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Decline in Industrial Pollution in Northern Europe: An Empirical Analysis

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【Abstract】

This paper aims to better understand the reason behind the decline in industrial pollution intensities in Northern Europe. It applies the divisia decomposition technique to a dataset of industry-specific emissions intensities for two common air pollutants, for two north European countries. This is to examine whether the decline in pollution intensities are due to the reductions in sectoral emissions intensities, such as through the effects of regulations and technology, or due to the changes of the product mix, such as the decline of pollution intensive industries. If the reductions in pollution were a result of changes to the product mix, the pollution may have transferred from one country to another, rather than a net reduction. This paper attempts to resolve this issue by applying the results of the analysis generally indicated the sectoral intensity effect to be dominant, though the CO_2 aggregate intensity trend for Norway had been inconsistent.

【Keywords】

pollution intensity, decomposition analysis, CO_2, SO_2, North Europe

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1. Introduction

Emissions of many air pollutants in Europe have steadily declined over the past decades resulting in improved air quality across the region (European Environment Agency, 2013). This raises the question of what is the driver behind this trend. Has more stringent environmental regulations led to new technologies reducing pollution per unit of output? Could there have been a shift in composition of European economies over the years with stringent regulations causing heavy industries to relocate or close down? If this is the case, then the decline of emissions intensities may be a transfer of pollution, such as from North to South and is not resulting in a net decrease in global emissions.[1]

This paper aims to examine the extent which the reduction in pollution per output and the composition shirt affect the industrial emissions intensities. These two mechanisms will be studied using dataset providing intensities of sulfur dioxide (SO_2) and carbon dioxide (CO_2) for 22 manufacturing sectors for two Northern European countries covering the period 1991-1998. Applying the divisia decomposition technique to these emissions intensity data allows us to assess the extent to which the aggregate pollution intensity of the Northern European manufacturing sector is changing as a result of changes to the product mix (i.e. the economic composition) and/or the emissions intensities of individual sectors.

The decomposition analysis have been used in a number of studies to examine changes in energy demand (Boyd *et al*., 1988; Huang, 1992; Choi and Ang, 2003) and there are some which examine the intensity of carbon dioxide (Ang and Pandiyan, 1997; Han and Chatterjee, 1997; Sun, 1999; Shyamal and Bhattacharya, 2004) However, there are only a few studies that have been extended to examine the intensities of other common air pollutants. These few cover data for only a very few economic sectors in a single country. An example is Lin and Chang (1996)'s decomposition analysis of the emissions of three air pollutants with limited data from only four economic sectors for Taiwan. A study which has extended the data used was the one by Cole et al. (2005). In this decomposition analysis of pollution intensity, data from 22 industries of 4 countries were used. However, it did not include either of the Northern European countries (Denmark and Sweden[2]) which were an early adopter of environmental taxes and are leaders in environmental activities. By decomposing emissions intensities for the Northern European countries, based upon data for 22 manufacturing sectors, it is believed that this paper will provide a notable contribution to this area of literature.

[1] For further information on the notion that low regulation countries may become havens for the world's dirtiest industries, 'pollution haven hypothesis' – see Neumayer (2001), Cole (2004) and Copeland and Taylor (2004).

[2] Sweden and Finland were out of the regime of this study due to data restriction.

The remainder of the paper is structured with Section 2 outlining the methodology and data sources that are used, Section 3 providing the results and Section 4 with the conclusion.

2. Methodology and Data Sources

The decomposition methodology used is based on that of Choi and Ang (2003). In equation (1), let E be total pollution emissions and Y be the total manufacturing production in a country. If the number of industrial sectors is n, then E_k and Y_k are the pollution emissions and production level in sector k, respectively. The sectoral pollution intensity within sector k can then be denoted by $I_k = E_k / Y_k$ and the share of industrial production can be denoted by $S_k = Y_k / \mathrm{Y}$. Then, the aggregate pollution intensity $I = E/Y$ can be represented as;

$$I = \sum_{k=1}^{n} \frac{E_k}{Y_k} \frac{Y_k}{Y} = \sum_{k=1}^{n} I_k S_k \qquad (1)$$

I, the aggregate pollution intensity is then effected by changes to the sectoral pollution intensity I_k, and/or by changes to the product mix S_k. As by Choi and Ang (2003), the two effects are separated using equation (2).[3]

$$\frac{I_t}{I_0} - 1 = \frac{1}{I_0} \sum_{k=1}^{n} \frac{L(I_{k,t}S_{k,t}, I_{k,0}S_{k,0})}{L(I_{k,t}, I_{k,0})}(I_{k,t} - I_{k,0}) + \frac{1}{I_0} \sum_{k=1}^{n} \frac{L(I_{k,t}S_{k,t}, I_{k,0}S_{k,0})}{L(S_{k,t}, S_{k,0})}(S_{k,t} - S_{k,0}) \qquad (2)$$

where L indicates a log-mean function and I_t indicates the aggregate emissions intensity in time period t and I_0 denotes the same intensity in time period 0. The two additional terms on the right-hand-side represent the sectoral pollution intensity effect and the product mix effect, respectively.

In order to explain the extent in which each of these two effects have contributed to the changes in northern European emissions intensity, equation (2) using industry level, and aggregate data for I and S is applied. The industry level pollution emissions data used in this paper are supplied by Eurostat as part of the National Accounting Matrix including Environmental Accounts (NAMEA). NAMEA compile the emissions data in a manner which is consistent with the way economic activities are quantified in national accounts. Data for sulfur dioxide (SO_2), and carbon dioxide (CO_2), for 22 manufacturing sectors for Denmark and Norway for the period 1990-2000 are applied. These emissions data are divided by industry specific value added data which provides industry

[3] The Appendix provides the mathematical derivation of equation (2).

specific measures of emissions intensity (I_k). The value added data also provide the sector share variables (S_k).[4] Value added data stem from the OECD STAN database. Table 1- 2 lists the 22 NACE classified manufacturing sectors used within this analysis.

3. Results

The decompositions of SO_2 and CO_2 for two countries are provided in Figures 1-4. Equation (2) was used for the decomposition analysis.

Figure 1. Decomposition of Aggregate SO2 Intensity: Denmark

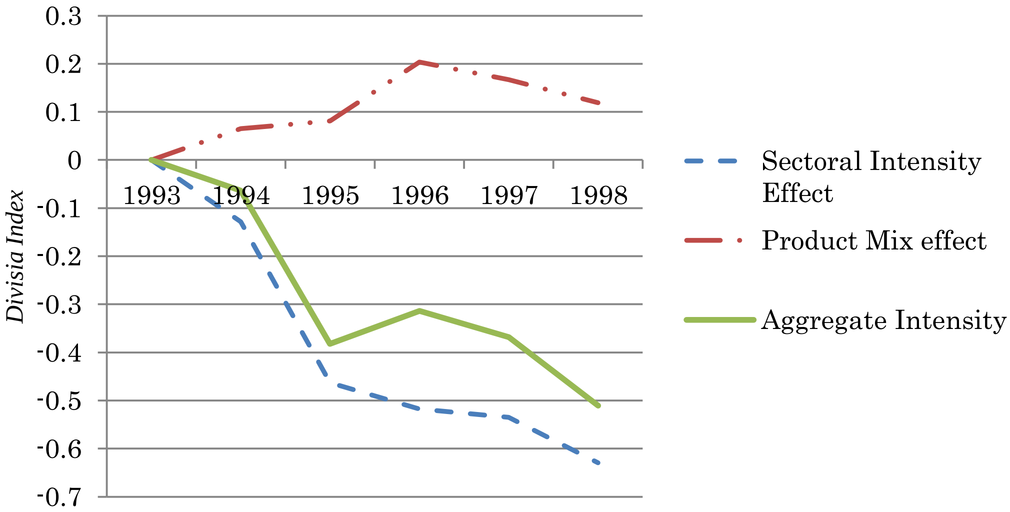
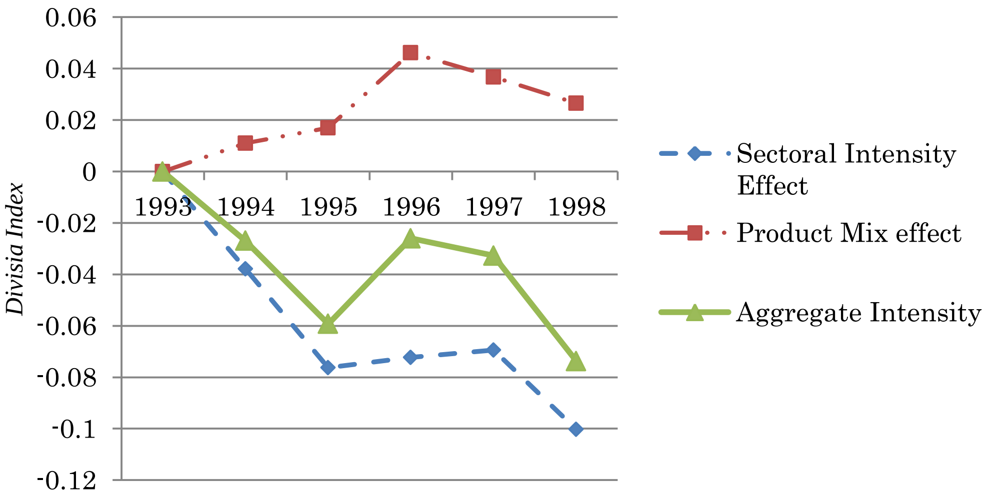


Figure 2. Decomposition of Aggregate CO2 Intensity: Denmark



[4] The analysis was also undertaken using output data instead of value added with similar results.

With regard to Denmark, Figure1 and 2 shows that the aggregate SO_2 and CO_2 pollution intensity is predominantly driven by the sectoral intensity effect. Thus, throughout the period under consideration, the aggregate SO_2 and CO_2 intensity of the Danish manufacturing sector appears to be largely driven by the effects of regulations and improved technology. Denmark had started CO_2 tax since 1992 and had set up the Green Tax Package including an additional CO_2 tax, a new SO_2 tax and new energy taxes. Firms are able to receive a reduction on their CO_2 tax rate if they enter a voluntary agreement[5] with the government to improve their energy efficiency. This may be another factor that is effecting the improvement of productivity. There have also been a series of abatement measures, especially on fuel quality standards. Over 100 initiatives have been started since 1996 since the launch of Denmark's energy action plan, "Energy 21", each contributing to a reduction of CO_2 emissions. Denmark has also made efforts to increase usage of environmentally friendly fuels, such as the decentralised cogeneration of heating and power and renewable energy, and energy savings. Other factors that have contributed to the decline of pollution intensity are tools to access information such as emission inventories[6] and economic instruments, and greater integration of environmental concerns in energy and transport policies (OECD, 1999). Furthermore, high level of democracy for the environment may have contributed to the declining of pollution intensity (OECD, 2007). The citizens of Denmark's enthusiasm towards recyclable energy have started during the oil crisis in the 1970s. After experiencing a serious oil crisis, the government was leaning towards nuclear power plants. However, the citizens took actions in support of natural energy such as large scale wind power plants and biomass energy plants. These actions may also have contributed towards to reduction in pollution intensity[7] (JETRO, 2011).

Figure 1 and 2 also shows that for both SO_2 and CO_2, the product mix effect does not appear to have had significant influence over aggregate emissions intensity in Denmark. Though there was a slight increase in the product mix effect till the mid of 1990's and has then showed some decline in the late 1990's, as a whole, it has slightly increased during this period. This suggests that the mix of industries within the Danish manufacturing sector has become slightly dirtier during this time period.

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[5] This scheme is later adopted by other developed countries such as Germany.

[6] The considerable work on *the emission inventories* are based on the "Revised 1996 IPCC Guideline for National Greenhouse Gas Inventories", the "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories" and the CORINAIR (Co-ordination of Information on Air emissions) methodology.

[7] The share of recyclable energy of total energy consumption in Denmark has grown from approximately 6%in the early 1990s to approximately 8% in the late 1990s (Danish Energy Authority, 2006).

With respect to Norway, Figure 3 shows that the aggregate SO_2 pollution intensity is predominantly driven by the sectoral intensity effect, as in the case of Denmark. Thus, throughout the period under consideration, the aggregate SO_2 intensity of the Norway manufacturing sector suggests that it has been mainly driven by the effects of regulations and technology.

Figure 3. Decomposition of Aggregate SO2 Intensity: Norway

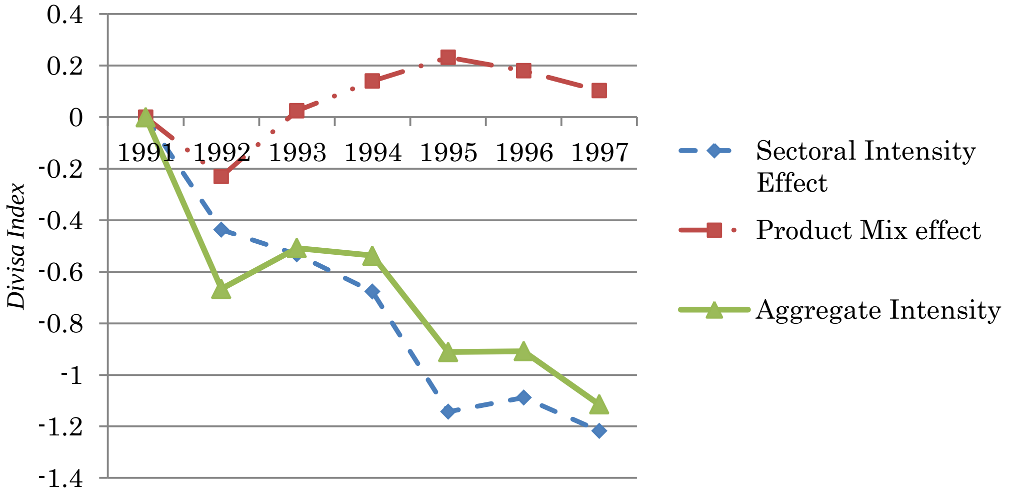
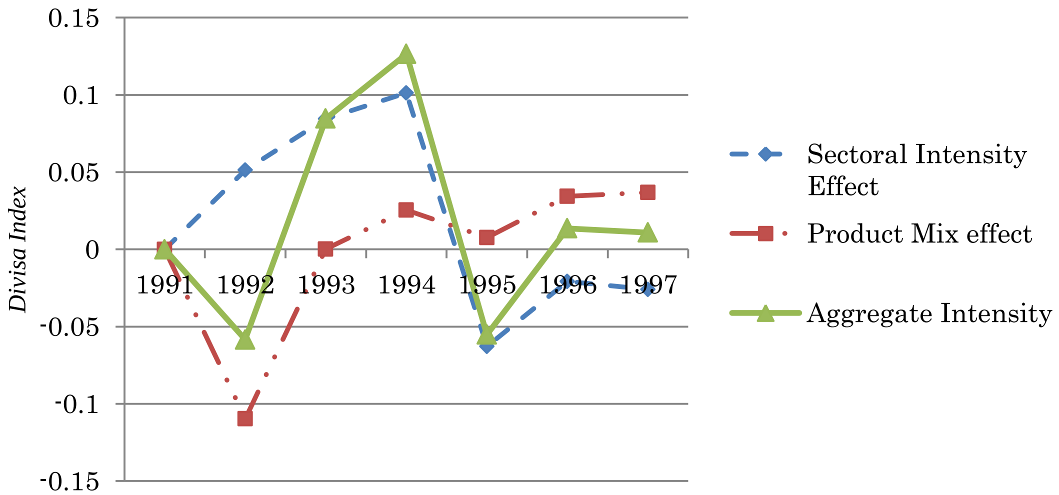


Figure 4. Decomposition of Aggregate CO2 Intensity: Norway



However, in the case of Norway, the results for CO_2, a pollutant more closely linked to energy use, shows a somewhat different result from those of SO_2 for Norway and from those of SO_2 and CO_2 for Denmark. That is, CO_2 aggregate intensity for Norway has, as a whole, slightly increased during the period investigated. The trend of the aggregate intensity for CO_2 of Norway had been influenced by both the pollution intensity factor and the product mix effect. The product mix effect had been also slightly increasing, which implies that the industrial composition will be slightly dirtier over the period examined. Compared to the SO_2 of Norway, the sectoral effect had slightly declined on the whole, despite the CO_2 tax introduced in 1991 and environmental related taxes[8] including pollution, energy, transportation taxes had increased during the period. This may be due to various tax incentives to improve international competitiveness for sectors that are related to high output of CO_2 (METI, 2004). Moreover, different from Denmark where carbon tax are imposed on the amount of carbon included in the materials or products, for Norway the environmental taxes are imposed on product unit or energy use unit, which may not be directly related to carbon usage.

[8] Environmental related taxes have increased from 27,319million NOK in 1991 to 39,555million NOK in 1997 (Statistics Norway/Division for Environmental Statistics, 2009).

Table 1. The Contribution of Each Sector to Total Manufacturing Pollution

Economic Sector	NACE	DENMARK		NORWAY	
		SO_2	CO_2	SO_2	CO_2
Food and beverages	15	24.18%	25.36%	3.15%	4.50%
Tobacco products	16	0.04%	0.12%	0.01%	0.03%
Textiles	17	0.41%	1.38%	0.19%	0.23%
Clothing manufacture	18	0.04%	0.21%	0.00%	0.02%
Leather, luggage and footwear	19	0.09%	0.11%	0.01%	0.03%
Timber	20	1.54%	6.13%	0.77%	0.58%
Pulp and paper	21	2.21%	2.81%	8.75%	3.89%
Publishing and printing	22	0.09%	0.79%	0.02%	0.31%
Coke oven &refined petrol prods.	23	21.89%	16.59%	8.48%	16.04%
Basic chemicals	24	6.31%	5.69%	27.33%	20.37%
Rubber products	25	0.28%	1.42%	0.12%	0.22%
Non-metallic minerals	26	39.97%	26.14%	6.10%	12.98%
Iron and steel	27	0.32%	1.70%	38.24%	38.73%
Fabricated metal products	28	0.56%	3.08%	0.09%	0.46%
Machinery and equipment	29	1.07%	3.14%	0.11%	0.42%
Office machinery, computers	30	0.00%	0.05%	0.00%	0.00%
Electrical machinery and apparatus	31	0.12%	0.51%	0.18%	0.32%
Radio, television and comms.	32	0.02%	0.29%	0.00%	0.01%
Medical, & precision instruments	33	0.04%	0.25%	6.13%	0.01%
Motor vehicles and trailers	34	0.10%	0.46%	0.04%	0.14%
Other transport equipment	35	0.25%	0.67%	0.22%	0.52%
Manufacture of other products	36	0.46%	3.10%	0.05%	0.19%

Average contribution over the period examined: Denmark (1993-1998), Norway (1991-1997)

Table 1 shows each sector's contribution to total manufacturing emissions for SO_2 and CO_2 of each country. Across all pollutants and both countries, the key sectors responsible for the manufacturing of emissions are NACE 23 (Coke Oven Products etc.), NACE 24 (Basic Chemicals), NACE 26 (Non-Metallic Minerals) and for Denmark, NACE 15 (food and beverage). On the other hand, in the case of Norway, NACE 27 (Iron and Steel), is the largest contributor for the manufacturing emissions. This suggests that the dirty industries are the main contributors of SO_2 and CO_2 emission.

Table 2. The Change in Output and Pollution Intensity 1991-1998

Economic Sector	NACE	DENMARK			NORWAY		
		VA	SO_2	CO_2	VA	SO_2	CO_2
Food and beverages	15	-2%	-21%	-5%	4%	-32%	24%
Tobacco products	16	20%	-87%	-21%	-41%	-87%	-13%
Textiles	17	-18%	-31%	-20%	12%	2%	66%
Clothing manufacture	18	-31%	-48%	-15%	12%	-33%	133%
Leather, luggage and footwear	19	-40%	-91%	-44%	-20%	-25%	29%
Timber	20	27%	26%	1%	27%	3%	12%
Pulp and paper	21	-7%	-87%	-4%	28%	15%	168%
Publishing and printing	22	7%	-12%	-15%	24%	-44%	7%
Coke oven &refined petrol prods.	23	24%	-57%	-7%	19%	-44%	8%
Basic chemicals	24	26%	-25%	0%	22%	32%	68%
Rubber products	25	14%	-2%	20%	34%	-9%	13%
Non-metallic minerals	26	19%	10%	14%	49%	59%	54%
Iron and steel	27	-5%	-38%	1%	39%	-32%	6%
Fabricated metal products	28	19%	1%	5%	62%	-52%	-1%
Machinery and equipment	29	14%	-46%	5%	53%	-31%	38%
Office machinery, computers	30	-15%	0%	-29%	47%	0%	-100%
Electrical machinery and apparatus	31	13%	-16%	5%	41%	513%	312%
Radio, television and comms.	32	25%	89%	37%	49%	-100%	-50%
Medical, & precision instruments	33	26%	0%	68%	60%	-38%	0%
Motor vehicles and trailers	34	9%	-35%	9%	75%	-33%	145%
Other transport equipment	35	-14%	-63%	36%	32%	-61%	-25%
Manufacture of other products	36	-2%	-20%	-9%	46%	-15%	46%

The period examined for average growth: Denmark (1993-1998), Norway (1991-1997). In order to remove the influence of the observations for the first and last years of the sample the percentage change is based on the difference between the average of the first two years and the average of the last two years.

Table 2 presents the change in output and pollutants for each sector of Denmark and Norway for both pollutants. Table 2 provides evidence of the significant reductions in SO_2 intensity experienced in almost all sectors in both countries during the 1990s. The vast majority of sectors appear to have benefited from the effects of regulations and technology, thereby explaining the sectoral intensity effects displayed in Figures 1 and 3. Moreover, the results may be interpreted as evidence of the

Environmental Kuznets Curve, which insists that developed countries' environmental welfare[9] will have improved.

Furthermore, if this paper observes the SO_2 intensities for each sector, in the case of Denmark, NACE 23 (Coke oven &refined petrol prods.), NACE 21 (Pulp and paper) and NACE 16 (Tobacco products) have seen the most improvements. The dirty industries have also shown strong improvements. On the other hand, in Norway, sectors involved in the manufacturing of machinery, such as NACE 34 (Motor vehicles and trailers), NACE 35 (Other transport equipment), NACE 2 (Radio, television and comms.) and NACE 33 (Medical, & precision instruments) showed the largest improvements. The dirty industries of Norway have also improved as in the case of Denmark.

The results for CO_2 intensities are not the same for both countries. Table 2 shows improvements in CO_2 for the majority of sectors in Denmark. It appears that it had benefited from the effects of regulations and technology, which explains the sectoral intensity effects displayed in Figures 2. However, in Norway a decline in CO_2 intensities could not been found for the majority of sectors. Furthermore, observations of the CO_2 intensities for each sector show that for Denmark, improvements were seen in sectors such as NACE 16 (Tobacco products) and NACE 22 (Publishing and printing). Dirty industries have also shown improvement. However, in Norway, the CO_2 intensities have grown in many of the sectors such as NACE 21 (Pulp and paper). Tax relief incentives on specific sectors or resources may be factors that have lead to the poor performance. However in some dirty industries such as NACE 27 (Iron and Steel) and NACE 23 (Coke oven &refined petrol products), CO_2 intensities have improved.

4. Conclusion

This paper has attempted to examine whether the decline in pollution intensities in northern Europe are a result of the reductions in sectoral emissions intensities, such as through the effects of regulations and technology, or due to the changes of the product mix, such as the decline of pollution intensive industries. It applied the divisia decomposition technique to a dataset of industry-specific emissions intensities for two common air pollutants (CO_2 and SO_2), for two northern European countries (Denmark and Norway), from 1992-1998.

The study finds that aggregate intensities of SO_2 for both Denmark and Norway have been mainly driven by changes in the sectoral intensities, affected by the stringency of regulations and development of technology. For this pollutant, the effect of the changes in product mix appears to have been minimal. With regard to CO_2, in the case of Denmark the aggregate intensity had been declining during the period and largely driven by the sectoral intensity effect whilst the product mix

[9] Concerning the previous studies on the Environmental Kuznets Curve, refer to Cole et al. (1997), Grossman, and Krueger (1995), and Selden and Song (1994).

effect did not appear to systematically influence the decrease of pollutant's aggregate intensity. For Norway, no systematic patterns are discernible for CO_2 aggregate intensity. The aggregate intensity of CO_2 is relatively related to both the sectoral intensity effects and the product mix effects. However, for Norway, neither the sectoral intensity effect nor the product mix effect fall or rise consistently during the 1990s.

To conclude, the observations indicated a dominance of sectoral intensity effects over product mix effects, suggesting that emissions intensities have been mainly driven by the effects of environmental regulations and development in technology. This implies that the regulations have been successful in reducing emissions intensity without causing a loss of competitiveness or the relocation of pollution intensive industries.

Appendix: The Derivation of Equation (2)

Starting from equation (A1) (identical to equation (1) in the main text);

$$I = \sum_{k=1}^{n} \frac{E_k}{Y_k} \frac{Y_k}{Y} = \sum_{k=1}^{n} I_k S_k \tag{A1}$$

Assuming that a change in the aggregate pollution intensity from the base period 0 to the comparison period t is measurable in terms of the difference $I_t - I_0$, differentiating both sides of equation (A1) gives;

$$\frac{dI}{dt} = \sum_{k=1}^{n} S_k \frac{dI_k}{dt} + \sum_{k=1}^{n} I_k \frac{dS_k}{dt} \tag{A2}$$

By integrating both sides of equation (A2) in the interval [$0,t$] obtains

$$I_t - I_0 = \sum_{k=1}^{n} \int_0^t S_k \frac{dI_k}{dt} dt + \sum_{k=1}^{n} \int_0^t I_k \frac{dS_k}{dt} dt \tag{A3}$$

Equation (A3) can be rearranged as follows according to the mean value theorem for integrals

$$I_t - I_0 = \sum_{k=1}^{n} S_k^* (I_{k,t} - I_{k,0}) + \sum_{k=1}^{n} I_k^* (S_{k,t} - S_{k,0}) \tag{A4}$$

with $S^*_k \equiv S_k\ (t_{k,s})$ and $I^*_k \equiv I_k(t_{k,I})$ and $t_{k,s},\ t_{k,I} \in [0,\ t]$. Analytically, it is important for equation (A4) to be used with the chain linked calculation method in order to have the time interval as small as the data permits:

$$I_t - I_{t-1} = \sum_{k=1}^{n} S_k^*(I_{k,t} - I_{k,t-1}) + \sum_{k=1}^{n} I_k^*(S_{k,t} - S_{k,t-1})$$

$$I_{t-1} - I_{t-2} = \sum_{k=1}^{n} S_k^*(I_{k,t-1} - I_{k,t-2}) + \sum_{k=1}^{n} I_k^*(S_{k,t-1} - S_{k,t-2})$$

$$I_1 - I_0 = \sum_{k=1}^{n} S_k^*(I_{k,1} - I_{k,0}) + \sum_{k=1}^{n} I_k^*(S_{k,1} - S_{k,0})$$

such that

$$I_t - I_0 = \sum_{j=1}^{t}\sum_{k=1}^{n} S_{k,j}^*(I_{k,j} - I_{k,j-1}) + \sum_{j=1}^{t}\sum_{k=1}^{n} I_{k,j}^*(S_{k,j} - S_{k,j-1})$$

Equation (A4) is a prototype discrete approximation formula for the continuous time model given by equation (A3) as conducted by Choi and Ang (2003). The asterisked variables are replaced by appropriate functional forms.

The Montgomery (1937) formula is modified and applied below;

$$I_k^M \equiv \frac{L(I_{k,t}S_{k,t}, I_{k,0}S_{k,0})}{L(S_k, S_0)},\quad S_k^M \equiv \frac{L(I_{k,t}S_{k,t}, I_{k,0}S_{k,0})}{L(I_k, I_0)} \qquad \text{(A5)}$$

where the logarithmic mean function *L* is given as

$$L(x,y) = \frac{x-y}{\ln x - \ln y} \quad \text{if } x \neq y,\quad L(x,y) = x \quad \text{if } x = y \qquad \text{(A6)}$$

Equation (A4) with *S* *and *I* *being substituted by *S* and *I*, obtains the identity below, giving the decomposition of the aggregate pollution intensity difference;

$$I_t - I_0 = \sum_{k=1}^{n} \frac{L(I_{k,t}S_{k,t}, I_{k,o}S_{k,0})}{L(I_{k,t}, I_{k,0})}(I_{k,t} - I_{k,0}) + \sum_{k=1}^{n} \frac{L(I_{k,t}S_{k,t}, I_{k,o}S_{k,0})}{L(S_{k,t}, S_{k,0})}(S_{k,t} - S_{k,0}) \qquad \text{(A7)}$$

The normalized pollution intensity variable is achieved by dividing equation (A7) by I_0, which is identical to equation (A2) that had the empirical data applied;

$$\frac{I_t}{I_0} - 1 = \frac{1}{I_0}\sum_{k=1}^{n}\frac{L(I_{k,t}S_{k,t}, I_{k,0}S_{k,0})}{L(I_{k,t}, I_{k,0})}(I_{k,t} - I_{k,0}) + \frac{1}{I_0}\sum_{k=1}^{n}\frac{L(I_{k,t}S_{k,t}, I_{k,0}S_{k,0})}{L(S_{k,t}, S_{k,0})}(S_{k,t} - S_{k,0}) \quad \text{(A8)}$$

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