Intra-sectoral Efficiency Gains vs Delocalization: A Decomposition Analysis of Global Energy Intensity between 2001 and 2007.

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Overview

Between 2000 and 2010, global greenhouse gas (GHG) emissions have risen more rapidly than in the previous three decades. Drivers of emissions change can be decomposed into effects of population, GDP per capita, energy intensity of the economy and carbon intensity of energy. During the last four decades, population and GDP per capita have been constantly rising at a global scale, while carbon intensity has witnessed an increase only since the beginning of the new millennium. Energy intensity improvements have been a constant driver of decreasing emissions since the 1970s, though to different degrees across world regions and/or sectors.

Past research on energy intensity drivers – mostly focused on a limited set of single countries or world regions – shows that region-specific energy intensity strongly depends on the region's stage of industrialization (i.e. which economic sectors are being developed), the availability of energy sources and the energy mix (the composition of the extraction and energy sectors). Starting from these findings, the aim of this analysis is to determine sector-specific patterns in energy intensity change. Are technological spillovers at work also within a single sector across national borders or are there common trends in energy efficiency only among different sectors in a single region, which would suggest that new technologies diffuse in a geographically and politically limited area? Further, as we can observe the contribution of regional structural changes to energy intensity development, we intend to describe changes in the location of sectors among countries i.e. if production shares within a global sector are dislocated to regions with different energy intensity.

Method

In order to better understand mechanisms that have driven sectoral energy intensity changes in the past we decompose total energy intensity change of sectors into a technological and a localization factor. So far, energy intensity decomposition has been applied to differentiate along the regional dimension, thus making it possible to distinguish whether energy intensity improvements have been caused either by efficiency improvements within a region (e.g. better conversion technologies) or by a change in the region's economic structure (e.g. the switch from heavy manufacturing to service sectors).

In this paper, global energy intensity change between 2001 and 2007 will be decomposed by applying Index Decomposition Analysis (IDA) and the logarithmic mean Divisia method to production sectors. The standard Kaya decomposition will therefore be expanded in order to further decompose changes in energy intensity into a technological and a localization factor.

We decompose the energy intensity I of a sector s of the global economy at a time t into the product of two components, summed over all world regions r.

$$\boldsymbol{I}_{s,t} = \sum_r \frac{E_{s,r,t}}{Y_{s,t}} = \sum_r \frac{E_{s,r,t}}{Y_{s,r,t}} \cdot \frac{Y_{s,r,t}}{Y_{s,t}} = \sum_r \boldsymbol{T}_{s,r,t} \cdot \boldsymbol{L}_{s,r,t} \tag{1}$$

The first component is the share of the global sectoral output produced in region r (the localization factor $\boldsymbol{Y}_{s,r,t}/\boldsymbol{Y}_{s,t}$). The second component is the energy efficiency of sector s in region r (the technological factor $\boldsymbol{E}_{s,r,t}/\boldsymbol{Y}_{s,r,t}$). Following the same idea, we decompose also total energy intensity change $\boldsymbol{D}_{tot,s,t_1,t_2}$ for a sector s between time t_1 and t_2, thus obtaining, after rearranging the equation, the technological change factor $\boldsymbol{D}_{T,s,t_1,t_2}$ and the localization change factor $\boldsymbol{D}_{L,s,t_1,t_2}$.

$$\boldsymbol{D}_{tot,s,t_1,t_2} = \frac{I_{s,t_2}}{I_{s,t_1}} = \boldsymbol{D}_{T,s,t_1,t_2} \cdot \boldsymbol{D}_{L,s,t_1,t_2} \tag{2}$$

The technological change factor captures changes in energy efficiency. A value smaller than 1 indicates that, in t_2, the use of energy in sector s became more efficient than it was at time t_1.

The localization change factor indicates the part of sectoral energy intensity changes that can be accounted to the dislocation of a certain production share to world regions with different energy intensity. If the localization change factor is smaller than 1, greater shares of the sectoral output were produced in world regions with lower energy intensity in t_2 with respect to t_1.

In order to calculate the technological and the localization change factors, production output data and energy input data from the database of the Global Trade Analysis Project (GTAP) for the years 2001, 2004 and 2007 have been considered. As different GTAP versions use differently resolved aggregation schemes for different years, the regions have been reduced to a harmonized set of 77 in order to make the different versions comparable.

Results

Between 2001 and 2007, global energy intensity decreased by 21% ($\boldsymbol{D}_{tot,2001,2007} = 0.79$). This decrease is reflected also by the drop of energy intensity for the majority of sectors except for rice and wool production, beverages and tobacco production, electronic equipment and the dwellings sector.

At an intersectoral scale, the overall energy intensity decrease is due to energy efficiency improvements, with the location change component halting the trend. The cross-sector average for the technological change factor $\overline{\boldsymbol{D}_{T,s,2001,2007}}$ is 0.63, which is equivalent to an efficiency improvement by 37%. The localization change factor instead increased by 13% ($\overline{D_{L,s,2001,2007}} = 1.13$), thus weakening the resulting energy intensity reduction.

At the sectoral level the main contribution to energy intensity improvements is generally due to the technological change factor. Only for wheat production and rice processing the technological change factor is significantly higher than the localization change factor.

Conclusions

We observe a remarkable increase in energy efficiency for almost all sectors and a less pronounced but also spread shift of significant shares of production sectors to more energy intensive world regions.

An interpretation for common sectoral energy efficiency trends among different world regions is that, in an increasingly globalized economy, intra-sectoral technology diffusion is at work.

The observed dislocation to regions with higher energy intensity offers two possible interpretations. First, regions with an energy intensive economic structure gain higher production shares in energy intensive sectors. In this case, a regional agglomeration of energy intensive production would be taking place. Second, energy intensive sectors are moving to regions that produce less energy efficiently, either in order to avoid strict environmental standards or due to other favorable factors. Since the sector-based decomposition does not allow to identify to which extent each phenomenon (the agglomeration trend or the "pollution haven" factor) fostered delocalization, our results can serve as a solid starting point for future research.

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