Mariusz Plich

Structural Changes and its Effect on Emissions in Poland

10th Inforum World Conference 2002
July 28 to August 3, 2002
University of Maryland
USA

The paper concentrates on structural changes in gross output as well as their influence on the emissions of air pollutants. Changes in unit emissions are also considered. In the first stage the influance of changes in technologies and final users preferences on output by industry is established. This method was already presented at the 8th Inforum Conference, but now an additional observation has been included and a new method of presentation is used. With the results of output it became possible to determine the influence of structural changes on emissions of 7 air pollutants.

1 Changes in output

Method

Let us remind the well known Leontief model:

$$\boldsymbol{X}_t = (\boldsymbol{I} - \boldsymbol{A}_t)^{-1}\boldsymbol{Y}_t \tag{1}$$

where:

$\boldsymbol{X}$ – column vector of gross output,
$\boldsymbol{A}$ – matrix of technical coefficients;
$\boldsymbol{Y}$ – column vector of final demand.

Final demand can also be given as a vector $\boldsymbol{Y}^{(C)}$ of D categories (like various kinds of consumption, investments, exports). A bridge matrix $\boldsymbol{B}$ (or more matrices) can be used to convert the categories to products which satisfies final demand. In this case equation (1) takes the following form:

$$\boldsymbol{X}_t = (\boldsymbol{I} - \boldsymbol{A}_t)^{-1}\boldsymbol{B}_t\boldsymbol{Y}_t^{(C)} \tag{2}$$

Equation (2) allows to compute output for given parameters of the system (the parameters are matrices $\boldsymbol{A}$ and $\boldsymbol{B}$) and for given final demand by categories.

Parameters of formula (2) characterize the structures of economy:

– matrix $\boldsymbol{A}$characterizes the technology of production;
– matrix $\boldsymbol{B}$ shows how the final demand categories are spread across products, which can be interpreted as final users' preferences.

If parameters $\boldsymbol{A}$ and $\boldsymbol{B}$ for year t are not known, then to estimate output for that year one can use parameters taken from another year, (say) year ”0”. Thus equation (2) takes the following form:

$$\hat{\boldsymbol{X}}_t = (\boldsymbol{I} - \boldsymbol{A}_0)^{-1}\boldsymbol{B}_0\boldsymbol{Y}_t^{(C)} \tag{3}$$

where $\hat{\boldsymbol{X}}_t$ can be called theoretical or hypothetical output.

In ex-post simulations based on model (3) true values of final demand can be used. In this case $\hat{\boldsymbol{X}}_t$ shows theoretical output computed under the assumption of constant technology and final users' preferences. In the case parameters of equation (3) do not change much over time the computed output is a good approximation of the historical output, but if parameters do change significantly over time, large deviations betwen historical and theoretical output can be expected. The deviations $(\hat{\boldsymbol{X}}_t - \boldsymbol{X}_t)$ can be interpreted as simulation errors resulting from simplifying assumptions. Theoretical outputs answer the question: what the output in year *t* could be if the parameters in that year were like those as in year *0*.

Having in mind that all elements in formula (3), but the parameters, are taken from year *t*, the difference between the historical and the computed output $(\hat{\boldsymbol{X}}_t - \boldsymbol{X}_t)$ results from changes in the parameters only, i.e. changes in technology and final users' preferences. An individual element $\hat{X}_{it}$ of vector $\hat{\boldsymbol{X}}_t$ larger than output of *i*-th product in year *t* $\hat{X}_{it} > X_{it}$) means that producers of this product are "losers" in the structural changes that occurred between years *0* and *t* - if structural changes had not taken place the demand for their products would have been be higher. If $\hat{X}_{it} < X_{it}$, then producers of *i*-th good are the "winners" of structural changes in the economy. Please note that in the above approach only "aggregate" results of structural changes are observed. It does not tell us about the strength of individual change factors, which in fact can cancel each other out.

Results

The method described in the previous paragraph was applied to Polish economy. Data on output, imports and final demand categories for the period 1990-1999 was used and ***A*** matrix for 1995. Computations were made for 57 sectors and then the reults were aggregated to the level of classification, for which data on emissions was available (19 sectors).

Table1 compares historical output with historical data for 19 sectors. The first two lines for each sector characterize empirical output showing levels (in billions of zlotys) and growth rates (percentage), respectively. In the third line deviations between theoretical and empirical values are presented as percentages of empirical ones. Formulas for these deviations can be written as follows:

$$r_{it} = \hat{X}_{it} - X_{it}$$
$$r_{it}^{\%} = \frac{r_{it}}{X_{it}} \cdot 100 \qquad (4)$$

where r_{it} stands for deviations and $r_{it}^{\%}$ for percentage deviations.

Signs of deviations indicate "winners" and "losers" and deviation values – the strength of structural changes' impact. However, to identify "winners" and "losers" two periods should be distinguished: before and after the parameters' base year, i.e. 1995. All deviations in 1995 are zero, because all parameters used in formula (3) come from this year.

A positive deviation after 1995 means that the output of the sector in question would be higher, if both technologies and final users' preferences were "frozen" at the 1995 level or, in other words, ***if*** structural changes limited output growth. The negative deviation before 1995 also means that output was limited (as a result of using "prospective" structures from 1995. We can say that in both cases the sector's role in economy diminishes(the sector loses). Consequently, if theoretical output is higher after 1995 or lower before 1995 than the historical output the sector wins.

Table 1 Output in sectors: empirical values, growth rates and theoretical values deviations

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Coal	16 403	16 281	14 934	14 576	14 736	14 603	15 363	15 194	12 915	11 790
growth rate	-	-0.74	-8.27	-2.40	1.10	-0.90	5.20	-1.10	-15.00	-8.71
deviation	-25.72	-26.56	-15.82	-12.32	-7.65	0.00	1.18	9.07	36.67	59.48
OilGas	148	139	136	129	131	133	136	137	119	114
growth rate	-	-5.82	-2.41	-4.90	1.50	1.20	2.50	0.90	-13.10	-4.52
deviation	1 029.16	-60.40	155.51	-281.14	52.34	0.00	-354.51	-671.29	-854.72	-1 532.48
ElWatGas	31 482	30 929	27 266	24 042	25 137	25 341	25 438	26 326	26 486	26 907
growth rate	-	-1.76	-11.84	-11.83	4.55	0.81	0.38	3.49	0.61	1.59
deviation	-29.31	-28.66	-16.06	-3.20	-3.02	0.00	4.62	6.31	9.68	12.56
CokeRaf	8 342	7 099	8 008	8 993	9 641	10 181	10 466	10 643	9 260	9 418
growth rate	-	-14.90	12.80	12.30	7.20	5.60	2.80	1.70	-13.00	1.71
deviation	37.77	37.00	25.80	9.89	4.99	0.00	-1.64	-2.62	16.37	18.29
Matals	22 638	16 373	15 860	16 145	18 841	21 705	21 705	24 571	23 342	20 704
growth rate	-	-27.68	-3.13	1.80	16.70	15.20	0.00	13.20	-5.00	-11.30
deviation	-8.19	13.80	22.82	16.60	9.23	0.00	-1.76	-15.97	-16.90	-3.11
Machinery	25 925	24 667	26 066	28 802	33 198	39 294	45 118	51 369	57 316	60 778
growth rate	-	-4.85	5.67	10.49	15.26	18.36	14.82	13.85	11.58	6.04
deviation	60.76	51.23	46.33	27.60	18.28	0.00	-18.45	-30.00	-45.71	-51.80
NEnMining	4 549	3 713	3 591	3 466	3 510	3 510	3 651	3 642	3 126	2 912
growth rate	-	-18.38	-3.27	-3.50	1.27	0.01	4.01	-0.23	-14.17	-6.85
deviation	15.69	-6.38	10.55	-1.87	16.08	0.00	7.85	7.23	21.98	18.23
TransEquip	11 112	8 545	9 354	11 261	13 163	14 514	17 451	21 904	25 411	29 337
growth rate	-	-23.10	9.47	20.38	16.89	10.26	20.24	25.51	16.01	15.45
deviation	26.21	51.68	41.45	12.76	5.92	0.00	-28.81	-52.29	-60.43	-66.32
Chemicals	15 280	13 767	13 492	14 315	16 791	18 991	19 921	22 292	21 668	21 033
growth rate	-	-9.90	-2.00	6.10	17.30	13.10	4.90	11.90	-2.80	-2.93
deviation	52.28	50.55	62.27	43.60	20.35	0.00	-5.91	-23.91	-27.02	-30.12
MinerProd	8 179	7 980	7 705	8 460	9 695	10 160	11 126	12 449	13 993	15 477
growth rate	-	-2.43	-3.45	9.80	14.60	4.80	9.50	11.90	12.40	10.60
deviation	8.61	6.95	15.02	4.31	-3.86	0.00	-0.64	-3.85	-8.07	-12.67
WoodProd	5 319	5 318	5 981	6 202	6 859	7 545	8 503	9 524	10 448	11 968
growth rate	-	0.00	12.45	3.70	10.60	10.00	12.70	12.00	9.70	14.55
deviation	11.46	9.28	2.24	-0.01	-1.65	0.00	-3.79	-6.12	-5.80	-11.05
PaperProd	7 380	7 112	8 436	10 174	11 785	13 881	15 533	18 221	20 695	23 705
growth rate	-	-3.63	18.61	20.60	15.83	17.79	11.91	17.30	13.58	14.54
deviation	111.42	105.04	79.97	40.88	23.50	0.00	-13.94	-27.91	-35.41	-44.48
TexLeaProd	14 544	12 440	12 963	13 917	15 698	15 970	16 804	18 282	18 294	17 394
growth rate	-	-14.47	4.20	7.37	12.80	1.74	5.22	8.79	0.06	-4.92
deviation	-1.18	13.43	12.60	3.52	-4.37	0.00	0.85	0.36	7.46	20.58
FoodProd	42 202	42 206	43 388	47 251	53 245	57 990	63 242	69 204	73 895	73 608
growth rate	-	0.01	2.80	8.90	12.69	8.91	9.06	9.43	6.78	-0.39
deviation	21.96	23.77	23.26	16.82	7.21	0.00	-1.72	-5.02	-6.76	-1.30
OtherManuf	10 688	10 671	12 871	14 565	16 661	20 209	22 981	28 165	31 034	34 357
growth rate	-	-0.16	20.62	13.17	14.38	21.30	13.71	22.56	10.19	10.71
deviation	89.93	74.39	49.49	27.24	17.88	0.00	-11.28	-26.92	-33.69	-39.71
BuildInd	37 585	40 959	43 505	44 941	44 761	49 595	53 364	58 914	64 688	68 526
growth rate	-	8.98	6.21	3.30	-0.40	10.80	7.60	10.40	9.80	5.93
deviation	-1.14	-7.77	-9.99	-10.89	-3.08	0.00	7.17	13.63	16.38	18.09
Agriculture	47 982	47 214	41 218	44 021	39 927	44 199	44 509	44 420	47 040	44 594
growth rate	-	-1.60	-12.70	6.80	-9.30	10.70	0.70	-0.20	5.90	-5.20
deviation	-19.64	-16.59	-1.45	-6.84	10.06	0.00	4.92	10.99	8.93	19.90
Transport	23 233	21 187	21 290	22 460	21 405	22 903	24 483	26 687	29 062	30 687
growth rate	-	-8.81	0.48	5.50	-4.70	7.00	6.90	9.00	8.90	5.59
deviation	-19.54	-15.61	-9.15	-13.55	-4.63	0.00	-2.09	-0.40	1.12	2.49
OtherSectors	207 801	190 670	209 345	219 585	222 527	235 955	255 989	275 698	292 959	314 654
growth rate	-	-8.24	9.79	4.89	1.34	6.03	8.49	7.70	6.26	7.41
deviation	-4.72	4.19	-0.59	-2.41	0.01	0.00	-2.59	-2.99	-3.73	-5.76
AllSectors	540 792	507 271	525 408	553 305	577 711	626 681	675 784	737 642	781 751	817 963
growth rate	-	-6.20	3.58	5.31	4.41	8.48	7.84	9.15	5.98	4.63
deviation	3.84	7.34	7.97	3.05	3.69	0.00	-3.13	-6.32	-7.91	-8.31

Output in billions zlotys; growth rates and deviations in %

Source: author's calculations.

The above discussion can be generalized in the following way: an upward trend of deviations means that an output of a sector is lower and lower in comparison with the theoretical output in sucessive years (the sector is a ”loser”). A downward trend reveals an opposite situation, i.e. that the historical output of a sector is larger and larger than theoretical (the sector is a „winner”).

Now let us look at the values and tendecies of deviations showed in Table 1.

In 1990 output in the whole economy would be 3.8% above its historical level if 1995 structures were used. In 1992 the difference rises to almost 8%. Starting from 1994 deviations decline year by year. In 1999 the theoretical output is over 8% lower than historical. This means that in the period 1990-1994 economy did not necesarily benefit from structural changes - this period was unstable - deviations came up and down alternately. Starting from 1994 a downward trend can be observed which means constant increase in output as a result of structural changes.

The highest absolute values of deviations occur in the OilGas sector - they exceed reasonable limits and are difficult to accept (for instance over 1500% in 1999). This is rather a characteristic of the sector than a challenge to the method – in Poland OilGas production is marginal compared with domestic demand (in 1995 over 97% of domestic demand was satisfied by imports). The sector is skipped on the graphs below.

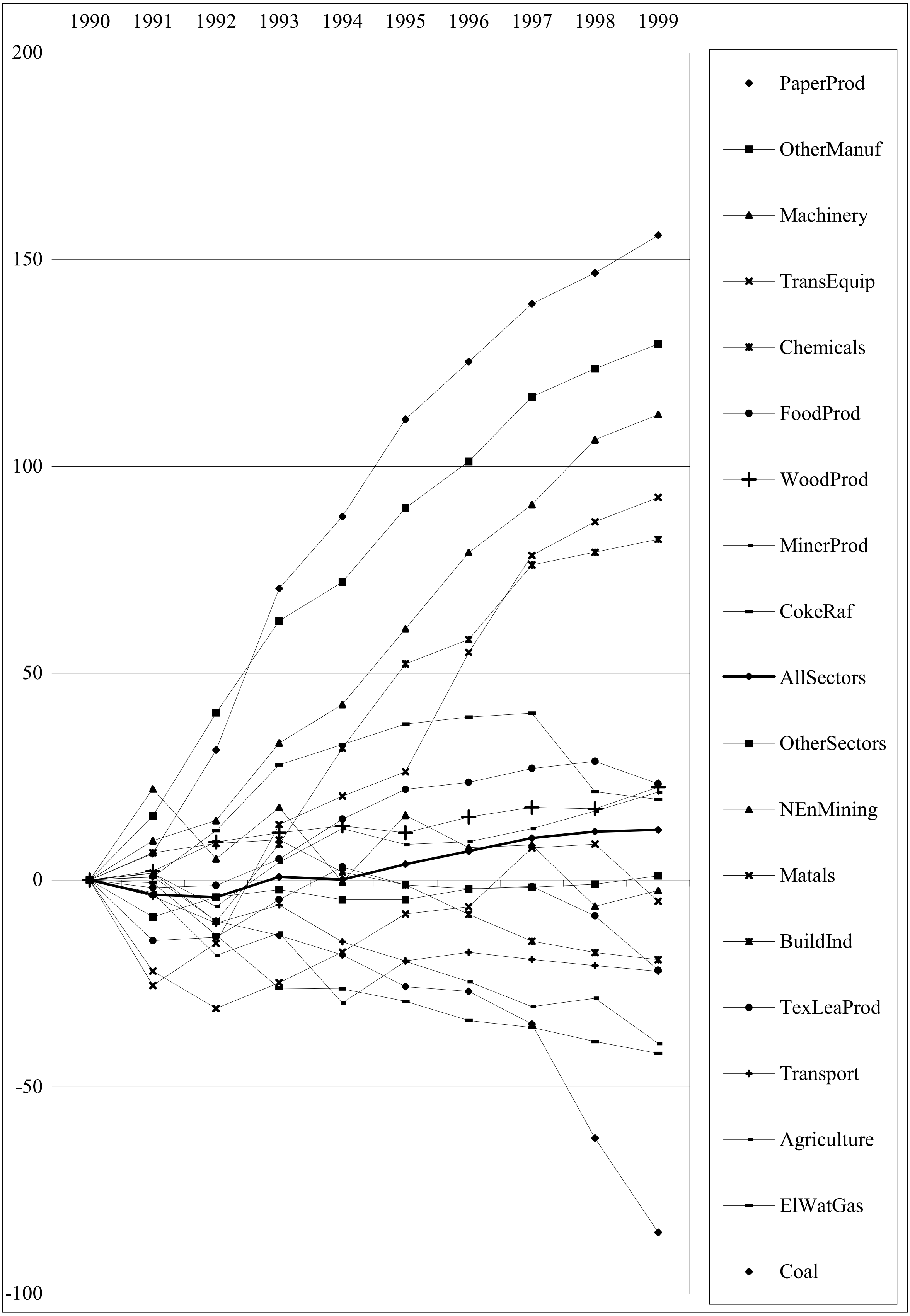
Deviations presented in the table show that in 1999 historical output of some sectors (TranspEquip Machinery, Paper and OtherManuf) were 30–66% higher than theoretical output computed under the assumption of constant technologies and final users' preferences – this means that structural changes in the 1990s supported the expansion of the sectors mentioned above. In 1999 the greatest losers were Coal (historical output lower than theoretical by almost 60%) as well as CokeRaf, TexLaeProd, Building and Agriculture which "lost" around 20%.

The deviations can be presented in a graphical form. Comparisions of time paths as well as scale of deviations between sectors will be easier if the deviations are "normalized" for 1990. This is done here by computing "distance" between percentage deviation for a given year and deviation observed in 1990:

$$o_{it} = r^{\%}_{i1990} - r^{\%}_{it} \qquad (5)$$

Of course, distances equal to 0 for all sectors for 1990. Distances are shown in Graph 1. Points over the level of 0 indicate "winners" and below – "losers".

Graph 1 Distances normalized for 1990



Source: Author's calculations.

An analysis of the graph provides similar conclusions as those drawn from Table 1. The graph however allows to compare changes in distances between sectors over time. For example, sector Paper – leader in 1999 – was not so good in 1991 as three other sectors: NEnMining, OtherManuf and Machinery. In consecutive years the last one however won and lost alternately. Looking at the other side of the graph two sectors draw our attention: ElWatGas and Coal. The first one lost the most at the begining of the 1990s (particularly in 1992 and 1993). This was probably a consequence of the adjustment processes in Polish economy to market conditions which caused that energy and water started to be used more efficiently. The sector Coal started to lose already in 1991 but not so rapidly as ElWatGas and some other sectors. In 1998 and 1999 this process accelerated visibly which may be due to restructurisation of the coal industry started in 1998. The shape of the line for Metals is also interesting – generally the sector lost at the begining of the transition period. It was a winner between 1993 and 1998 and in 1999 this trend was stopped.

To capture the long term trends of the discussed deviations (i.e. between the theoretical and empirical output), they were nomalized for 1990 like distances were (see formula (5)) and the normalized deviations were cumulated:

$$o'_{it} = r_{i1990} - r_{it}$$
$$o'^{s}_{it} = \sum_{k=1990}^{t} o'_{ik} \qquad (6)$$

Empirical output of each sector was also cumulated:

$$X^{s}_{it} = \sum_{k=1990}^{t} X_{ik}$$

to express cumulated deviations as percentages of cumulated output:

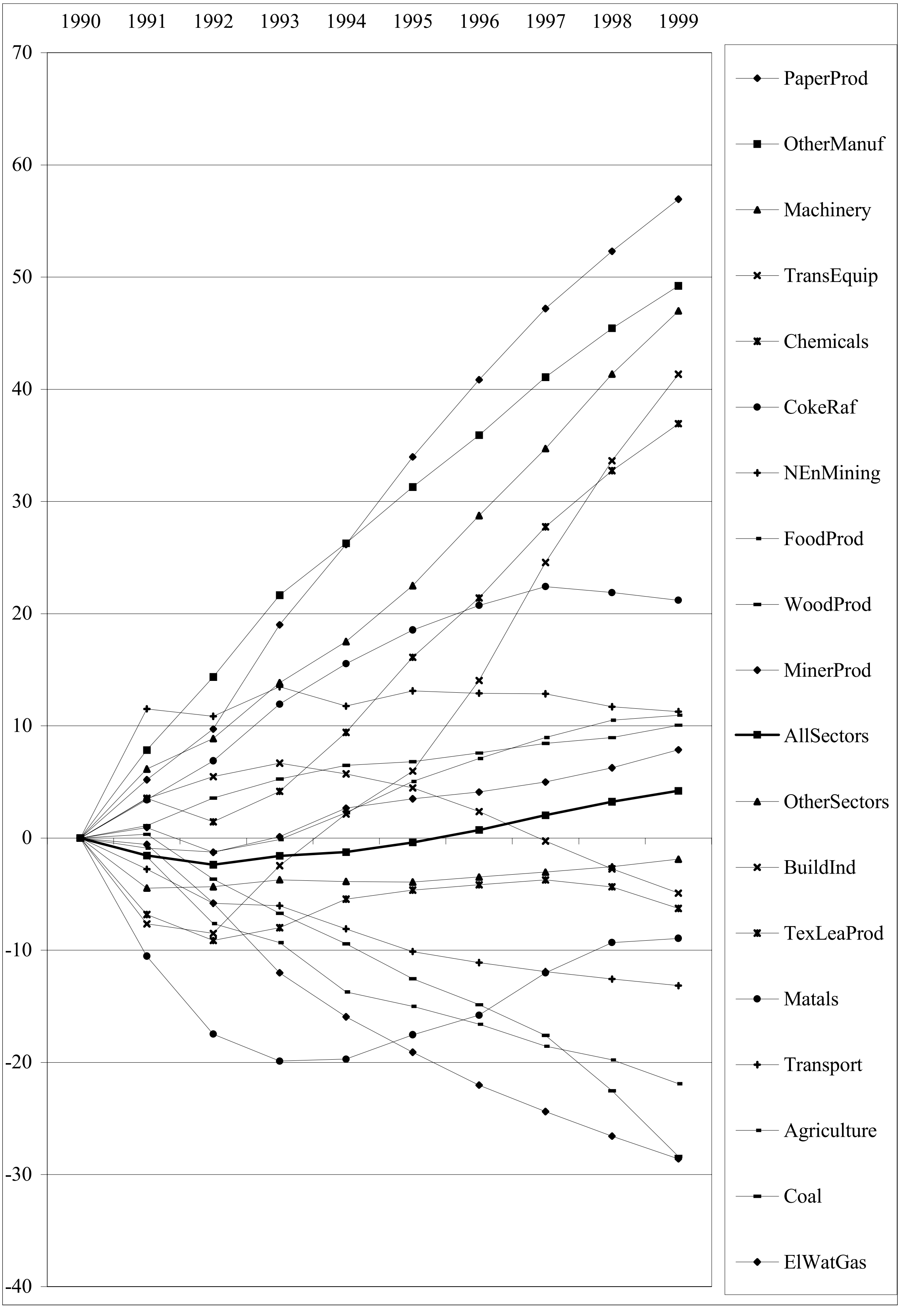
$$o'^{s\%}_{it} = o'^{s}_{it} / X^{s}_{it} \qquad (7)$$

The cumulated percentage deviations show an average influence of structural changes on sectoral output within a year starting from 1990 – average yearly deviation in the period 1990 to the year *t* .

Graph 2 shows these percentage cumulated deviations $o'^{s\%}_{it}$ in the period 1990–1999. In the legend sectors are ordered descendingly for the deviations of 1999 (following Graph 1).

When the order of sectors in both graphs is compared some differences can be observed, but they do not concer the main “winers” and “losers”. The sector Building draw attention – for this sector the cumulated average deviations are lower and lower from 1994. Also the upward trend in CokeRaf sector reversed in 1998. The trend of TranspEquip reversed too but in the other direction – the average deviations were lower and lower at the begining of the 1990s and then started to rise rapidly.

Graph 2 Cumulated deviations (% of cumulated output)



Source: Author's calculations.

2 Structural changes and emissions

Method

The simplest model for any emission can be written as:

$$E = \boldsymbol{eX} \tag{8}$$

where $\boldsymbol{e}$ is a vector of emission coefficients by sectors defined as an amount of emission per unit of output in a given sector. If the theoretical output ***is*** taken from formula (3), the above equation for year *t* takes the following form:

$$\widehat{E}_t = \boldsymbol{e}_t\widehat{\boldsymbol{X}_t} \tag{9}$$

Theoretical amounts of emission $\widehat{E}_t$ answer the question what emission would be like if no structural changes took place.

Let us consider another modification of model (8), assuming that emission coefficients are constant (taken from year "0"):

$$\widehat{E}_t^0 = \boldsymbol{e}_0\widehat{\boldsymbol{X}_t} \tag{10}$$

Differences between $\widehat{E}_t^0$ and $\widehat{E}_t$ show how changes in an emission coefficient contribute to changes in emission amounts.

Results

Models (9) and (10) were used for simulation analyses of emission amounts in the Polish economy in the period 1993–1999[1]. In the simulations the year 1995 was used as a base year (year "0"). Scenario given by equation (9) is called "changes in output" (because results help capture changes in output caused by structural chganges) and the other scenario given by equation (10) is called "constant coefficients" (which means that emission coefficients are taken from year 0).

Results for 7 air pollutants are shown in table 2. In the table three rows are reserved for each pollutant. The first shows empirical amounts of emission and two other contain simulation results as deviations from empirical amounts (percentage of empirical amount). For "changes in output" scenario the deviations were computed using the following formulas:

$$\begin{aligned} r_{zt} &= \sum_{j=1}^{19}\left(\widehat{E}_{zjt} - E_{zjt}\right) \\ r_t^{\%} &= \frac{r_t}{E_{zt}} \cdot 100 \end{aligned} \tag{11}$$

where r_{zt} is the level of deviation, $r_{zt}^{\%}$ – percentage deviation and E_{zt} is an amount of pollutant of type *z* emmited in year *t* by all sectors, that is $E_{zt} = \sum_{j=1}^{19} E_{zjt}$.

Deviations in the scenario "constant coefficients" were computed in the same way, but theoretical amounts of emissions $\widehat{E}_{zjt}^0$ were taken instead of $\widehat{E}_{zjt}$.

Results for the scenario "changes in output" in table 2 lead to the conclusion that in 1999 amounts of emissions, computed under the assumption of constant parameters, were greater than empirical emissions (signs of deviations of all pollutants are positive). This means that structural

[1] In fact the equations were more complicated (types of fuels were distinguished) but the general idea was the same.

changes (changes in technologies as well as changes in final users' preferences) contributed to the decrease in air emissions. This effect is the highest for SO2 (9.7%), the lowest for CO (0,9%).

Table 2 Air emissions and deviations of theoretical and empirical emissions in the period 1993–1999

	1993	1994	1995	1996	1997	1998	1999
CO2	298 671	294 408	303 828	321 135	312 073	293 111	283 375
chnges in output	-1.05	-0.92	0.00	1.29	-0.38	2.06	4.63
constant coefficients	-7.40	-0.90	0.00	-1.75	5.39	16.12	24.55
CO	1 972 215	1 902 077	2 273 204	2 508 163	2 262 999	1 931 095	2 067 591
chnges in output	-7.04	-0.42	0.00	-1.48	-2.05	-2.23	0.92
constant coefficients	1.57	11.61	0.00	-5.95	11.40	38.97	36.44
CH4	51 744	39 483	62 533	72 939	42 810	39 352	40 213
chnges in output	-3.34	2.21	0.00	0.19	-0.79	0.24	2.05
constant coefficients	10.10	52.70	0.00	-10.42	61.36	84.38	88.04
N2O	4 705	4 650	5 027	5 118	5 406	5 113	5 098
chnges in output	-3.23	-1.49	0.00	1.24	1.14	3.43	6.46
constant coefficients	-3.02	3.22	0.00	2.45	2.20	13.06	18.27
NMVOC	323 402	294 055	361 131	384 882	385 196	297 959	332 657
chnges in output	-10.02	-2.91	0.00	-1.46	-0.35	0.76	2.91
constant coefficients	-3.24	12.75	0.00	-2.47	5.66	48.02	39.75
NOx	1 012 971	1 002 782	1 053 950	1 006 515	1 035 373	936 389	923 976
chnges in output	-4.39	-1.29	0.00	0.59	0.10	1.74	4.35
constant coefficients	-6.72	-0.26	0.00	8.91	11.79	29.93	37.18
SO2	2 030 086	1 992 663	1 903 221	1 888 420	1 767 369	1 593 825	1 429 269
chnges in output	-1.31	-1.75	0.00	2.86	2.82	6.52	9.67
constant coefficients	-13.56	-7.74	0.00	5.31	17.48	34.68	56.10

First line of each pollutant shows amounts of emissions in thousands of tones (CO2 in millions)
Second and third line show deviations of simulations as percentages of empirical amounts

Source: Authors calculations.

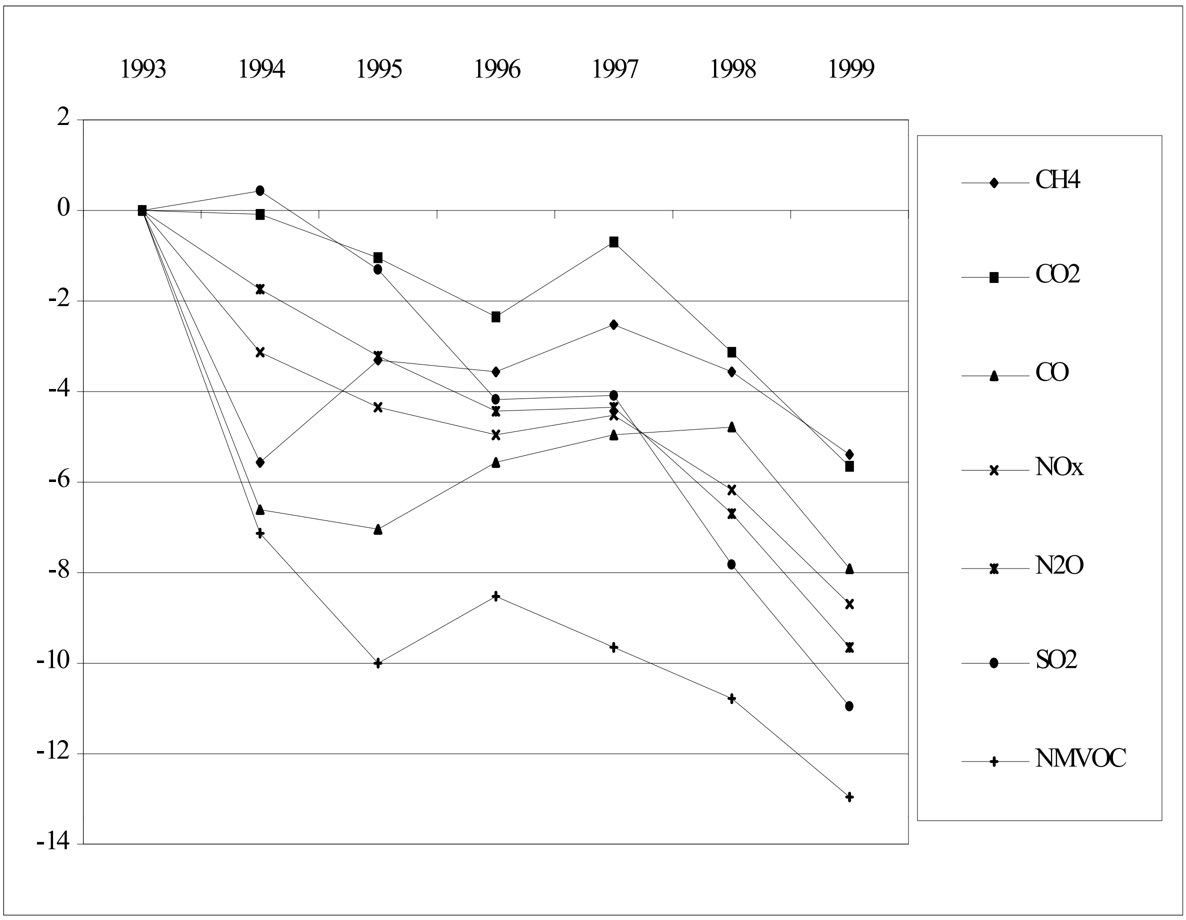
Let us remind that the scenario„constant coefficients" reflects the total effect of assuming non-existence of structural chnages (as in the scenario„changes in output") and constant sectoral emission cofficients at the 1995 level. Therefore, comparing the outcomes of both scenarios allows to estimate the impact of changes in sectoral emission coefficients on the amount of emission.

It turns out that changes in the sectoral emission coefficients considerably contributed to reduced emissions of pollutants in 1999 compared with the base year, which is proved by positive signs and large differences between results of both simulations. If the 1999 emission coefficients were like those in 1995 (with at the same time "frozen" technologies and preferences of the final users), then the emission of methane would be almost 90% larger than actual. The smallest devaition in this scenario is 18% and it concerns N20.

As in analyses of changes in output, also in the case of analyses of changes in emission we calculated distances of percentage deviations with respect to 1993 – see formula (5). Results for the scenario„chnages in output" are shown in Graph3 and „constant coefficients" in Graph 4.

Calcualtion results in Graph 3 show that in the case of all analysed pollutants structural chnages that occurred in the years 1993–1999 contributed to a lower level of emissions. The impact of the changes on the amount of emission measuered by the distance between deviations in the years 1993 and 1999 ranges from ca. 5 points (in the case of methaneand carbon dioxide) to 13 points (NMVOC). Even though the results show an explicitly positive impact of the structural chnages on reduced emissions, the obbserved time paths are not stabilised – the directions of impact vary. This is especially evident in the case of the carbon oxides emissions – after the deep drop in 1994 the next three years an upward trend can be observed. It seems positive that in the years 1998 and 1999 the analysed values clearly drop for all pollutants (an exception is carbon dioxide in 1998).

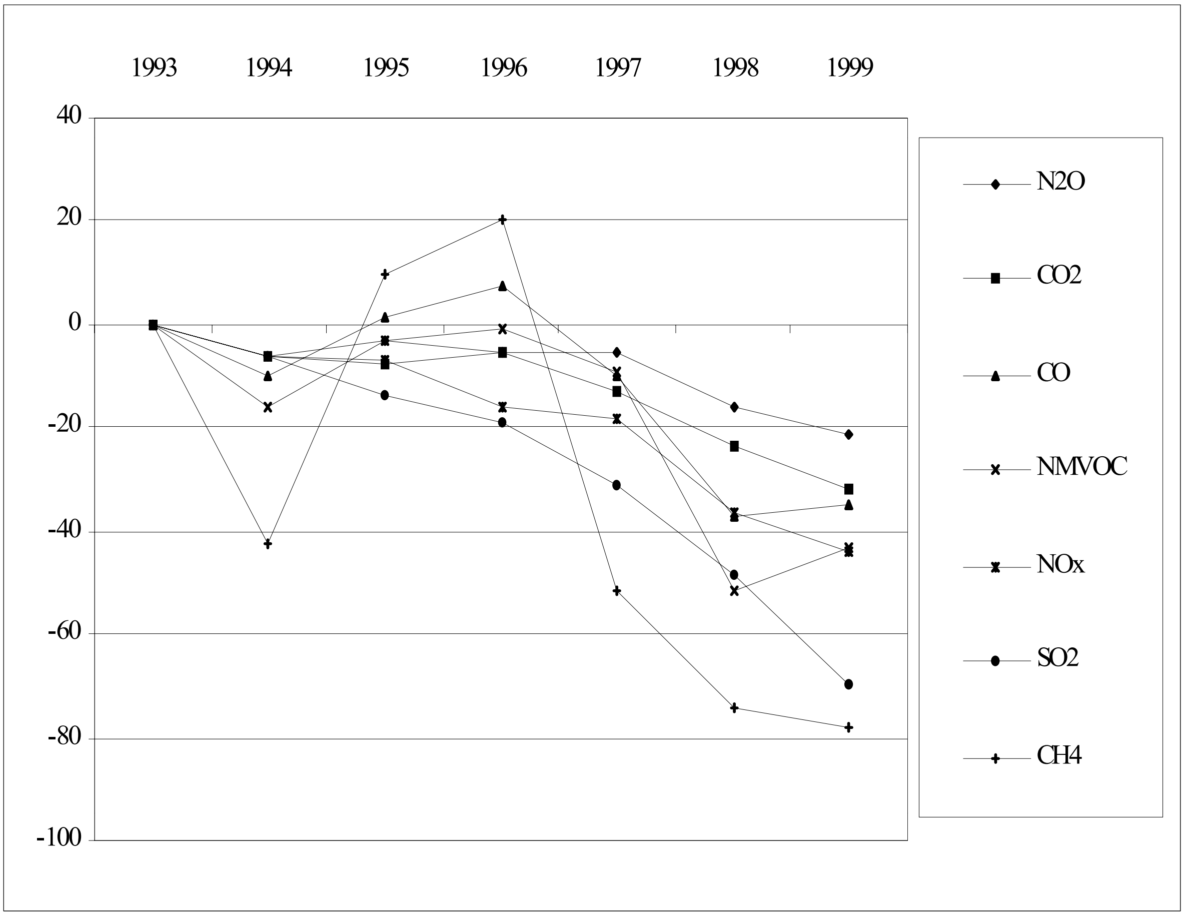
Graph 3 Deviations normalized for 1990 r.: scenario "changes in output"



Source: Author's calculations.

Percentage deviations of the scenario "constant coefficients" analysed in terms of of the distance from deviations in 1993 (Graph 4) are characterised by a considerable spread (from 20 to 80 points), which proves varying rates of changes in the emission coefficients of various types of pollutants. Particularly interesting is the methane curve that shows a rapid growth in 1995 and even stronger drop in 1997. These dramatic changes can be due to the modified methodology of making inventories of pollutants emissions, which should make us cautious about the presented results

Graph .4 Deviations normalized for 1990: scenario "constant coefficients"



Source: Author's calculations.