International trade and energy intensity in Europe, 1870-1935

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Abstract

Previous research suggests 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. The upswing of the curve in the phase of early industrialization in the second half of the 19th century was due to the performance of two large coal-based economies: Germany and Britain. Other European countries either had a flat or declining energy intensity curve in that period. 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. Perhaps Germany and Britain, as the 'workshops of the world', were doing the dirty work for goods consumed by others, as is argued for China today. We use an entirely new database that we have constructed (TEG: Trade, Energy, Growth) to test if 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.

The analysis confirms our hypothesis. The pronounced German curve without trade adjustments entirely disappears when we account for energy embodied in the traded commodities. For Britain the EKC curve changes into a fluctuating pattern during the second half of the 19th century, before falling from WWI onwards. On balance for the total of our sample of seven European countries the upward slope of the curve also disappears when trade is taken into account. Still, for Europe as a whole it is not likely that the curve disappears, but rather becomes weaker, after trade adjustment.

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: the so-called consumption based approach. Calculating consumption-based environmental impact has become popular but only covers recent decades. Often the consumption-based approach has a focus on patterns and levels of consumption of individuals. However, from a national perspective 'consumption' is defined as production minus exports plus imports. Often contemporary consumption studies draw the conclusion that the developed world is outsourcing energy intensive and environmentally damaging production abroad (Peters), but this can be questioned (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.

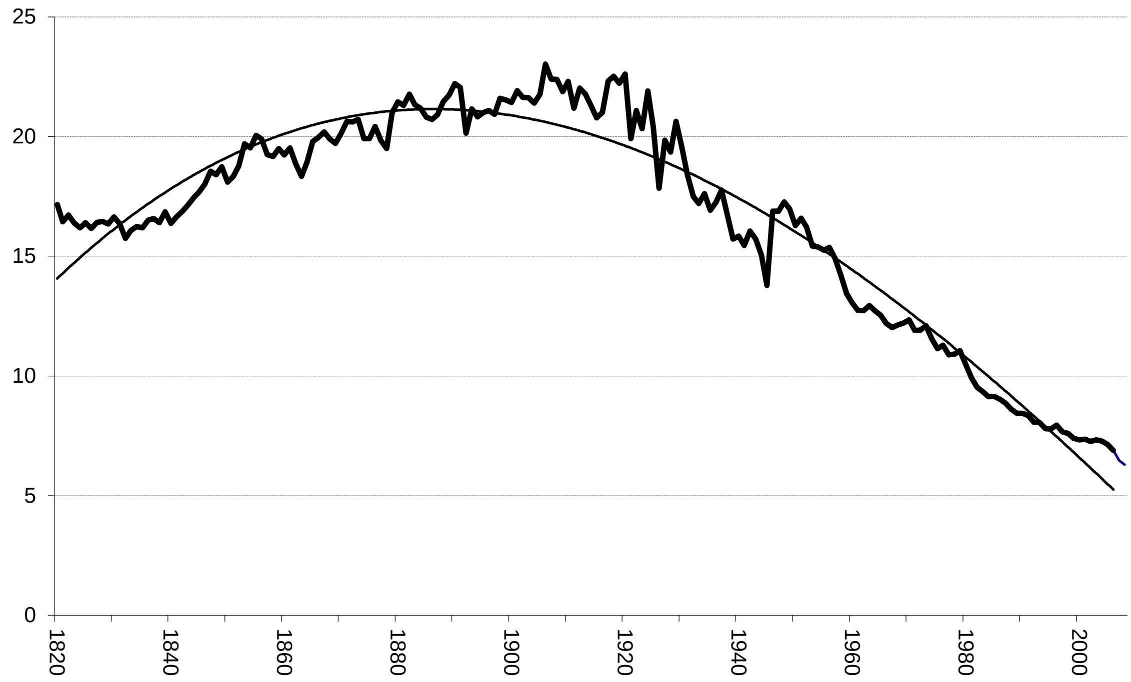
There is a widespread view regarding material resource use and pollution, called the environmental Kuznets curve (EKC), which claims that resource pressure and pollution increases during industrialization and declines as the nations mature into service oriented countries (ref), at least in relative terms, i. e. in relation to GDP. The basic idea is that things need to get worse before they can get any better. Another implication drawn from 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 in creates. This idea is however much contested (Stern 2004, …). Some authors have mistaken relative decoupling with absolute decoupling (Radetzki 1990) and erroneously drawn the conclusion that if the pollution per GDP unit goes down the environment is less pressured overall. This is of course not true: if the scale of the economy grows faster than the delinking of energy and growth, the absolute environmental pressure will increase.

For energy consumption a similar idea of an inverted-U for energy in relation to GDP (energy intensity) has been proposed (Reddy and Goldemberg 1990). The existence of such a curve for energy intensity with the same shape for all countries, only differing in time and levels of the peak, would indicate that all countries go through the same kind of industrialization, even though they can learn from each other and import more efficient technologies. It suggests that all countries need to 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 EKC is not true for a number of European countries, where energy intensity actually falls throughout the long period 1800 until today. (Gales et al 2007). Still the EKC 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 follows an inverted U-shape (Kander et al 2013). In this article we critically revisit the EKC again. Could it even be the case that there was no EKC for Europe when international trade is taken into account? That Germany and England were exporting so much energy embodied in goods in the 19th century to countries outside Europe 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 the world trade in 1913 and mainly exported manufactured goods and imported primary goods (Kenwood and Lougheed 1993). 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).

Previous work has already demonstrated that an important part of the explanation for the upward slope in energy intensity during industrialization identified by Reddy and Goldemberg, was that traditional energy use of wood and draft animal power for non-coal economies had been underrated, and with proper inclusion the picture changed. In fact, the European countries that did not have access to domestic large 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, when all traditional energy carriers are properly taken into account. (Gales et al 2007). They did not have a phase of increasing energy intensity during their industrialization. But the coal-rich countries, primarily Britain and Germany do however show increasing energy intensity during their industrialization (Warde, 2006; Malanima, 2016; Kander et al 2013). In Britain's case this upward shift began fairly early, as coal already became the dominant fuel during the seventeenth and eighteenth centuries. 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. But would a trade-adjusted view, examining the matter from the consumption side, change that picture? Thus this article will explore the impact of international trade on the apparent existence of an inverted U-shape curve for energy intensity in Europe. Will the inverted U-curve for energy intensity cease to exist for Britain and Germany (and thus for Europe) when their international trade is accounted for?

Previous research

Figure 1: Graph of European aggregate energy intensity



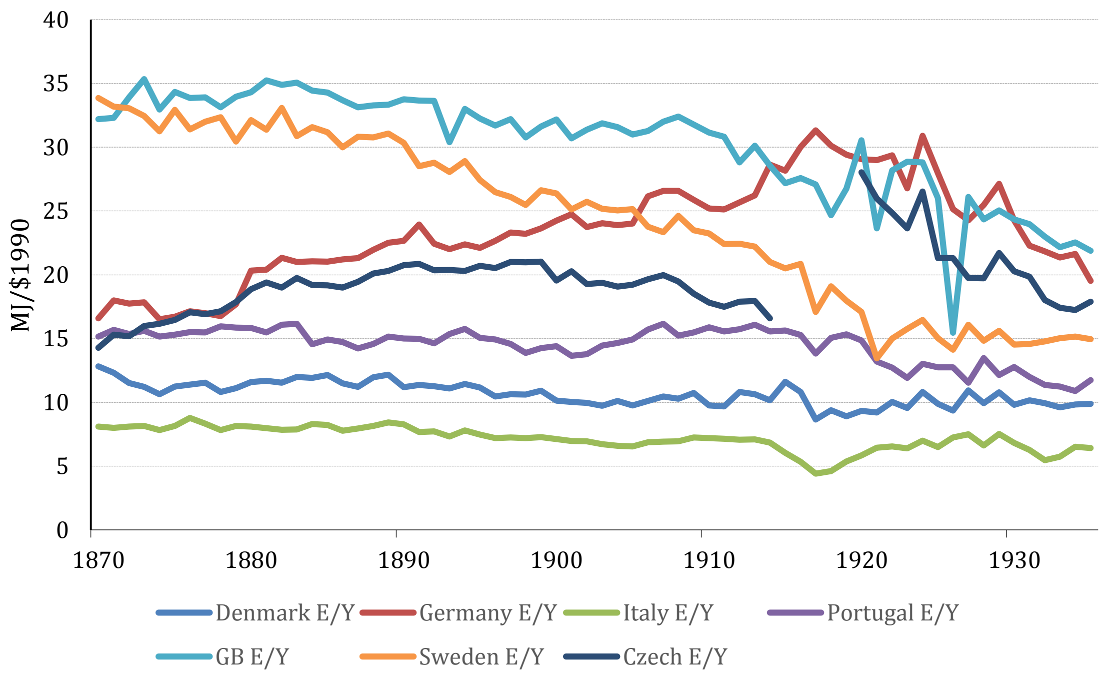
Source: Kander et al., (2013) based on 8 countries.

For the countries in our sample in this article (7 countries no longer France, Spain and Netherlands but we have included Denmark (Henriques and Sharp, 2015, Henriques and Borowiecki, 2014) and the Czech lands (Nielsen 2016 forthcoming).

Figure 2: Energy intensity of Great Britain, Germany, Czech lands, Denmark, Sweden, Italy and Portugal 1800-2000, MJ per constant international dollar, 1990 price level.

Source: our construction with the data from Henriques, (2011); Kander et al., (2013); Olsson-Spjut et al (2016), Henriques and Borowiecki (2014) and Henriques and Sharp (2015), Nielsen et al. (2016).

Figure 3: Individual country trends, Energy Intensity (MJ/$1990)



Sources: For Portugal: Henriques (2011), For Denmark: 1870-1913 Henriques and Sharp (2015), 1914-1935 Henriques and Borowiecki (2014). For the Czech lands, Nielsen et al. (2016). For the other countries: Power to the People, Kander et al (2013). Note: Swedish energy intensity is revised from the book Power to the People as new research as shown firewood use for charcoaling in the iron industry to have been higher than in previous estimates (see paper Olsson-Spjut, Lindmark and Kander 2016 forthcoming)

Figure 3 shows the energy intensities of the individual countries in the sample behind the curve in figure 2. These are the countries for which we have been able to establish figures for energy embodied in trade. The advantage with using this sample 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 curve. We do not need to know how the trade between these countries was precisely distributed The net balance will suffice.

Methods and Data

We are in the process of constructing a new database, the TEG (Trade, Energy and Growth), which will be linked to the LEG database that was published online together with "Power to the People" (link). The LEG database gives detailed national energy data for both traditional and modern energy carriers for eight west European countries: Germany, UK, Sweden, France, Portugal, Italy, Spain and Holland. TEG includes Germany, UK, Sweden, Portugal, Italy, Denmark and the Czech lands. For the Czech lands, all data prior to WWII refer to Czech lands only, thus the geographical area which more or less corresponds to the current territory of the Czech Republic. Within the period of 1870-19313, the Czech lands were a part of larger entity – the Austrio-Hungarian Empire. For the period after WWII, the geographical scope includes the newly created republic of Czechoslovakia, thus both the Czech and Slovak Republic.

We include as energy sources primary energy carriers, both traditional and modern. Traditional energy sources are firewood, muscle energy from draft animals (not humans in this case), and direct working water and wind (negligible shares of the total). Modern are fossil fuels (coal, oil and later natural gas), and electricity produced from other sources than these fuels: hydro, nuclear, wind, solar etc.

In Appendix A we provide the main sources of information for the individual countries and products.

The basic method we use to trace the energy embodied in the goods that are exported and imported is process analysis. We follow the main production steps of a final good and add figures at each step to produce an aggregate total. For instance the production of metal goods contain three main production steps: 1) mining the ore 2) reducing the oxygen of the ore and refining it into pig iron 3) melting and working the metal into metal products. Step 2 and 3 are the most energy consuming and has the highest technical coefficients (energy needed to produce one ton). When data permits, the final step is disaggregated top take into account further steps in the production of differentiated goods The different steps also produce some waste, as well as by-products to which, in certain circumstances, energy inputs should be allocated. These are accounted for by applying multiplicators.

The work of constructing the TEG database has taken place in three steps:

1) The technical coefficients

The first step in calculating energy embodied in trade is to find information about the amount of energy of different kinds (wood, coal, electricity etc) that are used to produce the total sales value, or quantities in tons of the products of an industry; i. e. the technical coefficients. The technical coefficients allow us to assessing the flows of embodied energy.

The limiting factor in the TEG construction is the availability of detailed data on energy used in the production of product groups. Trade statistics of a detailed kind are the most widely available historical statistics in nearly all countries, often with very detailed annual data for both imports and exports far back into the 18th century. Logically this implies that the system for identifying homogeneous product groups is driven by the available energy data rather than the trade statistics.

The availability of information on energy inputs into production differs significantly over time and between different products. Generally in the 20th century there is more detailed data on industrial energy consumption available in national statistics; in some countries like Sweden there is annual data available from 1911 onwards in the industrial statistics providing information about energy use for all the subsectors of manufacturing. In other cases benchmark industrial censuses (eg. the Census of Production beginning in 1907 in Britain, although with some significant precursors in Factory Returns from the 1830s. In Germany the first complete industrial census was in 1936, but there were more limited censuses from 1875, and more frequent industry-specific ones before WWI). In the 19th century data is less easily available, but the industrial structure was also relatively simpler with fewer products and large groups with relatively homogeneous characteristics. Even in the absence of formal industrial censuses, there are occasional comprehensive surveys of fuel consumption in industry and/or the employment of steam power (such as the Royal Commission of 1870 in the UK, MOPCI, Inquérito Industrial de 1881 in Portugal), and sub-sectoral data on important products exists for a number of countries, such as iron and steel production (Arpi 1951). For more detailed descriptions of the data used to estimate technical coefficients for product groups in the different countries please see theAppendix.

The technical coefficients have been constructed for benchmark dates (circa 1870, 1913 and 1935) and where data is lacking for some of our countries we have assumed constant energy efficiency across countries in identical traded goods. For Great Britain, that saw an early upward trend in energy intensity that began even before the 19th century (Warde, 2006, Malanima, 2016) without trade adjustment we have also established trade balance benchmarks for 1832 and 1849.

2) Multipliers

The second step has been to make input-output schemes for traded commodities that contain substantial amounts of inputs for their production. For some goods, like iron & steel, textiles and for coal and coke themselves, this has a large impact on the results. The major logic behind using multipliers is to capture the actual material needs of various productive processes as each step of production may be to some extent characterized by some form of production losses. So for example, at the begnning of the 20th century around 8% of all raw cotton inputs were lost during the production of cotton yarn, which translates into actual primary material need of the spinning sector to be larger by 8% (a multiplier of 1.08 was used to capture the actual raw cotton consumption of the cotton yarn production). Similarly, products, which consist of a combination of multiple input commodities need multipliers in order to capture the actual weight of individual material inputs.

3) Count energy in trade.

The third step is to apply the overall technical coefficients (including the multipliers) to the trade statistics and calculate the 'hidden' energy flows in international trade. We have used national trade statistics for each country and our technical coefficients to assess the energy flows. We have avoided currency problems by always translating the sales values into tons.

Results

How did energy intensity change?

The methodological advantage of the current approach of aggregating the 7 country sample is that we can study the net-balance of energy from this group of countries through trade. This tells us something about a group of significant European countries, but not for Europe as a whole, because some major countries are missing in our data, such as Spain, the Netherlands and France. The overall results are provided in tables 1 and 2. Energy intensity changed drastically, not only for individual countries but also for Europe as a whole.

The German EKC for energy completely disappeared after trade adjustment, as did the British for the period after 1870. This was not only due to internal flows of embodied energy within our group of European countries. The aggregate curve also becomes flat in the late nineteenth and early twentieth century. It goes up a very small amount (2%) between 1870 and 1913, but this must be considered to be within the range of normal annual fluctuations and not as indicative of any trend. Can we then draw the conclusion that there is no EKC for energy in Europe, when trade has been taken into account? Actually not.

In order for the European energy intensity curve to change so that the upward slope of the inverted U-curve disappears it is necessary for Europe, or in fact Germany (1840-1910) and Britain, to have a significant net-export to other parts of the world. This will be further discussed in the next section about trade patterns for Britain and Germany.

Table 1: Total energy production based, total energy consumption based and old and new energy intensity for all our seven countries and the aggregate group.

	1832	1849	1870	1913	1935
Total Energy, production based	PJ	**2843**	**4798**	**14121**	**13074**
Denmark		34	48	124	200
Germany		481	1197	6227	5381
Italy		326	353	688	883
Portugal		54	66	116	136
GB	979	1711	3004	6114	5738
Sweden		149	190	360	420
Czech		87	179	492	623
Total Energy, consumption based			**4762**	**12140**	**12936**
Denmark			58	159	239
Germany			1511	5035	5111
Italy			374	802	1009
Portugal			71	139	151
GB	959	1535	2436	5350	5464
Sweden			157	305	393
Czech		86	155	350	569
Energy PJ			**4762**	**12140**	**12936**
GDP			235259	587719	770000
Denmark			3782	11670	20247
Germany			72149	237332	275496
Italy			43526	96856	137737
Portugal			4325	7212	11576
GB	35935	54213	93307	191009	262045
Sweden			5607	16205	28076
Czech		6798	12563	27433	34823
Old Energy intensity		MJ/$	MJ/$	MJ/$	MJ/$
Denmark			12,8	10,6	9,9
Germany			16,6	26,2	19,5
Italy			8,1	7,1	6,4
Portugal			15,2	16,1	11,8
GB	27,2	31,56	32,2	32,0	21,9
Sweden			33,9	22,2	14,9
Czech		12,8	14,3	17,9	17,9
Old E/Y 7 countries			20,4	24,0	17,0
New E/Y 7 countries			20,2	20,7	16,1
Energy intensity					
Denmark			15,3	13,6	11,8
Germany			20,9	21,2	18,6
Italy			8,6	8,3	7,3
Portugal			16,4	19,3	13,0
GB	26,7	28,3	26,1	28,0	20,9
Sweden			28,0	18,8	14,0
Czech		12,7	12,3	12,7	16,3

Table 2: Energy intensity, index 1870=100

	Old Energy intensity (1870=100)					
	1832	1849	1870	1913	1935	
Denmark			100	83	77	no EKC
Germany			100	158	118	clear EKC
Italy			100	88	79	no EKC
Portugal			100	106	78	tiny EKC
GB	85	98	100	99	68	long run EKC, but very flat 1849-1913
Sweden			100	66	44	no EKC
Czech			100	126	125	no EKC
	New energy intensity (1870=100)					
7 countries			100	118	83	EKC
7 countries			100	102	79	No EKC
Denmark			100	89	77	no EKC
Germany			100	101	89	EKC disappears
Italy			100	96	85	no EKC
Portugal			100	117	79	EKC
GB	102	108	100	107	80	No EKC
Sweden			100	67	50	No EKC
Czech			100	103	133	No EKC

More on the German and British trade patterns

As is obvious from Appendix B, in the late 19th century, only Britain had a large trade with non-European countries in economic terms (i.e. valued in £), about half of its foreign trade. The USA and India were the main non-European trading partners for the UK, and Canada, Argentina, Australia and Russia made up about 5% each.

Germany is the most interesting country from the EKC point of view. In the period after 1870 they are the only country driving the energy intensity curve up. Their energy intensity curve has a clear inverted u-shaped form, and it seems probable that their exported embodied energy contributed to this pattern, since they went from net-importers in 1870 to net-exporters in 1913.Thus at least part of the increase in national energy consumption to 1913, must have been satisfying the needs in other countries.

In fact Germany's energy intensity curve changes drastically after taking trade into account, as shown in table 2. Instead of an increasing and then decreasing curve in the period 1870 to 1935, peaking around 1910, we find that the upward slope of the curve disappears and we have a flat trend between 1870 and 1913. Thus the country mainly responsible for the European inverted U-shaped curve of energy intensity in this period actually no longer contributes to the image of increasing energy intensity in the period of rapid industrialization diffusion in the late 19th century. It would still be possible, however, for overall intensity to be driven up simply by Germany cornering a larger share of continental output, having a relatively high intensity. This effect was not however large enough to offset the net balance of energy embodied in trade from the sample

Germany's trading pattern with countries outside our sample is therefore of particularly high interest. If their energy embodied in goods largely went out of Europe, then we dare conclude that international trade was the main factor driving the curve up for Europe. However, Germany's trade was far more Europe-oriented than the trade of UK. Austria-Hungary, France, Russia and the UK were the main trading partners of Germany. Of these countries France and Austria-Hungary are not covered in our present 7-country sample of Europe.

In sheer economic (value) terms Germany always had a favourable balance of trade in relation to UK, but a negative balance in relation to their non-European trading partners: the USA and Russia.

German exports of especially energy intense goods, such as iron & steel and coal and coke, were very largely to European neighbours, as shown in table 3. Indeed, although most went to other European countries inside our sample, quite substantial amounts also went to European countries outside of our sample, like France, Belgium and the Netherlands. This means that a complete disappearance of the upward slope of the EKC curve for Europe as a whole is not likely.

Table 3: Share of German exports of iron and steel goods, coal and coke to main trading partners, 1913

Tons/country	Pig iron (782911)	Cast iron (700779)	Iron goods (1173265)	Coal (34598408)	Coke (6432986)
UK		71%	22%		
France	15%			9%	37%
Belgium	40%	10%		17%	15%
Netherlands			14%	21%	
Austria-Hungary	14%	6%		35%	16%
Japan			8%		
Argentina			8%		
Russia				6%	8%
Switzerland					6%

The individual country patterns

The overall picture of national energy histories among European countries changes substantially after accounting for the amount of embodied energy in trade. Trade has a large adjusting power on levels as well as trends (tables 4-10). However the impact is rather different in magnitude and direction. The range of impact is between +29 per cent (Czech lands in 1913) and -33 per cent (Denmark in 1870), measured as the net exports divided by the national energy consumption. Net exporters are the coal rich countries; the UK and Czechoslovakia, but also Sweden, rich in charcoal and iron ore. Coal-rich Germany is a very interesting case; it moves from being a net-importer in 1870 (-10%) to a net –exporter in 1913 (+17%) and continues to be a net-exporter in 1935, but less so (+4%). Net importers are Denmark, Portugal and Italy. These are countries that lacked domestic coal resources, and were not well equipped with iron ore.

The impact on trends varies. In Sweden and UK and Denmark there is a declining impact between 1870 and 1935. In fact Sweden and the UK are surprisingly similar in the ratios of net-exported energy at the three benchmarks, and trends are almost the same. So it appears that the comparative advantages of energy intensive production fell for these two countries over time. This is not surprising given dramatically falling transportation costs, which enabled the transport of coal across national borders and equalized energy costs internationally. Land-locked Germany is later in exploiting its coal-advantages by specializing in energy intensive exports and peaks around 1913.

In Portugal and the Czech lands the impact peaked in 1913 and declined thereafter as volumes of trade fall. Portugal was a late industrializer, and late in importing steel and coal and machinery, so this could be expected. The Czech lands could, to some degree, also be characterized as a late industrializer, though the nature of the country's trade pattern and domestic production changed substantially between 1870 and 1913. In fact, by the beginning of WWI the territories of the Czech lands covered the needs of the whole Austrio-Hungarian Monarchy and only some 30% of total domestic production was consumed within the borders of the Czech lands (Pokorny & Cisar, 1922). The trade pattern of the Czech lands in 1913 thus resembled much of the trade of other industrialized countries, mainly dominated by imports of raw materials and inputs and exports of manufactured goods. In particular, exports of iron and steel goods to other parts of the Monarchy gained momentum in this period. 'Before the war most of the products known on the world's market as Austrian, came from the territory comprising the new Republic.' (Cisar & Pokorny, 1922).

Table 4: Individual country patterns

	Imported fossil fuels, PJ	Total national energy consumption, minus food, PJ	Embodied in imports, PJ, (within brackets; of which coal and coke)	Embodied in exports, PJ	Net national energy consumption	Net-exported energy embodied in goods, PJ	Net exports/national energy, %
			Great Britain				
1832		979	23	43	959	20	2%
1849		1712	31	208(5)	1535	177	12%
1870	0.85	3004	94	662(21)	2436	568	23%
1907	31	6114	356	910(133)	5350	554	9%
1935	322	5738	149	423(73)	5464	274	5%
			Germany				
1870	105	1360	294 (7)	143	1511	-151	-10%
1906	271	4902	52(12)	888	4066	836	17%
1935	201	5312	178(24)	379	5111	201	4%
			Chech Lands				
1841	0	66	0.9	1.8	65	0,95	1.4 %
1870	0	148	8	28	128	20	13 %
1913	0[1]	492	20	163	350	142	29 %
1935	59[2]	623	34	85	573	51	8.1 %
			Sweden				
1870	12.5[3]	190	8 (0.8)	41	157	33	17%
1913	173	340	52 (16)	87	305	35	10%
1935	253	410	72 (36)	89	393	17	4%
			Denmark				
1870	21	44	17 (1)	2	58	-14	-33%
1913	98	124	60 (9)	24	159	-35	-28%
1935	170	200	71 (18)	32	239	-39	-19%
			Portugal				
1870	5.6	66	6.6 (0.3)	0.7	71	-5.9	-9%
1913	37.2	116	27.8 (3.1)	4.3	139	-23.5	-20%
1935	36.2	136	19 (1.7)	4.5	151	-14.5	-11%
			Italy				
1870	34	353	31 (1,8)	10	374	-21	-6%
1913	352	688	151 (19)	37	802	-114	-14%
1935	516	883	163 (38)	37	1009	-126	-12%

[1] 89 exported, [2] 70 exported

[3] Of coal 12.3 PJ or (93%) was imported. All oil (0.2 PJ) was imported in 1870.

Concluding discussion

The results show that the coal-rich countries were making use of their coal resources and specializing in heavy industrial production, much of it for export to other European countries, mainly those that lacked domestic coal resources. The role of coal for specialization peaked before the first World War and diminished in the interwar period. This is especially obvious in the case of Germany that net-exported 17 % of their national energy consumption before the War. This ratio dwindled in the interwar period to a minor 4% in 1935. This affected the energy intensity pattern for Germany and our set of 7 countries substantially.

However, Europe is larger than our set of 7 countries, and more than half of Germany's export of heavy industrial goods went to European countries outside of our sample, like France and Belgium. So for Europe it is not likely that the curve disappears, but it is likely to become less pronounced.

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