ANALYZING INDUSTRIAL ENERGY CONSUMPTION IN THE CZECH REPUBLIC

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Abstract

The logarithmic mean Divisia index decomposition method is used to analyze the changes in the energy consumption of the Czech industrial sector during the period of 1993 to 2011. The results show the energy consumption was mainly affected by the improvements in the energy efficiency (which, however, lost most of their momentum after 1999). The impacts of the changes in the structure exhibit two opposing periods: from 1993 to 1999, the energy consumption was pushed up, up to the overall increase of nearly a third of the industrial energy consumption in 1993. However, this structural consumption increase was almost completely eradicated in the period 2004 to 2011. The change in the consumption due to the changes in the economic activity of the industry would have contributed to the net increase of the energy consumption by 6704 TOE. With the combination with other factors, the overall decrease of energy consumption in the examined period was over 42% of the industrial energy consumption in 1993.

Key words: LMD1, Energy, Energy consumption, Industry

JEL Code: Q43

Introduction

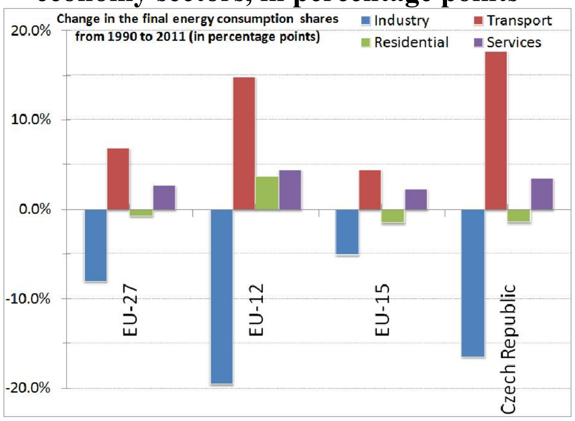
Following the overthrow of the communist regime and in the following two decades the industrial sector in the Czech Republic (and generally in the transforming countries) has gone through significant changes.

The improving technology and market adaptation resulted in decreasing energy consumption and increasing energy and market efficiency[1]. As the Fig. 1 and Fig. 2 indicate, the industry sector has gone through intense changes not only in the Czech Republic or transforming countries, but also in most of the European countries. We can also observe the economies are experiencing a shift of the energy consumption from the industry to other sectors (mainly to transport). Nevertheless the industrial sector still represents about a quarter (in EU average) or a third (in CZ, see Fig. 2) of the total energy consumption and remains in

[1] By 2011, the energy consumption decreased by 6155 TOE (from the original 14589 TOE in 1993). The energy intensity indicator (in the industry) has changed from nearly 24 TOE / mil. CZK in 1993 to 7 in 2011.

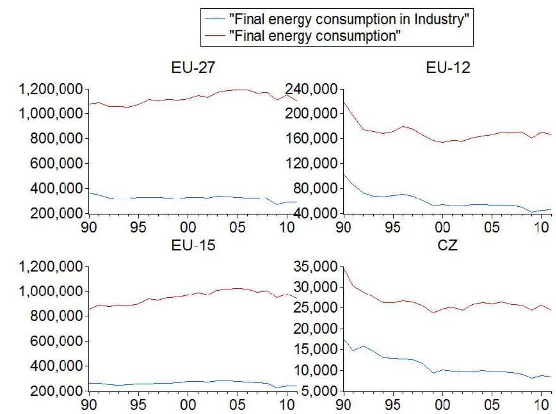
the live interest of many government policies (for instance the overwhelming energy conservation and CO_2 reduction scenarios such as the Energy Policy for Europe (rather well known as the 20-20-20 plan)).

Fig. 1: Change in the energy consumption shares from 1990 to 2011, per major economy sectors, in percentage points



Data source: Eurostat's table [nrg100a]

Fig. 2: Final energy consumption (in TOE), overall and in the industrial sector, 1990-2011



Data source: Eurostat's table [nrg100a]

This article aims to inspect the changes in the energy consumption of the Czech industrial sector, using the logarithmic mean Divisia index method, proposed by Ang & Liu (2001). This method will allow us to quantify how much the energy consumption has changed due to the changes in the structure of the industry (the structural effect), the activity of the economy (the activity effect) and the improvements in the energy efficiency (the energy intensity effect). All the figures and the tables presented in this article are my own.

1 Data and methodology

The main indicators necessary for the analysis are the final energy consumption and the gross value added (GVA). The data on the energy consumption are available under Eurostat's table [nrg100a] , and are measured in thousand tons of oil equivalent (TOE). The data on the gross value added are from the Czech Statistical Office table TB0001B1Gc and are in millions of CZK (in constant prices of 2005). The data were matched according to NACE2 classification.

The history index decomposition analysis (IDA) to decompose an aggregate values dates back to 1970s (see Ang a Zhang (2000) for comprehensive review). Nowadays, the IDA methods gained a solid position as an analytical tool for the policy making (Ang, 2004), and are also employed by the renowned international bodies such as the International Energy Agency (IEA, 2012).

The so called logarithmic mean Divisa 1 index decomposition method is employed here to analyze the change in an aggregate variable as the contribution of the predefined factors.[2] The object of interest, the change in an aggregate, denoted e.g. V, can be expressed either in the multiplicative or the additive form, i.e. either as $D = \frac{V^T}{V^0}$ or $\Delta V = V^T - V^0$.

There are couple advantages of the LMD1 method over other decomposition methods. Probably the most important one is that this method passes the factor reversal test (among others suggested by Fisher (1967)). This test can be expressed as $D^{0T} = \frac{E^T}{E^0} = \prod_{k=1}^{n} D_k$ for the multiplicative form or $V^T - V^0 = \sum_{k=1}^{n} \Delta V_k$ for the additive form. the product (for the multiplicative form) or the sum (for the additive form) of the individual factor contributions must equal the observed change in the aggregate – hence the decomposition must be perfect, leaving no unexplained residual.[3]

Furthermore, this method also passes the so-called time reversal test – as the name suggests, to pass this test, the index number for a change from the period $t = 0$ to $t = T$ must be a reciprocal value (for the multiplicative form) or the negative (for the additive form) of the change from period $t = T$ to period $t = 0$, i.e. $D^{0T} = \frac{1}{D^{T0}}$ or $\Delta V^{0T} = -\Delta V^{T0}$.

Another useful property is that this method is zero-value robust with rather easy modification of the dataset, i.e. replacing the zero values by very small number ($\delta = 10^{-20}$), as described in Ang & Choi (1997). Further methodological discussion of this issue can be found in Ang & Liu (2007). Finally, the LMD1 is consistent in aggregation (i.e. the results (the contribution of the individual effects) from the analyses using detailed classification remain unchanged if the underlying dataset gets aggregated). Note this property is not met by the alternative LMD2 decomposition. For the interested reader, an extensive comparison of the properties of the various decomposition methods can be found in Ang & Zhang (2000).

The starting point of describing the object of interest, the change in energy consumption, ΔE is to express the energy consumption E as an identity $E = Q.EI$. This relationship can be further rewritten as:

[2] The LMD2 method differs from LMD1 only in the normalization of the weights so that they sum exactly to 1.

[3] The refined Laspeyer's index methods (see e.g. Albrecht, Francois & Schoors (1997), Sun (1998) or Diezenbacher & Los (1998)) also provide means of perfect decomposition. However, these generally do not allow aggregation of the results, easy transformation from additive to multiplicative form nor easy extensibility to high number of effects.

$$E = Q\sum_i \frac{E_i Q_i}{Q_i Q} = Q\sum_i EI_i S_i \tag{1}$$

with energy intensity $EI_i = \frac{E_i}{Q_i}$ and economic share $S_i = \frac{Q_i}{Q}$. After differentiating the equation and some manipulation, we will get:

$$E^T - E^0 = \int_0^T \left(\sum_i w_i(t) \frac{\partial}{\partial t} \ln\left(Q(t)\right) + \sum_i w_i(t) \frac{\partial}{\partial t} \ln\left(S_i(t)\right) + \sum_i w_i(t) \frac{\partial}{\partial t} \ln\left(EI_i(t)\right) \right) dt \tag{2}$$

with $w_i = Q(t) EI_i(t) S_i(t)$. Since in practice, we can only observe the discrete data, discretization of the equation (2) will result in:

$$E^T - E^0 \cong \sum_i w_i(t^*) \ln\left(\frac{Q^T}{Q^0}\right) + \sum_i w_i(t^*) \ln\left(\frac{S_i^T}{S_i^0}\right) + \sum_i w_i(t^*) \ln\left(\frac{EI_i^T}{EI_i^0}\right) \tag{3}$$

with several options for $t^* \in (0;T)$. However, some weighting schemes, such as the LMD1 scheme (where weights $\tilde{w}_i = L\left(E_i^T; E_i^0\right)$ are given as logarithmic mean of energy consumption in time $t = T$ and energy consumption in time $t = 0$), exhibit a desirable behavior, namely passing the factor reversal test (in other words, perfect decomposition without any residual). Thus we can write:

$$E^T - E^0 = \underbrace{\sum_i \tilde{w}_i \ln\left(\frac{Q^T}{Q^0}\right)}_{\text{Activity effect}} + \underbrace{\sum_i \tilde{w}_i \ln\left(\frac{S_i^T}{S_i^0}\right)}_{\text{Structural effect}} + \underbrace{\sum_i \tilde{w}_i \ln\left(\frac{EI_i^T}{EI_i^0}\right)}_{\text{Intensity effect}} \tag{4}$$

All of the effects describe, how the energy consumption (in TOE) would change due to a change in the pre-defined factor, if the other characteristics remained the same. The activity effect therefore describes the impact of overall economic activity in the industrial sector, while keeping the energy intensities and structure of the industry unchanged. Analogously, the structural effect describes the change in energy consumption caused by the observed changes in the economic shares of the industrial sub-sectors (i.e. the changes in the structure of the industry) had the overall economic activity of the industrial sector and energy intensities remained unchanged. Finally the energy intensity effect how would the energy consumption change due to the actual energy intensities improvements *ceteris paribus*.

Note that the multiplicative decomposition can be derived in a similar fashion. Also, since with LMD1 it also holds that $\frac{\Delta V_{total}}{\ln\left(D_{total}\right)} = \frac{\Delta V_{effect_1}}{\ln\left(D_{effect_1}\right)} = \frac{\Delta V_{effect_2}}{\ln\left(D_{effect_2}\right)} = \ldots = \frac{\Delta V_{effect_k}}{\ln\left(D_{effect_k}\right)}$, we can easily compute the results for the multiplicative decomposition from the results of the additive decomposition and vice versa.

2 Results

The results of the decomposition analysis are summarized in the following figures (the results for the individual sub-sectors are available from the author). Fig. 3 shows the chained year-by-year effects and Fig. 4 the cumulated sums (therefore the values shows how the energy consumption changed compared to the base year of 1993). We can see that by 2011, the overall decrease of the observed consumption reached 6155 TOE (i.e. approx 41% of the overall industrial energy consumption in 1993) and was primarily the result of energy intensity improvements.

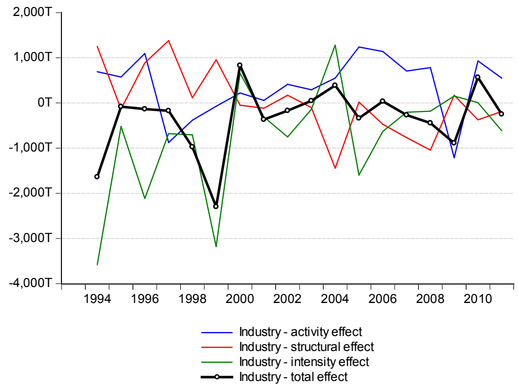
Contrary to what one would have expected in the transformation period, the changes in the structure contributed to increasing the energy consumption. Specifically, up to the year 1999, these changes accounted for rather significant amount of 4455 TOE. Since 2000 (though most remarkably in 2004-2011), however, the story has reversed and we can observe the net effect of only +254 TOE of energy consumption for the whole period due to the changes in the structure.

Overall, the energy intensity effect, capturing the actual energy efficiency improvements per se, amount to 10 785 TOE up to 1999. From 1999 to 2011, these savings only accounted for 2328 TOE. On one hand, the reductions in 1990s were certainly easier to do, not only with the much higher base consumption values, but especially given the abundance of inefficient dated technologies and demand for upgrades. However, even though the 2000s were riddled with many energy savings and energy efficiency boosting policies (especially after the EU accession), it seems they had rather little effect.[4]

Nevertheless, had the energy intensities not improved, the increasing economic activity in the Czech industry in the examined period would have increased the energy consumption by 6704 TOE. Rather interesting are also the significant magnitudes of the drops, mainly in this effect, in the periods of crises, namely 1997 (-870 TOE) and 2009 (-1211 TOE) (and with about a one year lag also in overall change, measured by the total effect). The periods of crisis indeed also worsen the energy efficiency (driving energy intensities higher).

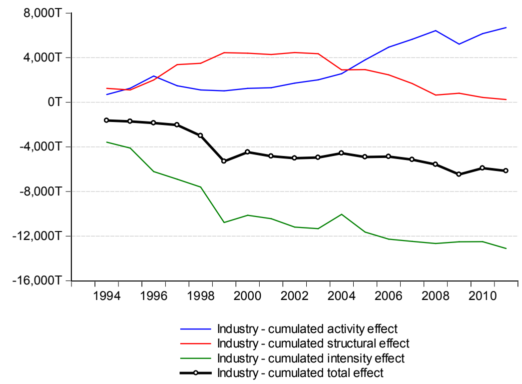
[4] Especially if we compare the industrial energy intensities (in TOE / 1000 EUR in value added) across the European averages, in 2009 it was still about twice as high in EU-12 (0.19) or CZ (0.22) than in EU-15 (0.11). This shows there is still vast room for improvements, though it is question whether the seemingly not quite well working, yet publicly financed, policies are the best way to achieve higher energy efficiency.

Fig. 3: Individual year-by-year effects, additive decomposition, in toe, 1993-2011



Data source: own computations

Fig. 4: Cumulated effects, additive decomposition, in toe, 1993-2011



Data source: own computations

Conclusion

The results show the rather significant 42% energy consumption reduction in the examined period. This was predominantly affected by the improvements in the energy efficiency, though the majority of these changes happened up to year 1999 (with 10 785 of the overall 13 113 TOE savings achieved in this period). With roughly twice as high (in 2009) industrial energy intensity indicator (compared to the EU-15 countries), it is somewhat questionable whether the significant energy efficiency policies (most of them taking place after the year 2000) had reasonable impact, and represents a viable objective for further research focused on the energy intensity development (especially, given the fact that without these improvements (bear in mind, this would mean no improvements only in the industry), the Czech Republic's (!) energy imports would need to increase by nearly 62% compared to the current state.

The structural effect shows two distinct periods – up to 1999, when, contrary to what we might expect in what presumably still was a transformation period, the energy consumption was pushed up by the structural changes. On the other hand, almost all of this increase was eliminated by the negative structural effects, especially during the period of 2004-2011. Nevertheless, the high values show two significant structural transformation periods that have taken place in the Czech industry, and more so, this clearly shows the transformation period had not stopped in the 1990s (at least in the industrial sector).

As for the remaining activity effect – had none of these two effects taken place, the increasing economic activity of the Czech industrial sector would mean the necessity of gaining additional 6704 TOE (in other words, roughly 74% of the energy exports of the Czech

Republic in 2011) of energy to cover its needs, instead of what we actually observed, i.e. reduction of the consumption by 6155 TOE.

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