DECOMPOSITION ANALYSIS OF AIR POLLUTANTS DURING THE TRANSITION AND POST-TRANSITION PERIODS IN THE CZECH REPUBLIC

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Overview

We examine the main driving forces of significant reduction in quality pollutants that occurred during a transition of the Czech economy towards market economy in the 1990's and how these driving forces affected the emission volumes during succeeding post-transition period up to 2016. By using Logarithmic Mean Divisia Index decomposition (Ang & Liu, 2001), we statistically decompose the annual changes in the emission levels of four kinds of air quality pollutants, such as SO2, NOx, CO and particulate matters into five factors, over the period 1990–2016. Unique environmental dataset allows us decomposing the emission-output intensity effect further into [i] the emission-fuel coefficient factor, [ii] the fuel-mix factor, and [iii] the fuel-intensity factor, yielding the 5-factor decomposition. Zooming in the emission intensity, we found that the most prominent driver of the emission reductions in the Czech economy was the emission content of fuels used in the economic production. Emission reduction resulted mainly from the end-of-pipe technologies being installed as a consequence of command-and-control regulation introduced in the 1990's. However, the fuel-intensity effect contributed most to reduction of SO_2, NOx and PM emission in the first 3 years after the Velvet revolution (1990-1992). Since 2008, activity, structure, fuel-intensity and emission-fuel factors have contributed to emission changes by similar magnitudes, but in different directions. In the last two years, the emission-fuel factor effect has become important again, as the large stationary emission sources were required to comply with new emission limits set by the EU Industrial Emissions Directive. In order to examine the effect of the key LMDI parameters on the decomposition outcome, we perform a sensitivity analysis to decompose SO_2 emissions on different numbers of effects (3-, 4- and 5-factors) and when different sectoral detail is assumed.

Methods

According to Ang (2004), the method of decomposition should be chosen such that it passes both factor and time reversibility and circular tests (Ang & Zhang, 2000). The most important test is the factor reversibility. It requires perfect decomposition – that means with no residual term. The conventional Laspeyres index is not recommended due to huge residuals. We apply the logarithmic mean Divisia index (LMDI) method, which satisfies the property of perfect decomposition (Ang & Liu, 2001). We follow Ang & Liu, (2007), who resolve also the problem with zero value observation by substituting the zero values by very small number (e.g. between e^{-10} and e^{-20}). Both multiplicative and additive decomposition can be applied with equal results. Following Ang (2005), the general index decomposition analysis (IDA) identity is given by

$$E = \sum_i E_i = \sum_i x_{1,i} x_{2,i} \dots x_{n,i} \,,$$

where E is emission, x_n are factors contributing to changes in E over time and subscript i denotes a sub-category fo the aggregate for which structural changes is to be studied. The emission changes from $E^0 = \sum_i x_{1,i}^0 \, x_{2,i}^0 \dots x_{n,i}^0$ in period 0 to $E^T = \sum_i x_{1,i}^T \, x_{2,i}^T \dots x_{n,i}^T$ in period T.

The general formulae for additive approach of LMDI for the effect of the kth factor is:

$$\Delta E_{x_k} = \sum_i L(E_i^T, E_i^0) \; ln\left(\frac{x_{k,i}^T}{x_{k,i}^0}\right).$$

$L(a,b)$ is the logarithmic average of the two numbers, a and b.[1]

Since we analyse the emission development over the period of up to 27 years, when the magnitude of changes in emissions has declining trend, we mainly focus on the additive LMDI that has more intuitive interpretation with regard to magnitude of changes in emissions.

The standard, tree factor IDA identity for emission level of the pollutants from industry is:

[1] Specifically, $L(a,b) = \frac{a-b}{\log a - \log b}$, if a≠b, otherwise $L(a,b) = a$.

$$E = \sum_i E_i = \sum_i Q \frac{Q_i}{Q} \frac{E_i}{E} = \sum_i Q S_i E_i,$$

where E is total level of emission from the industry, subscript i denotes sector, $Q(= \sum_i Q_i)$ is total industrial activity level, $S_i(= \sum_i Q_i/Q)$ and $I_i(= \sum_i E_i/Q_i)$ are, respectively, the activity share and emission intensity of sector i. The change in total emission from time 0 to T is then:

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}.$$

The subscripts act, str and int denote the effect associated with the overall activity level (scale), activity structure and sectoral emission intensity, respectively.

In addition to the emission level in each sector i, our data set contains information on consumption of fuel j in sector i and also on how much pollutants are emitted by each type of fuel: $E_{i,j}$. Using the richer information outlined above, we conduct not only the conventional three-factor decomposition analysis but also a five-factor analysis:

$$\Delta \boldsymbol{E_{tot}} = \boldsymbol{E^T} - \boldsymbol{E^0} = \Delta \boldsymbol{E_{act}} + \Delta \boldsymbol{E_{str}} + \Delta \boldsymbol{E_{int}} + \Delta \boldsymbol{E_{mix}} + \Delta \boldsymbol{E_{emf}},$$

where subscripts $\boldsymbol{act}$, $\boldsymbol{str}$, $\boldsymbol{int}$, $\boldsymbol{mix}$ and $\boldsymbol{emf}$ denote the activity (scale) effect , structure effect, energy intensity effect, fuel mix effect and emission coefficient effect, respectively.

Results

The first interesting finding is that the emission coefficient effect is negative for all the pollutants until 1999, i.e., when the Air Quality Act required the fulfillment of the emission targets. It suggests that the firms focused their effort on satisfying the requirement by introducing or adjusting end-of-pipe technologies, which is a "quicker and easier" solution for satisfying the limit, compared to other emission reduction methods, e.g., the change in fuel mix. In terms of NOx emission, the emission coefficient factor had a smaller effect than the other pollutants, such as SO2 and PM, due to the fact that it is more difficult to abate nitrogen emissions than the other air pollutants.

Conclusions

we can identify three sub periods in our time span with common trends and similar patterns for SO2, NOx and particulate matters; 1990-1999, 1999-2007 and 2008-2016. CO emissions developed differently than those of the other pollutants. The largest drop in emissions of all four pollutants occurred in the period from 1990 to 1999, when the emissions decreased cumulatively by at least 74 %. In this period, firms faced a newly competitive environment and new command-and-control regulations. As a result, a negative fuel emissions factor effect was the key driver of emissions reductions. However, the fuel intensity effect contributed most to reduction of SO2, NOx and PM emissions in the first 3 years after the Velvet Revolution, when the Czech and Slovak economies uncoupled. In 1999, all large stationary emission sources were required to comply with emission limits introduced in 1991. Therefore, it was mainly market mechanisms that affected development of SO2, NOx and PM emissions. Economic growth reflected by a strong positive activity effect pushed emissions upwards, though reductions driven by fuel intensity held emissions down. Since 2008, the magnitude of activity, structure, intensity and emissions factor effects moved closer. In the last two years of our time span, 2015 and 2016, the emissions factor effect became important again, as large stationary emission sources were required to comply with strict new emissions limits based on the directive on industrial emissions. The fuel mix effect reaches absolute values higher than 6 % only in relation to CO emissions (up to 15 % in 2005-2006 and 2006-2007).

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