A Structural Decomposition Analysis of Global and National Energy Intensity Trends

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Research question

The central question of our work is to what extent national and global improvements in energy efficiency can be attributed to structural change, to international trade and to technological improvements. The relative share of these components is important for the question of how economic growth can be decoupled from energy consumption.

In our work, structural change is to be understood as a shift of market shares between different economic sectors. If relatively efficient sectors expand to larger market shares at the expense of energy-intensive industries, the energy intensity of an economy decreases. International trade can influence the global energy efficiency if production of, for example, energy-intensive goods is outsourced to trade partners. Lastly, technological progress is measured as efficiency gains that are achieved within sectors. For our analysis, we use the World Input Output Database (WIOD), which provides trade data for 40 countries, subdivided into 35 industrial sectors, between 1995 and 2009, as well as environmental accounts, that include sector-specific information on energy consumption.

Methods

Our analysis consists of two steps. First, we adjust energy use as provided in the WIOD with respect to intersectoral trade using the environmentally extended input-output analysis (EEIOA). This enables us to determine the magnitude of energy use that a sector ultimately causes through its final demand by also considering energy consumption embodied in trade. For example, consider the construction sector that not only uses energy in its production processes, such as fuel and electricity for vehicles and machinery, but also relies on inputs from other sectors. The production of these inputs, however, requires energy that is not considered in the WIOD environmental accounts but that we take account of through the EEIOA. Such an adjustment transforms the WIOD data into a consumption-based accounting of sectoral energy use, whereas WIOD itself take the view of production-based energy consumption. While the latter approach is important in assessing the sources of energy use in production processes, the former perspective is necessary to measure a country's or industry’s actual share in the responsibility for the total energy consumption.

In a second step we decompose global and national energy intensity developments into a structural, a trade-related and a technological component, according to the LMDI-II method presented in Ang and Choi (1997) and Voigt et al. (2014). The structural component measures the effects of shifts in the market share of different sectors within a country to national energy intensities. The trade-related component determines the impact of international trade, i.e. the shift of production from developed countries to the developing countries, to global energy intensities. Finally, the technological component includes all improvements in the energy intensity that are generated within a sector, such as more efficient production methods.

Results and conclusions

We find large effects of energy use adjustments according to the EEIOA. In particular, the energy use associated with final demand in the construction and service sector exceeds by far the energy consumption in their production processes. This indicates a strong reliance on energy-intensive inputs from other sectors. Conversely, the manufacturing industry as well as the electricity, water and gas sector that, to a large degree, deliver intermediate inputs to other sectors, show lower energy use when adjusted for energy embodied in trade. Overall, we find that the global energy intensity from 1995 to 2009 was declining predominantly due to more efficient technology used within sectors than due to a structural change in the economy. Nevertheless, structural change within countries played a sizable role in the reduction of energy consumption. Furthermore, our analysis shows that international trade by itself led to a higher energy intensity level. This is likely a result of outsourcing production processes to countries with lower levels of energy intensities.

Decomposing adjusted and unadjusted energy use reveals that the role of structural change is systematically overestimated in previous studies. This is because after adjusting sectoral energy use according to intersectoral trade, changes in structural composition, both within and between countries, appear to have a smaller impact on global energy intensities. Nevertheless, also the unadjusted decomposition identifies the efficiency gains within sectors change as the main driver of reducing energy use relative to output. However, this qualitative similarity on a global level does not hold for each country. For instance, we show, that in some countries, like USA, Japan and Turkey, the technological effect is strongly underestimated. While structural change seems to be the driving factor of energy intensity reductions using unadjusted data, intra industry efficiency improvement plays the dominant role using adjusted energy consumption. Hence, our adjusted measure of energy use indicates that these countries are not exceptions from the general global pattern in which the main force of increasing energy efficiency is technological progress.

Our analysis implies that green growth policy has to take into account the adjustment of sectoral data in order to obtain a correct picture of what can be considered a "green" or "dirty" sector. More importantly for policy-makers is the fact, that technological advances seem to play the largest role in the energy intensity trends. Given that environmental policy mostly affects within-sector efficiency and structural change itself is rather difficult to influence, such policy is likely able to play a strong role in achieving efficiency goals.

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