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International Trade and Energy Intensity During European Industrialization, 1870–1935

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ABSTRACT

Previous research suggests that there is an inverted U-shape curve for energy intensity in the long-run for Western Europe with a peak in the early 20th century. This paper tests the hypothesis that the increase of German and British energy intensity was an effect from the concentration of heavy industrial *production* to these countries, although the *consumption* of a significant share of these goods took place elsewhere. We use an entirely new database that we have constructed (TEG: Trade, Energy, Growth) to test whether these countries exported more energy-demanding goods than they imported, thus providing other countries with means to industrialize and to consume cheap-energy demanding goods.

We find that the U-shape curve is greatly diminished but does not disappear. The pronounced inverted U-curve in German energy intensity without trade adjustments is reduced when we account for energy embodied in the traded commodities. For Britain the shape of the curve is also flattened during the second half of the 19th century, before falling from WWI onwards. These consumption-based accounts are strongly influenced by the trade in metal goods and fuels, facilitating industrialization elsewhere.

1. Introduction

Today, China is often perceived as the workshop of the world, producing large amounts of cheap consumer goods for others. A century ago Britain and Germany (along with the United States) played a similar role both for Europe and globally. In these 'workshops of the world' energy and other resources are used to produce goods to satisfy foreign demand. This means that national levels of energy consumption may look profoundly different when international trade is taken into account and energy use is attributed to the final consumer, rather than producer of a good: the so-called consumption based approach (Davis and Caldeira, 2010), or ecological footprint approach (Wackernagel and Rees, 1996). Calculating consumption-based environmental impact has become popular but only covers recent decades. Often the consumption-based approach focuses on the patterns and levels of consumption of individuals.

However, from a national perspective 'consumption' is defined as production minus exports plus imports. Often contemporary consumption-based studies draw the conclusion that the developed world is outsourcing energy intensive and environmentally damaging production abroad (Peters et al., 2011). However this can be questioned. Some of what appears to be the displacement of emissions from the developed to the less developed countries is an illusion, caused by trade between nations with energy systems of differing levels of carbon intensity, and/or levels of energy efficiency. An improvement in energy efficiency in a developed nation, for example, could appear to be a relative 'outsourcing' of environmental damage to a developing nation without any actual alteration in trade. Yet this is hardly outsourcing as commonly understood (Jakob and Marschinski, 2012; Kander et al., 2015). Furthermore, if earlier growth in consumption levels across much of the world depended on high levels of consumption of energy by the historical 'workshops', this argument is reversed for the past: Britain and Germany were providing the rest of the world economy with cheap coal and steel, while suffering pollution and resource depletion.

The main objective of our paper is to understand the nature of nations' energy needs over different phases of their historical development. The means for achieving this objective is to explore if, and how, the energy intensity curves for-7 European countries change from 1870 onwards when measuring energy use from the trade-adjusted consumption side, instead of attributing energy use solely to the point of combustion.

A standard way to measure the relationship between economic development and energy use is through energy intensity (EI), the amount of energy required to produce a unit of GDP. It has been argued that material resource use and pollution both increase, at least in relative terms, i.e. in relation to GDP, during industrialization and decline as the nations mature into service-oriented countries (Panayotou, 1993). This argument is formalised as the Environmental Kuznets Curve (EKC). It

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implies that in the course of development things need to get worse before they can get better. Another implication drawn from this argument is that economic growth tends to solve its own environmental problems, at least in relative terms. The economy becomes less demanding of natural resources and less polluting in relation to the value of output it creates. In reality the interrelations of the economy and the environment are more complex. As demonstrated in a World Bank Report of 1992, while certain environmental damages tend to gradually diminish over time as incomes rise, such as smoke pollution, others show continuous increases, such as the volume of garbage. Other impacts are not easily measured, such as biodiversity or ecosystem quality. An additional problem is that some authors have mistaken relative decoupling of environmental impact and GDP with absolute decoupling (Radetzki, 1990) and erroneously drawn the conclusion that if the pollution per unit of GDP goes down, then the environment is less pressured overall. This is of course not true: if the scale of the economy grows faster than the rate of delinkage of energy consumption and growth, then absolute environmental pressure will increase. The lion's share of EKC studies deal with absolute environmental pressure or emissions in relation to income levels, but there are some examples where pollution intensity is addressed instead (Sun, 1999; Tan et al., 2015). One can therefore distinguish between a weak and strong hypothesis for the EKC, where the weak hypothesis only suggests that pollution intensity resembles an inverted U (Blackwood, 2002:124–126).

Reddy and Goldemberg (1990) proposed the idea of a similar inverted-U curve for energy intensity, although its is important to note that this is not identical with the EKC even in the case of the weak hypothesis (pollution intensity), as different energy carriers pollute to a very different degree (compare windpower with coal, for example).[1]

The existence of such a curve for energy intensity with the same shape for all countries, only differing in the timing and level of the peak, would suggest a universal pattern of industrialization, even though latecomers can learn from pioneers and by the use of more efficient technologies and peak at a lower level. Such a model suggests that all countries go through a period of increasing energy intensity as they industrialize. Previous research has not entirely confirmed this picture. Our earlier research has demonstrated that the inverted-U curve does not hold for a number of European countries, where energy intensity actually falls over the long period 1800 until today, if we include both traditional and modern energy carriers in the picture (Gales et al., 2007; Kander, 2002). In these studies imports of coal and other fossil fuels are included in national energy consumption, and direct exports of such fuels (such as coal from England and Germany) are deducted from their energy consumption. However, the embodied energy in goods consumed elsewhere is not adjusted for in these calculations. It was found that the inverted U-curve of energy intensity holds for the UK and Germany, and their share of total European GDP and energy consumption was so large that the whole continent's energy intensity also followed an inverted U-shape (Kander et al., 2013).

In this article we critically revisit the inverted U-curve for energy consumption. Could it even be the case that there was no such curve for Europe when energy embodied in international trade is taken into account, that is, when we employ a consumption-based measure? This would indicate that the inverted U-curve is not associated with rising incomes and a stage of development per se, but the concentration of energy intensive activity in particular countries or regions. Perhaps Germany and Britain were exporting so much energy embodied in goods in the 19th century to countries outside the continent that European energy intensity, from a consumption perspective, may have been stable or even fallen during industrialization? This is not entirely improbable. The period 1800–1913 saw a rapid expansion in world trade: from 3% to 33% of world production. Europe made up 62% of world trade in 1913 and mainly exported manufactured goods and imported primary goods (Kenwood and Lougheed, 1992). Manufacturing exports were dominated by the UK (which sold 70% of its exports to non-European countries in 1913) and Germany (selling 34% of their exports outside Europe) (Svennilson, 1954). We will examine whether the inverted U-curve for energy intensity ceases to exist for Britain and Germany (and thus for Europe) when their international trade is accounted for. Equally, will we find countries whose energy consumption appears considerably higher once imported goods are brought into the picture? Our analysis covers seven countries: the UK, Germany, the Czech lands, Denmark, Sweden, Italy and Portugal, over the time period 1870–1935.

Section 2 of the article discusses previous research on long-term energy intensity, where this has not been adjusted for energy embodied in traded goods. Section 3 describes the new dataset that we have constructed, and how it relates to similar approaches by other researchers. We also provide a more extensive document of supplementary information (SI) alongside this paper, describing in far more detail the methods employed and results obtained, in particular on how the energy embodied in particular traded commodities has been calculated. Section 4 presents the overall results for our set of countries, firstly on energy embodied in traded commodities, both imports and exports, and secondly on how energy intensity changes after trade-adjustment. The discussion in Section 5 evaluates the implications of our results for the wider understanding of long run energy history.

2. Previous Research on Long Term Energy Intensity

Previous work has already demonstrated that Reddy and Goldemberg (1990) overestimated the upwards slope of energy intensity during industrialization because they did not include traditional energy carriers such as wood and draft animal power. Initial levels of energy consumption were much higher than they appreciated. European countries that did not have access to large domestic deposits of coal, such as Sweden, the Netherlands, Italy and Spain, all showed either a slowly or even drastically declining energy intensity curve over time (Gales et al., 2007). Analyses of Canada and the United States have also shown drastically declining energy intensity during the 19th century (Csereklyei et al., 2016; Henriques and Borowiecki, 2017; Unger and Thistle, 2013). These results disproved the existence of a uniform inverted U-shape curve for all countries. Nevertheless it remained the case that some countries endowed with large deposits of domestic coal, primarily Britain and Germany, do show increasing energy intensity during their industrialization (Kander et al., 2013; Warde, 2007). In Britain's case this upward shift began early, as coal became the dominant fuel during the seventeenth and eighteenth centuries (Malanima, 2016; Warde, 2007). Since they were such large economies and took an increasing share of the continent's economic activity, their pattern affects the aggregate western European picture which thus also becomes an inverted U-shape curve.

Fig. 1 presents both the aggregate curve of energy intensity since 1820 for the eight Western European countries that were covered by our previous research, and a stylized inverted U-shape graph based on this.

In this article for reasons of data availability we use a different sample of countries but the shape of the curve, still driven by Britain and Germany, is very similar (see Fig. 2).[2] Although we have not been able to

[1] Due to the non-proportional relationship between energy and environmental pressure as some energy carriers are polluting and others are not, and due to the possible confusions between the weak and strong EKC hypothesis, we refrain from the use of the EKC concept entirely, when we speak about energy intensity and instead use "the inverted U-curve." The ideas that structural change (industrialization, service transition) explains the shape of the curve are however the same for both EKC and energy intensity.

[2] The advantage with using this sample throughout the rest of this paper is that we can aggregate the national figures of energy embodied in imports and also aggregate the energy embodied in exports and get a grand total net balance for our combined set of countries. We can then see how much it can alter the aggregate shape of the European energy intensity curve for exactly this sample of countries. For this purpose we do not need to know exactly how this trade was distributed between these countries (i.e. the precise flows between each other); we only need to know what were the inflows and outflows for the whole of our sample, as any intra-sample trade cancels out.