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Regional Analysis: Differences in Emission-Intensity Due to Differences in Economic Structure or Environmental Efficiency?

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Abstract

The economy is a complex system with many aspects having different interrelated dimensions. Many of these different aspects of the economy may have consequences for the quality of water. Therefore a clear but complex link exists between the economy and the quality of water. This relationship is currently an important issue in estimating the costs of implementing the Water Framework Directive. There are many mechanisms by which the Water Framework Directive affects water quality and the economy. The Water Framework Directive sets water quality targets at river basin level. This is partly explained by the fact that water pollution is very much a local environmental problem. Between river basins exist large differences in emissions to water and economic activity. As a result, the emission-intensity, here defined as the ratio between emissions and value added, differs between river basins. This paper tries to give an answer to why there are differences in emission-intensity between river basins in The Netherlands. In doing so, we will focus on differences in economic structure and environmental efficiency.

Keywords: Water pollution, Water accounts, Emission-intensity, Economic structure, Environmental efficiency

1. Introduction

Sustainable economic development is an increasingly important issue among policymakers and the public. There is thus a high demand for statistics that can support the measurement and analysis of sustainable development. The system of integrated environmental accounts, also known as SEEA (UN, 2003), is a useful tool for monitoring, measuring and analyzing the relationship between environmental policies and the economy by providing consistent time series of data, tables and accounts. The SEEA is a satellite system of the System of National accounts. It brings together economic and environmental information in a comprehensive framework to measure the contribution of the environment to the economy and the impact of the economy on the environment. Specific accounts cover natural resources such as oil and gas, material flows, air emissions, water emissions, waste, and environmental expenditure. At international level the water accounting framework 'the *System of Environmental-Economic Accounting for Water'*, commonly referred to as SEEAW, has been prepared by the United Nations Statistics Division (UNSD, 2006). The SEEAW is a conceptual framework for the organization of physical and economic information related to water using concepts, definitions and classifications consistent to those of the *System of National Accounts 1993* (UN, 1993). The SEEAW framework is an elaboration of that in the handbook *Integrated Environmental and Economic Accounting 2003* (UN, 2003).

In the Netherlands, the economic framework National Accounting Matrix (NAM) has also been extended with satellite accounts for the environment. These satellite accounts describe the relationship between environmental pressure and added value for different economic sectors in the economy (NAMEA). A further specification of NAMEA (De Haan, 1994) for water issues is the satellite account Water Accounts, also known as NAMWA (De Haan, 1997) (Note 2). NAMWA provides information about the connection between the physical water system and the economy at national and river basin scale. NAMWARIB is developed in order to provide information at river basin level (Brouwer et al., 2005). NAMWARIB provides economic and environmental related information at the level of four main river basin districts in the Netherlands; Rhine (Rijn), Meuse (Maas), Scheldt (Schelde) and Ems (Eems). In view of the fact that the Rhine basin covers approximately 70 percent of the entire Dutch territory, this basin is furthermore split into four sub regions: North, West, East and Centre. The Dutch river basin districts are presented in figure 1.

In this paper we make use of the emission accounts at river basin level which provide information on the release of pollutants in wastewater in physical units and of the economic information at river basin level which are both provided by NAMWARIB. The importance of these accounts is strengthened by the introduction of the European Water Framework Directive (WFD). The WFD states that all domestic waters should meet certain targets by 2015, as well in quality as in quantity.

In this paper the differences in emission-intensity, here defined as the ratio between emissions and value added between regions, are investigated. Data has been used on emissions and economic variables for 58 different sectors in the economy. We will try to indicate whether the differences in emission intensity can be traced back to differences in structure of the economy or to differences in environmental efficiency of industries. This analysis is done with use of the so called ‘shift share methodology’. This methodology has been used in the 1960s to explain regional differences in productivity and employment (Dunn, 1960). Here we want to explain regional differences in emission-intensities. The specific method we used is based upon the work of Mazzanti & Montini (2009) and Esteban (2000).

First, we will concentrate on macro figures on emissions and value added. Subsequently, we will have a look at the data on sector level. Next we will present the methodology used to trace back differences in emission intensity due to economic structure and/or environmental efficiency. After presenting the results we get to the conclusion.

2. Data on emissions and the economy at macro and sector level

The two most important groups of substances causing environmental problems are heavy metals and nutrients (phosphorus and nitrogen). Heavy metals, like arsenic, cadmium, chrome, copper, mercury, lead, nickel and zinc are natural to some extend, but are toxic in high concentrations. An excess amount of phosphorus and nitrogen in the water causes algae and duckweed to grow disproportional, which can cause certain species of fish, high water plants and other organisms to die off (CBS, 2008). In the NAMWA, the emission of nutrients and heavy metals to the water are allocated to the economic activity which they cause, based on the ‘residents’ principle. One important pillar for making reliable water emission accounts is the availability of a consistent time series of water emission data. In the Netherlands, these data on water emissions are compiled by a number of governmental institutions working together in the framework of the Pollutant Release and Transfer Register (PRTR). Statistics Netherlands is one of the partners in this project. The database of the PRTR is situated at the Netherlands Environmental Assessment Agency and contains all identified emissions to water, air and soil within the Netherlands territory. Emissions can be presented for a large selection of sources like industry branches, consumers, transport traffic and agriculture. The database facilitates presentation of regional data; for water emissions in particular per water quality management authority (water board) or per Water Framework Directive (sub) river basin. The regional data are accessible for the general public via the website www.emissieregistratie.nl. Part of total emissions is reported by the companies themselves via environmental reports and part of the emissions is estimated by means of calibrating techniques. The mentioned website supplies information on methods for estimating emissions to water.

In figure 2, value added and emissions to water in 2005 for the various river basins are presented. The largest part of value added in 2005 is created in Rhine-West (50 percent of total value added) while the smallest parts are created in river basins Ems and Scheldt (only less than three percent). Rhine-West is responsible for 45 percent of total emissions while the river basins Ems and Scheldt are responsible for 6 and 7 percent of total emissions in the Netherlands.

Viewed nationally, the emissions of heavy metal equivalents (Adriaanse, 1993) to water by companies in the Netherlands have decreased constantly in the period 1995-2005. At the same time, the economy has grown quite rapidly. As a result, the emission intensity had decreased substantially. In other words, environmental performance of companies and institutions has improved substantially in this time period. However, with regard to the river basins, there are large differences between economic growth and emissions of heavy metals. In figure 3, growth in value added and reduction in emissions for the different river basins is presented. In the period 1995-2005 economic growth in the river basin Rhine Central was 39 percent, while in the Ems river basin it was only 8 percent. In the Ems area emissions of heavy metals fell only slightly, while emissions in Rhine West dropped considerably. As a result, the emission intensity dropped the most in the Rhine West area. In spite of high economic growth in this region, emissions decreased substantially. One reason for this was the reorganisation of the fertiliser industry in the area. This industry emitted large amounts of heavy metals. The decrease in emission intensity was smallest in the Ems river basin. The emission-intensity is calculated at river basin level for 1995 and 2005 and this is presented in figure 4.

The emission-intensities of the different regions can be deducted with the emission-intensity of the Netherlands (based upon the sum of the regions). It then becomes clear how the region is doing in terms of emission-intensity in comparison to the national average. Figure 5 displays the difference in emission-intensity of the regions compared with the Netherlands for the period 1995-2005. Most regions are not performing as well as the national average. These regions are Scheldt, Ems, Rhine-East, Rhine-Central and Rhine-North. The regions Rhine-West and Meuse are performing better than the Dutch average.

It is even more interesting to look at sector level by analysing why emissions are high in some river basins and low in other river basins. The distribution of value added and emissions to water over economic sectors differs a lot between river basins. Tables 1 and 2 give a clear picture of the share of value added created by a particular sector in the economy and the related emissions to water (measured in heavy metal-equivalents).

3. Methodology

The main question in this paper is how differences in emission-intensity between regions can be explained and to what extent certain economic sectors play a role in explaining these differences. In explaining differences in emission-intensity, we concentrate on economic efficiency, economic structure and different sectors.

Data is used on emissions and economic variables for 58 different sectors (aggregated to 3 sectors) in the economy. Then we will try to indicate whether the differences in emission intensity can be traced back to differences in structure of the economy or to differences in environmental efficiency of industries. This analysis is done with use of the so called 'shift share methodology'. This methodology has been used in the 1960s by Dunn to explain regional differences in productivity and employment. Here we want to explain regional differences in emission-intensities. The specific method used here is based upon the work of Mazzanti & Montini (2009) and Esteban (2000).

This formulated problem is mathematically written as follows:

$D_{r-nl} = X_r - X_{nl}$, stand for the difference in emission intensity between a region and the Netherlands

where,

$X_r = \sum_{in} P_r^{in} X_r^{in}$, emission-intensity region *r*

$X_{nl} = \sum_{in} P_{nl}^{in} X_{nl}^{in}$, emission-intensity Netherlands

$X_r^{in} = \frac{E_r^{in}}{Y_r^{in}}$, emission intensity industry *in* in region *r*

$X_{nl}^{in} = \frac{E_{nl}^{in}}{Y_{nl}^{in}}$, emission intensity industry *in* in the Netherlands

$P_r^{in} = \frac{Y_r^{in}}{Y_r}$, share in total value added of industry *in* in region *r*

$P_{nl}^{in} = \frac{Y_{nl}^{in}}{Y_{nl}}$, share in total value added of industry *in* in the Netherlands

where,

- X_r =emission intensity region *r*
- X_{nl} =emission intensity the Netherlands
- E = emissions to water E
- Y = value added in basic prices
- *nl* stands for the Netherlands
- *r* stands for region *r*
- *in* stands for industry
- Empirical model for explaining differences in emission-intensity between regions:

$$D_{r-nl} = \beta_1 Q_r^A M_r^A + \beta_2 Q_r^I M_r^I + \beta_3 Q_r^S M_r^S + \beta_4 Z_r^A P_r^A + \beta_5 Z_r^I P_r^I + \beta_6 Z_r^S P_r^S + c$$

Where,

$M_r^A = \sum_A (P_r^A - P_{nl}^A) X^A$, represents the industry mix effect of agriculture.

The industry mix effect of manufacturing (I) and Services (S) is calculated using the same line of reasoning as for agriculture (A) (see appendix 1).

$P_r^A = \sum_A P_{nl}{}^A (X_r^A - X_{nl}{}^A)$, represents the efficiency effect of agriculture.

The efficiency effect of manufacturing (I) and Services (S) is calculated using the same line of reasoning as for agriculture (A) (see appendix 1).

$Q_r^A = \frac{E_r^A}{E_r}$, represents the share of emissions of agriculture in total emissions in region *r*.

This share of emissions is also calculated for manufacturing (I) and Services (S) (see appendix 1).

$Z_r^A = \frac{Y_r^A}{Y_r}$, represents the share of value added of agriculture in total value added in region *r*.

This share of value added is also calculated for manufacturing (I) and Services (S) (see appendix 1).

The data entered in the model are the emissions to surface water and waste water over the years 1995, 2000, 2004 and 2005. The emitted heavy metals are arsenic, cadmium, chrome, copper, mercury, lead, nickel and zinc. The emitted nutrients are phosphor and nitrogen. The included river basins are Meuse, Scheldt, Ems, Rhine-West, Rhine-East, Rhine-North, Rhine-Centre. Data on emissions and economic variables is available for 58 different economic sectors. This results in 280 ($10 \times 4 \times 7$) unique data points.

4. Results and discussion

Differences in emission-intensity are explored using two tools, namely the regression analysis, whose results are presented in table 3, and a more intuitive graphical tool. This graphical tool represents emission-intensities at sector level (heavy metal equivalents). This has been done for three sectors: *Agriculture*, *Manufacturing* and *Services (aggregated from the 58 sectors)*. Together these sectors form the total economy of a particular region. These sector-specific emission-intensities can also be deducted with the Dutch average for the particular sector under consideration. By means of these tools, the differences in emission-intensity between river basins are explained. This explanation is at sector level. Agriculture, manufacturing and services will subsequently be discussed hereafter.

4.1 Agriculture

Differences between regions in the economic structure of agriculture can have a significant influence on the difference in emission-intensity between regions. Agriculture can be represented by a lot of horticulture in one region (e.a. Rhine West), while in the other region arable farming is strongly represented (e.a Rhine North). Arable farming is on average more emission-intensive than horticulture. In order to explain differences in overall emission-intensity, differences in the structure of agriculture can sometimes be a significant explaining factor for some toxic substances. For the substances copper, lead, nickel, phosphorus and nitrogen the structure of agriculture is a significant factor in explaining differences in emission-intensities between regions.

A difference in environmental efficiency is also an explaining factor for differences in emission-intensities between regions. At industry level, one can compare environmental efficiency between regions. For example, arable farming in region A emits per euro value added more emissions to water than arable farming in region B. Accordingly, arable farming in region A is performing in a less environmental friendly way than arable farming in region B. In other words, environmental performance of arable farming in region A is worse than in region B. For the substances cadmium, lead, nickel, zinc, phosphorus and nitrogen holds that differences in environmental performance is a significant explaining factor for the differences in emission-intensity between regions.

The graphical tool for agriculture is presented in figure 6. This figure presents pollution per euro added value for different river basins in the years 1995, 2000 and 2005. Considering agriculture, the emission-intensity in the Meuse region is smaller than the Dutch average. In the Meuse region, environmental regulation related to manure treatment is very strict (LEI, 2006). This is because there are a lot of sandy soils in the Meuse region which are very vulnerable for run-off of heavy metals and nutrients. Life stock activities in this area are very intensive and are responsible for a lot of value added in this area. A large part of the produced manure is transported to areas other than Meuse (CBS, 2007).The manure intensive sector, life stock farming, thus transports its environmental problems to other regions.

In Rhine West, the emission intensity is lower than the Dutch average as well. This is explained by the large horticulture sector in this area. This sector is creating a lot of value added while emissions to water are relatively small. In contrast, arable farming is relatively large in the Ems and Rhine North areas. This sub sector of agriculture creates relatively little value added while the activities go along with a lot of emissions to water indirectly by the run-off of agricultural land to surface water.

4.2 Manufacturing

Differences between regions in the economic structure of manufacturing can have a significant influence on the difference in emission-intensity too. Manufacturing can strongly be represented by for example the chemical and metal sector in one region while in the other region printing and publishing is strongly represented. The chemical and metal sectors are more emission-intensive than for example printing and publishing on average. In order to explain differences in emission-intensity, differences in the structure of manufacturing can be a significant explaining factor. For the substances arsenic, cadmium and copper hold that the structure of manufacturing is a significant factor in explaining differences in emission-intensities between regions. For the other substances hold that differences in the structure of manufacturing is not significantly explaining the differences in emission-intensity. For the substances cadmium, mercury, lead and phosphorus holds that differences in environmental performance in manufacturing is a significant explaining factor for the difference in emission-intensity.

The graphical tool for manufacturing is presented in figure 7. This figure presents pollution per euro added value for the various river basins in the years 1995, 2000 and 2005. The manufacturing sector in river basin Meuse is less emission intensive than the Dutch average (see figure 7). However, the environmental advantage of river basin Meuse has declined over time. This is displayed by the conversion of Meuse's emission-intensity to the Dutch average over time. Emission intensity in Rhine West was higher than the Dutch average in 1995, but hereafter Rhine West's emission intensity improved due to the reorganisation of the fertiliser industry. Emissions reduced sharply while value added declined only slightly. Manufacturing in river basins Ems and Scheldt emitted more emissions to water per euro value added created than the Dutch average. This is due to fact that the chemical sector is quite big and very emission intensive in these two regions. The emission-intensive metal sector is also quite large, especially in the Scheldt region. This is partly explained by the favourable locations of industrial zones nearby important shipping routes in these river basins. Indeed, the metal- and chemical sector produce a lot for foreign consumption (exports). Manufacturing in Rhine East, Rhine North and Rhine Central has a less emission-intensive character. Many manufacturing activities in these regions are represented by less emission-intensive industries. The bad environmental efficiency in Scheldt and Ems is partly explained by more flexible environmental regulation directed by local authorities. The emission permissions issued by 'Rijkswaterstaat' (Dutch water regulator) are more flexible in these regions. The license holder fine tunes the permission in accordance with the impact on the aquatic system. The aquatic system in large outside waterways is less vulnerable than small river aquatic systems. Environmental efficiency may have been bad in these regions but the expected environmental performance (i.e. the impact on water quality) could indeed be reasonable. Apparently, the companies in these regions took advantage of these flexible permissions. The analysis done here is based upon initial emissions to water, not on the final impact on water quality.

4.3 Services

Lastly, differences between regions in the economic structure of services can have a significant influence on the difference in emission-intensity between regions. Services can strongly be represented by the environmental services or health services in one region while in the other region financial services, retail -and wholesale trade are strongly represented. Environmental services and health services are more emission-intensive than for example financial services, retail -and wholesale trade on average. In order to explain differences in emission-intensity, differences in the structure of services can be a significant explaining factor. For the substances chromium, copper, mercury and nickel hold that the structure of services is a significant factor in explaining differences in emission-intensities between regions. For the other substances hold that differences in the structure of services is not significantly explaining differences in emission-intensity. For the substances arsenic, cadmium, mercury, nickel, phosphorus and nitrogen hold that differences in environmental performance in services is a significant explaining factor for the difference in emission-intensity.

The graphical tool for services is presented in figure 8. This figure presents pollution per euro added value for the different river basins in the years 1995, 2000 and 2005. With regard to the services sector, the emission-intensity in the Scheldt area is extremely high compared to the Dutch average and the other areas. This is explained by the fact that there exists a lot of transport over water in this river basin. Transport over water causes a lot of copper and cadmium emissions due to the anti fouling paint used on boats. A lot of toxic substances are emitted in the Scheldt river basin, while the responsibility for this emission burden, at least for the biggest part, does not lie on Dutch residents but on foreign residents. A lot of these foreign transport boats are crossing the Dutch part of the Scheldt river basin on their way to Antwerp (Belgium) and back. For now, these emissions are attributed to transport over water in the Scheldt river basin. On the other hand, the economic value of the transport activities is based upon the resident principle (in line with the National Accounts) instead of upon the territory principle. This leads to an extremely high emission-intensity of the transport over water sector in the Scheldt river basin. This emission-intensity must be interpreted very carefully because the ratio is based upon two different principles. In the future a method for differentiating 'residents emissions' and 'non-residents emissions' needs to be developed in order to correct for this statistical mismatch related to emissions of transport over water. The emission-intensity of river basin Meuse is also quite high. This is explained by the relatively low emission efficiency of the environmental services sector.

5. Conclusion

Differences in economic structure have an important role in explaining the variance in emission-intensity between regions. Even if one corrects for differences in economic structure, differences in emission intensity remain. This leads us to believe that a difference in environmental efficiency of industries between river basins also plays an important role. In this paper it has been tested which factors play a significant role in explaining differences in emission-intensity. It is important to note that differences in emission-intensities between river basins are very large, especially in agriculture. The differences in emission-intensities for the sector agriculture are much larger than the differences seen in manufacturing and services. This indicates that the structures of the agricultural sector as well as the environmental performance of a particular sub sector of agriculture are both very important indicators for the overall emission intensity of a particular region.

The emission-intensity for the sector agriculture in Rhine-West is lower than the Dutch average, which is explained by the large horticulture sector in this area. This sector is creating a lot of value added while emissions to water are relatively small. In contrast, arable farming is relatively large in the Ems river basin. This sub sector of agriculture creates relatively little value added while the activities go along with a lot of emissions to water. Here the economic structure plays an important role in explaining overall emission-intensity. Transportation of produced manure is a way to improve environmental efficiency of agriculture in one region. Still this measurement creates an environmental problem for another region.

Manufacturing in Ems and Scheldt emit more to water per euro value added created than the Dutch average. This is explained by the large chemical sector which is quite emission intensive in these two regions. The metal sector is also quite large here, especially in the Scheldt region. This is partly explained by the favourable locations of industrial zones nearby important shipping routes in these river basins. Bad environmental efficiency of manufacturing in Scheldt and Ems is partly explained by more flexible environmental regulation directed by local authorities.

With regard to the services sector, the emission-intensity in the Scheldt area is extremely high compared with the Dutch average and the other areas. This is explained by the fact that there exist a lot of transport over water activities in this river basin. Here a statistical problem needs to be solved. The economic value of the transport activities at river basin level is based upon the resident principle while the calculation of emissions is based upon the territory principle. A recommendation would be to construct a method for differentiating 'residents emissions' and 'non-residents emissions' related to emissions of transport over water at river basin level.

Differences in emission-intensity are explained by various factors. Some factors have significant impact while other factors don't explain the difference in emission-intensity significantly. The factors which explain the differences are very 'substance' dependent. What holds for substance X does not necessary hold for substance Y. This conclusion leads to the recommendation that emissions to water and water quality should be analysed at river basin level and at substance level. Problems related to water emissions cannot properly be analysed if one looks at national data and to emissions of heavy metal equivalents and nutrients equivalents only. Data at river basin level can help to get a better picture of the problems in the river basin and can ultimately help in developing better water quality measurements for the river basin. Data at national level alone is not sufficient in developing these policies. The availability of economic and emission data at river basin level is vital in developing and implementing emission reduction programmes at minimum costs to society as a whole.

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Notes

Note 1. Both authors are statisticians at the Dutch Bureau of Statistics, CBS. The views expressed in this paper are those of the authors only and do not necessarily reflect the opinion of Statistics Netherlands.

Note 2. The NAMWA is developed in close cooperation with the Water Service (former RIZA).

Table 1. share in total value added per river basin

River basin	Agriculture	Manufacturing	Services
Meuse	3%	31%	66%
Rhine-West	2%	17%	80%
Scheldt	5%	42%	53%
Ems	3%	33%	64%
Rhine-East	4%	29%	67%
Rhine-North	6%	34%	60%
Rhine-Central	3%	19%	78%

Table 2. share in total emissions per river basin (heavy metals, see appendix 2 for data at substance level)

River basin	Agriculture	Manufacturing	Services
Meuse	13%	24%	63%
Rhine-West	18%	15%	67%
Scheldt	18%	23%	59%
Ems	23%	48%	30%
Rhine-East	31%	16%	53%
Rhine-North	53%	12%	36%
Rhine-Central	28%	12%	61%

Table 3. Results of linear regression analysis

	Agriculture	Beta	*T*-value	Sig	Manufacturing	Beta	*T*-value	Sig	Services	Beta	*T*-value	Sig
Industry mix	Arsine	0,065	0,580	0,568	Arsine	0,469	3,546	0,002*	Arsine	0,308	1,728	0,099
	Cadmium	0,024	0,736	0,470	Cadmium	0,177	6,223	0*	Cadmium	0,003	0,083	0,934
	Chrome	-0,221	-0,411	0,685	Chrome	-0,482	-1,709	0,102	Chrome	0,601	2,271	0,034
	Copper	0,283	3,744	0,001*	Copper	0,458	8,461	0*	Copper	0,879	8,232	0*
	Mercury	-	-	-	Mercury	-0,042	-0,552	0,586	Mercury	0,325	3,027	0,006
	Lead	0,486	4,833	0*	Lead	-0,049	-0,612	0,547	Lead	-0,068	-0,743	0,466
	Nickel	0,343	2,556	0,018	Nickel	-0,060	-0,424	0,676	Nickel	0,533	3,630	0,002*
	Zinc	-0,100	-0,605	0,551	Zinc	-0,013	-0,088	0,931	Zinc	0,281	1,188	0,248
	Phosphorus	0,064	2,881	0,009	Phosphorus	0,014	0,739	0,468	Phosphorus	0,009	0,389	0,701
	Nitrogen	0,683	14,968	0*	Nitrogen	0,025	0,590	0,562	Nitrogen	0,014	0,321	0,752
Efficiency	Arsine	-0,071	-0,519	0,609	Arsine	0,186	1,754	0,094	Arsine	0,407	3,530	0,002*
	Cadmium	0,187	3,718	0,001*	Cadmium	0,765	13,718	0*	Cadmium	0,138	4,422	0*
	Chrome	0,055	0,110	0,913	Chrome	-0,025	-0,124	0,902	Chrome	0,172	0,524	0,606
	Copper	-0,148	-1,206	0,241	Copper	-0,009	-0,147	0,885	Copper	-0,074	-1,333	0,197
	Mercury	-	-	-	Mercury	0,896	13,734	0*	Mercury	0,772	6,767	0*
	Lead	0,547	5,066	0*	Lead	0,214	3,069	0,006	Lead	-0,028	-0,368	0,716
	Nickel	0,359	2,458	0,023	Nickel	-0,007	-0,055	0,956	Nickel	0,564	3,694	0,001*
	Zinc	0,551	2,059	0,052	Zinc	0,950	0,967	0,345	Zinc	0,233	1,866	0,076
	Phosphorus	0,571	7,550	0*	Phosphorus	0,156	6,764	0*	Phosphorus	0,362	4,956	0*
	Nitrogen	0,432	6,974	0*	Nitrogen	-0,016	-0,372	0,714	Nitrogen	0,134	2,587	0,017

Results of linear regression analysis

Figure 1. The Dutch main river basin districts (Source: website CBS)

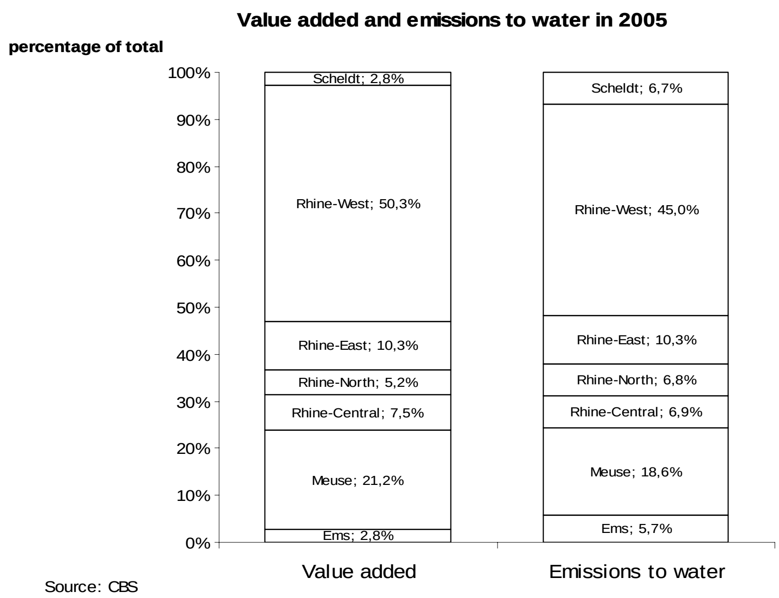

Figure 2. Value added and emissions to water in the various river basins, 2005

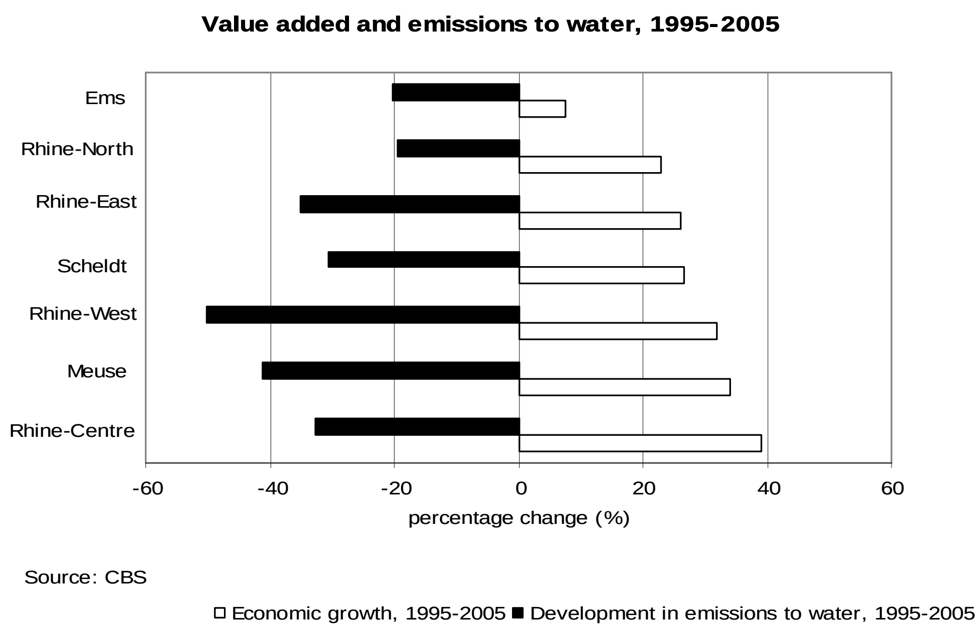

Figure 3. Value added and emissions to water in the various river basins, 1995-2005

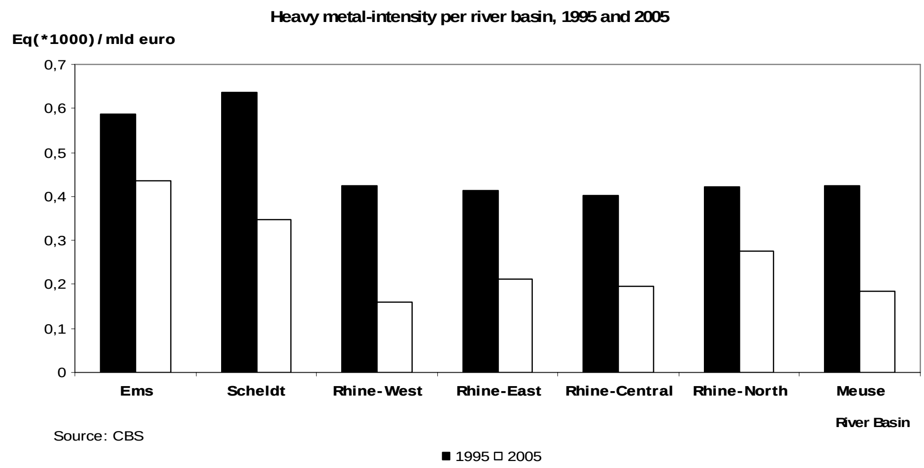

Figure 4. Emission intensity in the various river basins, 1995 and 2005

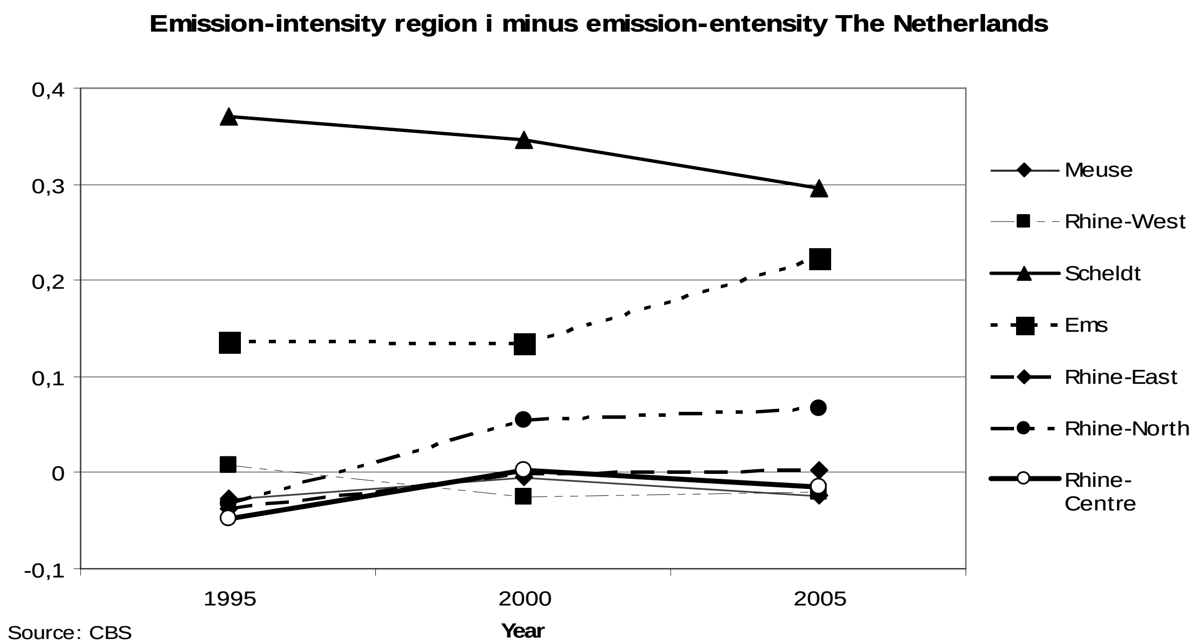

Figure 5. Emission-intensity of the various river basins 1995-2005

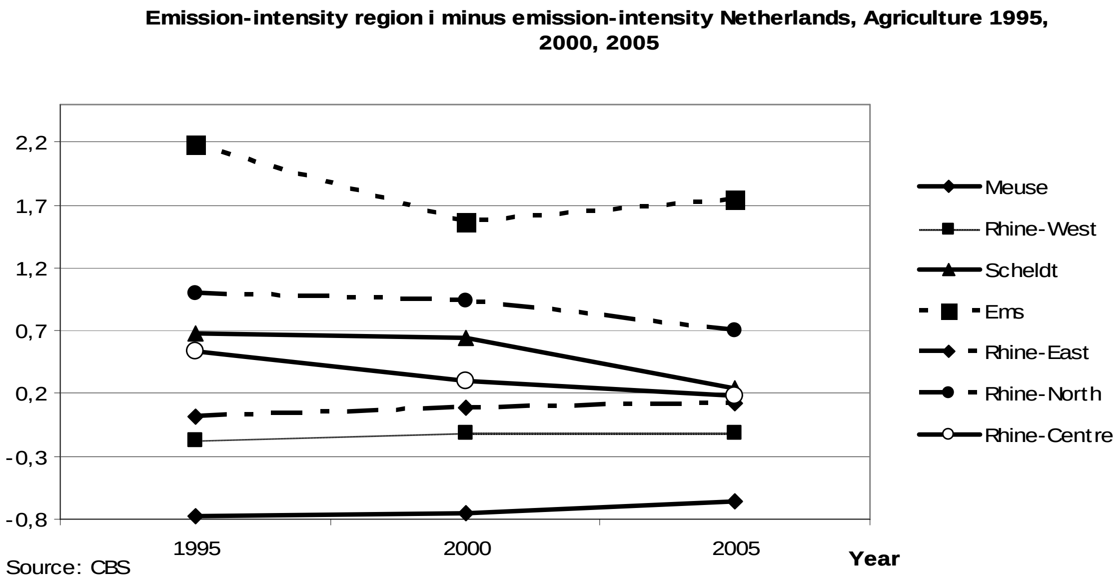

Figure 6. Pollution per euro added value for the various river basins in the years 1995, 2000 and 2005, agriculture

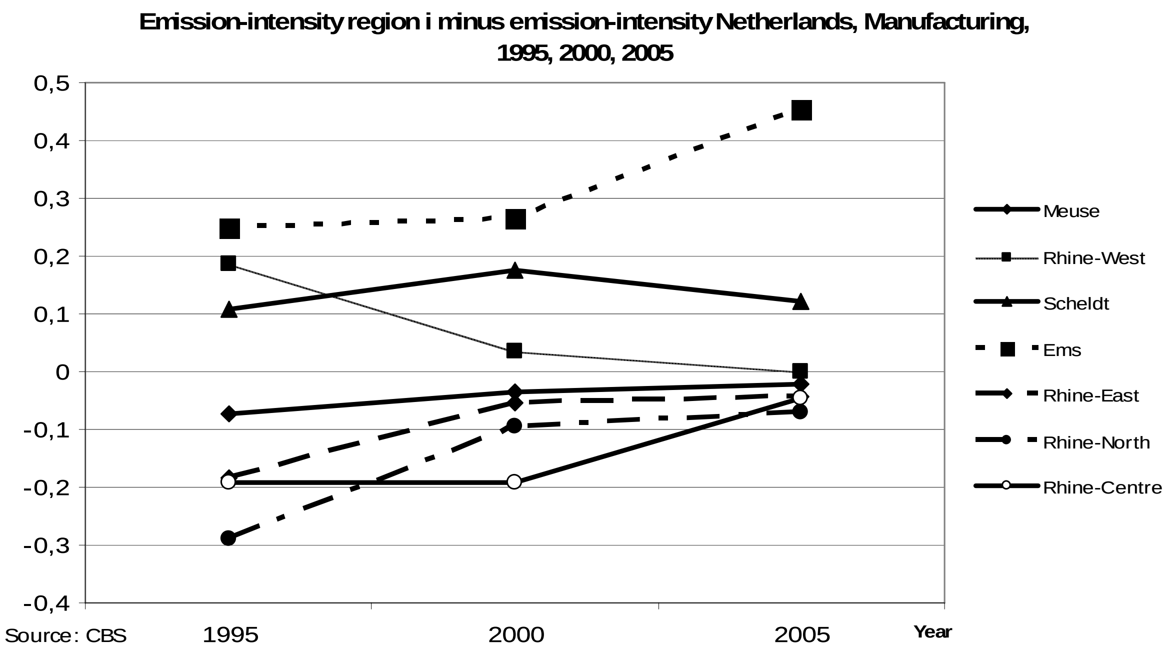

Figure 7. Pollution per euro added value for the various river basins in the years 1995, 2000 and 2005, manufacturing

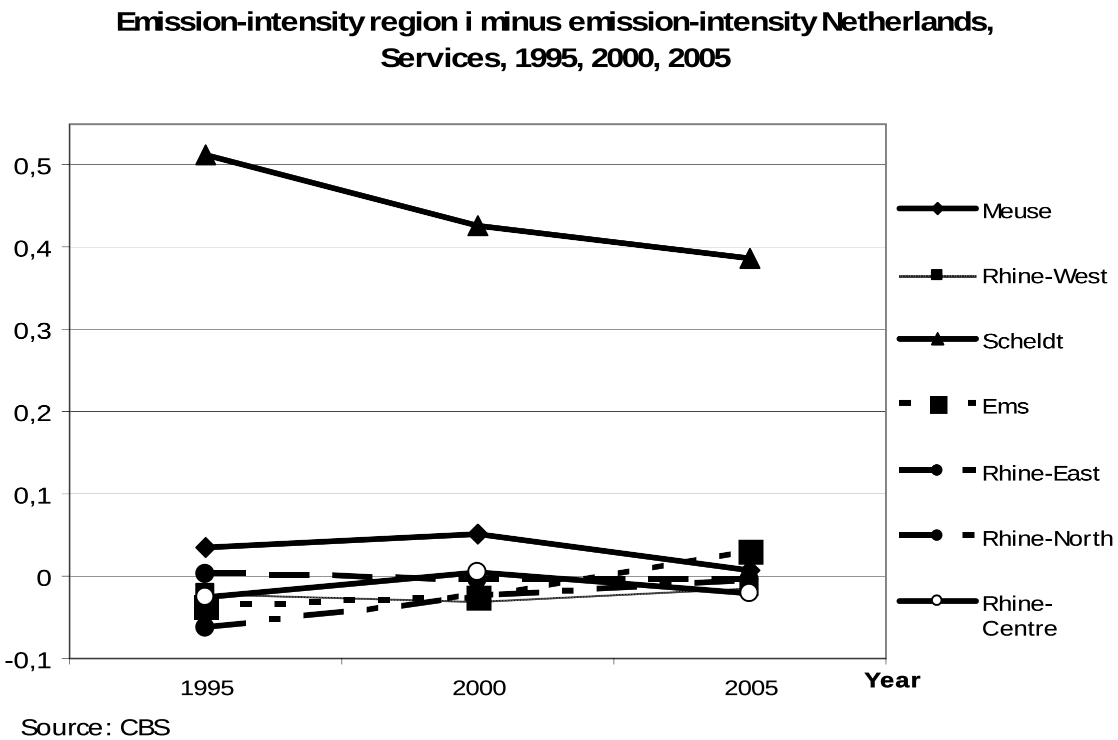

Figure 8. Pollution per euro added value for the various river basins in the years 1995, 2000 and 2005, services

Appendix 1

$M_r^I = \sum_I (P_r^I - P_{nl}^I) X^I$, industry mix effect of manufacturing

$M_r^S = \sum_S (P_r^S - P_{nl}^S) X^S$, industry mix effect of services

$P_r^I = \sum_I P_{nl}{}^I (X_r^I - X_{nl}{}^I)$, efficiency effect of manufacturing

$P_r^S = \sum_S P_{nl}{}^S (X_r^S - X_{nl}{}^S)$, efficiency effect of services

$Q_r^I = \frac{E_r^I}{E_r}$, share of emissions of manufacturing in total emissions in region *r*

$Q_r^S = \frac{E_r^S}{E_r}$, share of emissions of services in total emissions in region *r*

$Z_r^I = \frac{Y_r^I}{Y_r}$, share of value added of manufacturing in total value added in region *r*

$Z_r^S = \frac{Y_r^S}{Y_r}$, share of value added of services in total value added in region *r*

Appendix 2

Share in total emissions per river basin (data at substance level)

Substance	Maas_Agriculture	RijnWest_Agriculture	Schelde_Agriculture	Eems_Agriculture	RijnOost_Agriculture	RijnNoord_Agriculture	RijnMidden_Agriculture
Arsenic	0%	0%	0%	0%	0%	0%	0%
Cadmium	41%	20%	11%	19%	67%	71%	37%
Chromium	0%	0%	0%	0%	0%	0%	0%
Copper	13%	5%	17%	18%	31%	55%	34%
Mercury	0%	0%	0%	0%	0%	0%	0%
Lead	70%	38%	82%	71%	84%	87%	77%
Nickel	15%	8%	37%	38%	52%	71%	52%
Zinc	19%	9%	24%	42%	50%	78%	41%
Phosperus	27%	15%	43%	58%	38%	55%	72%
Nitrogen	54%	37%	69%	58%	69%	77%	72%
Substance	**Maas_Manufacturing**	**RijnWest_Manufacturing**	**Schelde_Manufacturing**	**Eems_Manufacturing**	**RijnOost_Manufacturing**	**RijnNoord_Manufacturing**	**RijnMidden_Manufacturing**
Arsenic	18%	11%	28%	43%	3%	1%	3%
Cadmium	14%	14%	56%	66%	6%	2%	10%
Chromium	80%	87%	79%	91%	84%	77%	85%
Copper	38%	17%	24%	57%	29%	20%	19%
Mercury	3%	11%	35%	10%	5%	0%	0%
Lead	8%	8%	3%	19%	3%	1%	3%
Nickel	44%	32%	42%	49%	28%	17%	29%
Zinc	20%	10%	12%	38%	10%	4%	8%
Phosperus	31%	19%	34%	10%	24%	28%	9%
Nitrogen	20%	15%	11%	13%	13%	10%	9%
Substance	**Maas_Services**	**RijnWest_Services**	**Schelde_Services**	**Eems_Services**	**RijnOost_Services**	**RijnNoord_Services**	**RijnMidden_Services**
Arsenic	82%	89%	72%	57%	97%	99%	97%
Cadmium	45%	69%	33%	15%	27%	26%	53%
Chromium	20%	13%	21%	9%	16%	23%	15%
Copper	49%	61%	59%	24%	41%	25%	47%
Mercury	97%	89%	65%	90%	95%	100%	100%
Lead	22%	26%	15%	10%	14%	12%	20%
Nickel	41%	17%	21%	13%	20%	11%	20%
Zinc	61%	57%	65%	20%	40%	18%	51%
Phosperus	42%	36%	24%	33%	38%	16%	19%
Nitrogen	26%	41%	20%	28%	17%	13%	19%

Appendix 3

Output for the Scheldt region in 2005 (other river basins for all years available on request)

Total economy 2005		Xr	Xnl	Xr-Xnl	Difference (%)	m	p	a	m+p+a	sector	year
103	Arsenic	0.005478	0.002232	0.003246	145%	0.000947	0.002435	-0.000137	0.003246	Total economy	2005
104	Cadmium	0.024422	0.010324	0.014098	137%	0.014568	0.005299	-0.005769	0.014098	Total economy	2005
105	Chromium	0.004271	0.003092	0.001179	38%	0.0031	0.00333	-0.005251	0.001179	Total economy	2005
109	Copper	0.260757	0.095475	0.165282	173%	0.093475	0.215098	-0.14331	0.165263	Total economy	2005
110	Mercury	0.065325	0.051539	0.013785	27%	0.005471	0.010649	-0.002335	0.013785	Total economy	2005
111	Lead	0.011537	0.007204	0.004332	60%	0.005801	0.00802	-0.00949	0.004332	Total economy	2005
114	Nickel	0.2309	0.135039	0.095861	71%	0.107983	0.28396	-0.00949	0.382454	Total economy	2005
120	Zinc	0.134558	0.040587	0.093971	232%	0.032916	0.117648	-0.056598	0.093967	Total economy	2005
302	Phosporus	49.21718	22.25355	26.96363	121%	17.95157	25.03855	-16.02649	26.96363	Total economy	2005
303	Nitrogen	43.14165	23.45792	19.68374	84%	15.58417	38.72549	-34.62593	19.68374	Total economy	2005
ZMEQ	Heavy metalequivalents	0.506347	0.210454	0.295894	141%	0.156278	0.362481	-0.22289	0.295869	Total economy	2005
NEQ	Nutrientsequivalents	92.35884	45.71147	46.64736	102%	33.53574	63.76404	-50.65242	46.64736	Total economy	2005

Agriculture 2005		Xr	Xnl	Xr-Xnl	Difference (%)	m	p	a	m+p+a	sector	year
103	Arsenic	4.01E-07	5.09E-07	-1.08E-07	-21%	-8.72E-08	-1.17E-08	-8.79E-09	-1.08E-07	Agriculture	2005
104	Cadmium	0.051445	0.107291	-0.055846	-52%	0.021563	-0.013638	-0.063771	-0.055846	Agriculture	2005
105	Chromium	6.4E-06	8.13E-06	-1.73E-06	-21%	-1.4E-06	-1.87E-07	-1.4E-07	-1.73E-06	Agriculture	2005
109	Copper	0.910747	0.763125	0.147622	19%	0.422352	0.615863	-0.890593	0.147622	Agriculture	2005
110	Mercury	0	0	0	-	0	0	0	0	Agriculture	2005
111	Lead	0.189245	0.182335	0.006911	4%	0.022265	0.163299	-0.178653	0.006911	Agriculture	2005
114	Nickel	1.710241	1.99441	-0.284168	-14%	0.379503	1.160311	-1.823982	-0.284168	Agriculture	2005
120	Zinc	0.634748	0.490429	0.14432	29%	0.096053	0.659495	-0.611228	0.14432	Agriculture	2005
302	Phosporus	421.1687	314.8025	106.3662	34%	85.67536	414.6826	-393.9918	106.3662	Agriculture	2005
303	Nitrogen	593.683	453.5693	140.1136	31%	21.78354	682.9827	-564.6526	140.1136	Agriculture	2005
ZMEQ	Heavy metalequivalents	1.786193	1.543188	0.243005	16%	0.562231	1.425018	-1.744245	0.243005	Agriculture	2005
NEQ	Nutrientsequivalents	1014.852	768.3718	246.4799	32%	107.4589	1097.665	-958.6444	246.4799	Agriculture	2005

Industry 2005		Xr	Xnl	Xr-Xnl	Difference (%)	m	p	a	m+p+a	sector	year
103	Arsenic	0.003677	0.00124	0.002436	196%	0.001775	0.001301	-0.00064	0.002436	Industry	2005
104	Cadmium	0.032881	0.011476	0.021405	187%	0.022683	0.011694	-0.012972	0.021405	Industry	2005
105	Chromium	0.008074	0.01085	-0.002776	-26%	0.003005	0.011575	-0.017356	-0.002776	Industry	2005
109	Copper	0.147997	0.09815	0.049847	51%	0.054513	0.409256	-0.413967	0.049802	Industry	2005
110	Mercury	0.054559	0.018007	0.036552	203%	0.010538	0.054074	-0.02806	0.036552	Industry	2005
111	Lead	0.000757	0.00188	-0.001123	-60%	0.002052	-0.000162	-0.003016	-0.001125	Industry	2005
114	Nickel	0.230526	0.190239	0.040287	21%	0.044646	0.930546	-0.934905	0.040287	Industry	2005
120	Zinc	0.03754	0.022344	0.015196	68%	0.026393	0.168679	-0.179885	0.015186	Industry	2005
302	Phosporus	39.73077	21.39916	18.33162	86%	10.59508	30.9378	-23.20127	18.33162	Industry	2005
303	Nitrogen	11.8523	14.1614	-2.30909	-16%	8.496041	64.31296	-75.11809	-2.30909	Industry	2005
ZMEQ	Heavy metalequivalents	0.285485	0.163947	0.121539	74%	0.120959	0.656417	-0.655896	0.12148	Industry	2005
NEQ	Nutrientsequivalents	51.58308	35.56055	16.02253	45%	19.09112	95.25076	-98.31936	16.02253	Industry	2005

Services 2005		Xr	Xnl	Xr-Xnl	Difference (%)	m	p	a	m+p+a	sector	year
103	Arsenic	0.007394	0.00265	0.004744	179%	0.000954	0.002908	0.000882	0.004744	Services	2005
104	Cadmium	0.015302	0.006008	0.009294	155%	0.001943	0.003958	0.003392	0.009294	Services	2005
105	Chromium	0.001704	0.000657	0.001047	159%	0.000139	0.000745	0.000163	0.001047	Services	2005
109	Copper	0.287916	0.067492	0.220424	327%	0.056612	0.134776	0.029036	0.220424	Services	2005
110	Mercury	0.079822	0.064694	0.015128	23%	0.019835	-0.003245	-0.001462	0.015128	Services	2005
111	Lead	0.003332	0.001852	0.00148	80%	0.00032	0.004417	-0.003258	0.00148	Services	2005
114	Nickel	0.092934	0.041354	0.05158	125%	0.008861	0.035071	0.007648	0.05158	Services	2005
120	Zinc	0.163444	0.028346	0.135098	477%	0.016522	0.078819	0.039758	0.135098	Services	2005
302	Phosporus	21.85045	10.66068	11.18976	105%	2.27481	7.276407	1.638546	11.18976	Services	2005
303	Nitrogen	16.0814	9.066465	7.014934	77%	1.971723	4.133045	0.910166	7.014934	Services	2005
ZMEQ	Heavy metalequivalents	0.558915	0.1717	0.387215	226%	0.096326	0.222378	0.068511	0.387215	Services	2005
NEQ	Nutrientsequivalents	37.93184	19.72715	18.2047	92%	4.246533	11.40945	2.548712	18.2047	Services	2005