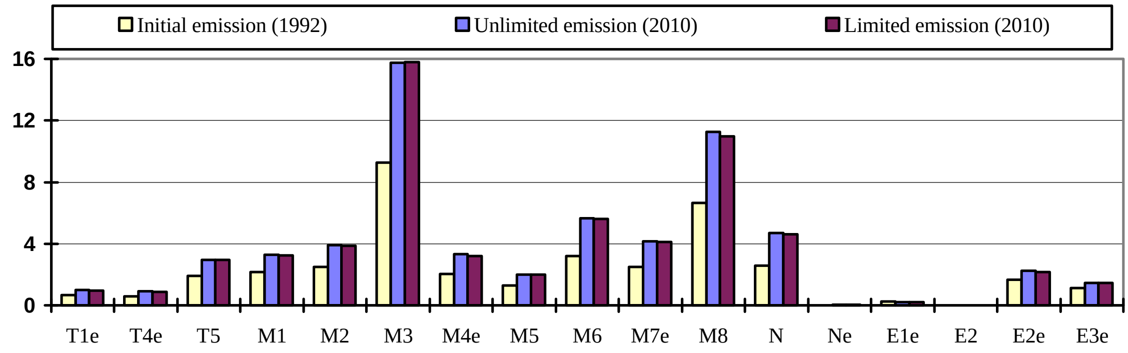
The following two charts illustrate the influence of an SSP policy on consumption. The question is: Will such a policy have a greater impact on poor or rich consumers? The results show that SO_2 emission limit has only a slight final distribution effect. There is no effect for some sectors. These could mean that passing costs on to consumers in the future will be much more difficult. Additionally, the demand of poor consumers decreases approximately at the same rate as the demand of rich consumers.

Chart 4. Consumer demand of the poor households [bln PLN]



Using quantity indices we can check how the average consumption level of either consumers' group will change. The Paasche quantity index is just a little lower than 1. This means that we cannot have any conclusion about consumers being better-off or worse-off. The Laspeyres index is also less than 1 and equal to Paasche index. This informs us that consumers are worse-off after the SSP policy. However, we are not able to compare this effect between two consumers groups, i.e. who will be in a worse position (poor or rich).

Chart 5. Consumer demand of the rich households [bln PLN]



Summing up, CGE modeling shows that fulfilling by Poland the commitments resulting from the participation in the SSP will have modest impact on economic indicators. Over 18 years GDP can decrease by up to 2 percentage points in comparison to a policy without an emission limit. Compared to other shocks that affect the economy in the transition period, the economic hardships caused by the SSP on the whole economy seem to be negligible. However, the model assumes a market for emission permits. In Poland such a market does not exist for the time being. This may provide an incentive for the government to introduce pollution permit markets. Otherwise abatement costs may turn out higher than predicted by the model. The model itself should be additionally modified by introducing variables which represent a negative influence of pollution on consumers. It is obvious that emission reduction improves people satisfaction and thus welfare. The present version does not account for such a feedback.

References

Bergman L. (1991), "General Equilibrium Effects of Environmental Policy: A CGE-Modeling Approach", Environmental and Resource Economics, No.1, p.43-61

Energy Computing Center (1992), *Emisja zanieczyszczen atmosfery w Polsce w ukladzie dzialowo-galeziowym w latach 1992-93*, Warsaw [Air pollution emission per sectors in Poland during 1992-93]

GUS (1993), *Budzety gospodarstw domowych 1992*, Warsaw [Statistical Yearbook of Households Budget]

GUS (1996), *Ochrona Srodowiska 1996*, Warsaw [Statistical Yearbook of Environmental Protection]

GUS (1998a), *Bilans przeplywow miedzygaleziowych w gospodarce narodowej w 1992 roku*, Warsaw [Input-Output Table 1992]

GUS (1998b), *Emisje dwutlenku siarki z procesow technologicznych w 1993 roku, Katowice*, unpublished data [Sulfur dioxide emission from technological processes in 1993]

GUS (1998c), *Statistical Yearbook of the Republic of Poland*, Warsaw

Hille E., M.J. van Leeuwen, N.H. van der Linden, M.Niemyski, W.Pellekaan, S.Szukalski, A.Umer and J.W.Velthuijsen (1993), *Task Force on Integrated Energy and Environmental Planning*, Vol.2, The Netherlands Energy Research Foundation ECN, Petten

Institute of Environmental Protection (1993), *Inwentaryzacja emisji*, Warsaw, unpublished manuscript [Emissions Inventory]

Leeuwen M.J., ed. (1997), *Energy Environment and the Economy in a CGE Model Concept*, SEO-report No.419, Amsterdam

Ministry of Environment (1994), *Protokol do Konwencji z 1979 roku w sprawie Transgranicznego Zanieczyszczania Powietrza na Dalekie Odleglosci dotyczacy dalszego ograniczenia emisji siarki*, Warsaw [Protocol to the Convention on Long Range Transboundary Air Pollution for farther emission reduction of sulfur dioxide]

Peszko G. (1997), *Integracja celow ekonomicznych i ekologicznych w strategiach rozwoju zrownowazonego*, Ph.D. work, Cracow School of Economics [Integration of Economic and Environmental Goals in Sustainable Development Strategies]