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How did Denmark delink energy consumption from economic growth?

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Abstract:

In the 30 years from 1976 to 2006, the Danish economy grew by 93% whereas the consumption and supply of primary energy grew by only 6%. This experience is important in assessing the realism of energy efficiency targets in EU and elsewhere. The paper reviews the evidence for and seeks to quantify the possible explanations for this delinking of energy consumption.

The paper extends the energy consumption by the Danish economy with energy used for international transport and imports. The more comprehensive measure of energy consumption is useful for intertemporal comparison of the linkages between energy use and economic growth. It shows that the energy required for the Danish economy to grow was not as delinked as the energy consumption on Danish soil. Still, the review includes evidence that several important linkages has been delinked to a high degree.

The paper concludes that the factors responsible for this delinking are identified and quantified with respoect to their importence. The most important factors include the real energy price (which is heavily affected by taxes) and the centrally planned expansion of combined heat and power production and remote heating. Institutionalised dissemination of technical and economic information addressing the efficiency paradox has been and still is an important element of Danish energy policy, but the results are debated.

*** Work in progress ***

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Delinking Energy from Economic Activities

During most of the 20th century, economic growth in Denmark was accompanied by a parallel growth in energy consumption. This was not surprising, as the unprecedented surge in productive capacity of the industrialised and industrialising economies from the 18th century onwards was technologically enabled by an equally unprecedented use of energy in machine power, chemistry, and transport.

The *gross energy consumption* (or *demand*) of the Danish economy in the 20th century (and the first years of the 21st) was primarily made up of fossil fuels. Peat and firewood made a contribution in the first half of the century and renewable energy sources in the last decade. But until the end of the 70s economic growth was closely associated with energy use and throughout the century energy was primarily supplied in the form of fossil fuels. However, after 1979, the energy consumption seems to have delinked from the further growth of economic activities.

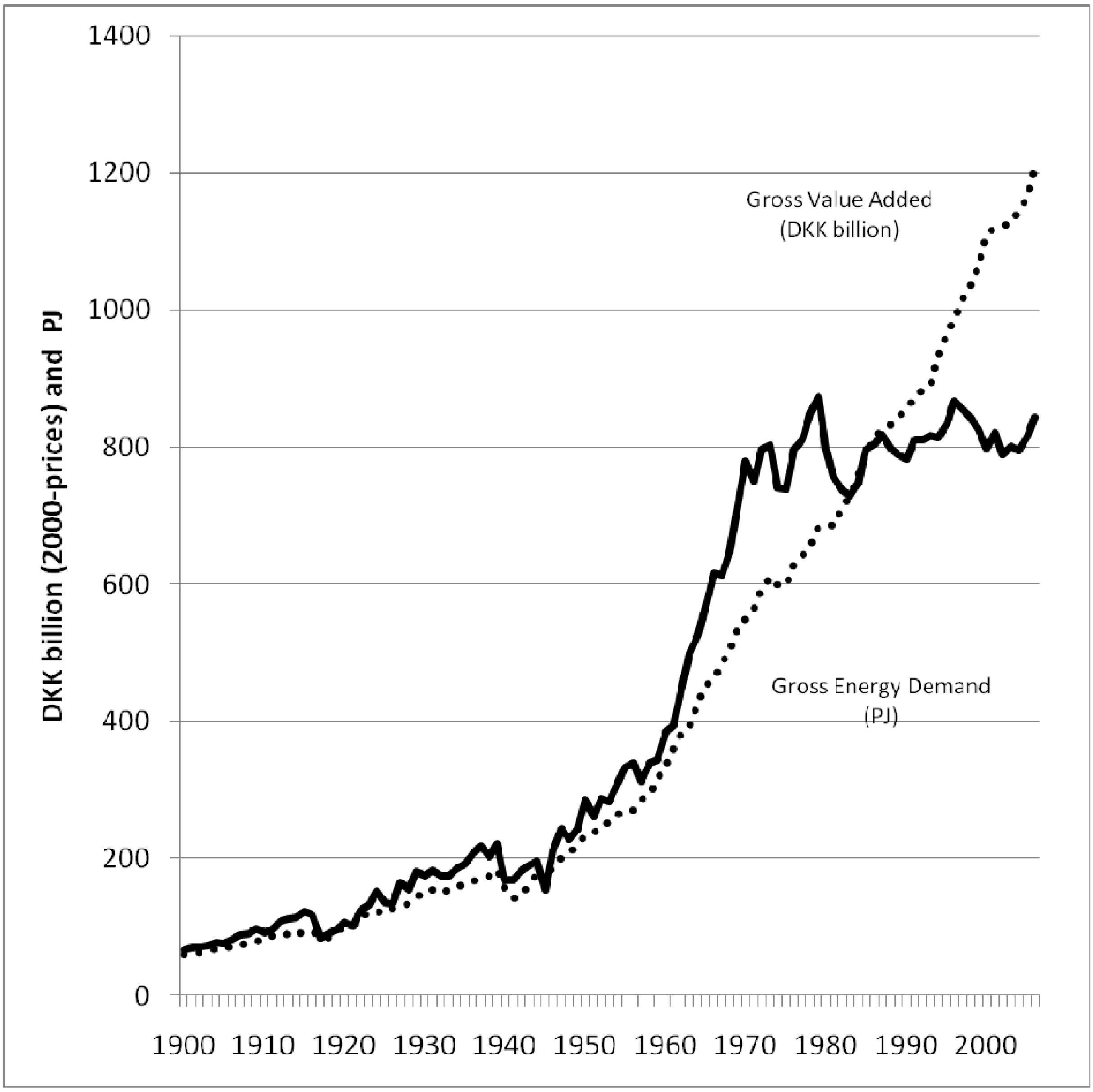

Figure 1. Linked and Delinked Energy Consumption in Denmark in the 20th Century

Source: 1900-1974 (Gross energy consumption and GDP in factor prices calculated with Laspeyres index method) from Hansen (2002) (http://dspace.ruc.dk/handle/1800/1124) merged with the gross value added series from Danmarks Statistik, Statistikbanken (06.05.08) (calculated with chain index method). Merged with backward rescaling with average 1975-1979 ratio. Difference between GDP in factor prices and gross value added is negligible in this context.

The link between energy demand and the level of economic activity became even closer during the 60s where energy consumption rose faster than economic growth. This was a period where productivity growth to a high degree was achieved by mechanisation replacing manual labour (human energy) by machines (fossil energy).

After 1973 energy consumption seems to return to the pattern of growing in parallel with the economic activity. The 70s were turbulent as far as energy is concerned and the close tie between energy and economic activity lasted only to the end of the decade.

From 1980 onwards, energy demand was delinked from economic growth with a remarkably clean cut. Energy demand was not totally unaffected by changes in economic activities, but the close link between energy economic activity was clearly broken.

However, the gross energy demand covered by figure 1 does not include bunker fuels, purchased by Danish shipping and airline companies in foreign ports. When EUROSTAT has chosen to call it gross inland consumption, it is for very good reasons – in particular for an economy like the Danish with a rather large trade fleet. If foreign bunkering is included in the total Danish energy consumption, there is a more continuing link between economic growth and the growth of energy demand.

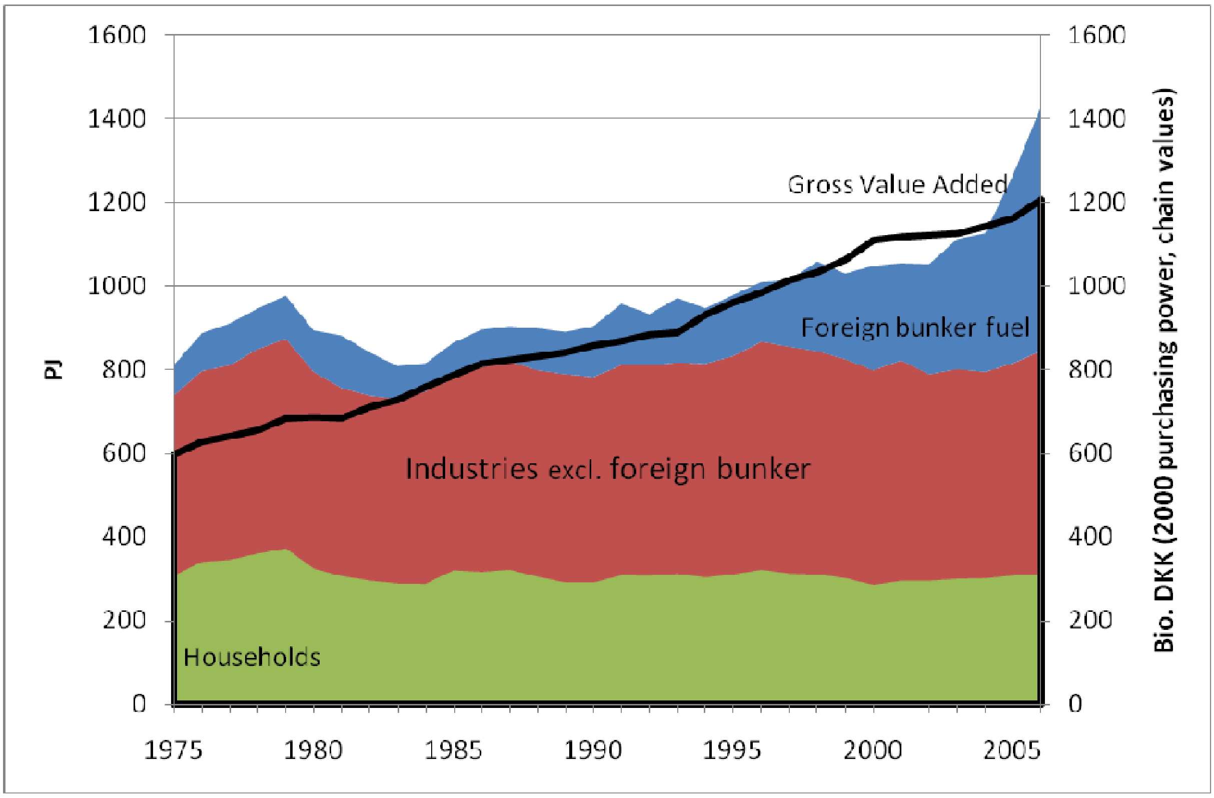

Figure 2. Gross energy demand to the Danish Economy 1975-2006. PJ.

Source: Statistics Denmark, Statistikbanken, 06.05.08, and Author's calculations.

In figure 2 the purchase of bunker fuel in foreign ports by Danish shipping firms and airlines is added to the gross energy demand on Danish territory. Whereas the inland consumption has oscillated around 800 PJ during a quarter of a century, the consumption of bunker fuels from foreign ports has increased steadily and amounts in recent years to almost as much as the industrial energy use at Danish territory.

We will return to the bunker fuel purchase in foreign ports, but first we focus on the economic activities taking place on Danish territory.

Earlier analyses (De Økonomiske Råd 2008), conclude unanimously that the most important factor behind the delinking of inland consumption is the progress in energy intensity (or energy productivity) within each industrial sector (apart from international transport). The changes in the industrial structure have less to say. However, the progress in the energy productivity of each industrial sector could be the result of changing structure of industrial activities within the sector. We will pursue that idea in the analysis below.

Methodology and Definitions

Energy efficiency, energy intensity, energy productivity

Delinking of energy consumption from economic growth is an indispensable condition for realisation of sustainable growth. That is, continuing growth in the value of things we produce and consume, while at the same time drastically reducing the tons and kilowatts that we use in our economic activities. Thus, the concept of energy efficiency must be in the focus of our interest.

It is common in studies of energy efficiency to use indicators of energy intensity of economic activities. At the aggregate level, they are expressed in the ratio of energy use to the constant price value of the economic activity. As underlined by, e.g., (Schipper, Unander et al. 2001), energy intensity is not identical to energy efficiency, but is an indicator of energy efficiency.

Energy intensity, so defined, is the inverse of energy productivity, an indicator comparable to the other indicators of partial productivity: Labour and capital productivity. Whether to use the indicator of energy intensity or energy productivity is much the same question as whether the glass is half empty or half full. In this study, we analyse with the use of the energy productivity indicator.

Inputs and throughput of energy

Aggregation of energy consumption is very different from aggregation of economic value. Energy as well as economic value is handed over from one industry to another in the supply chain from natural resources to final use. However, whereas more value is added by each link in the supply chain, the energy and matter is merely transformed, always involving some loss of energy. In fact, it is exactly this transformation that makes energy commodities available in a useful form at a useful place and a useful point of time and thus adds value to them.

Energy consumption depends on economic growth because energy is necessary to produce the output. The energy transforming industries do, however, not consume most of the energy commodities, they buy. They merely transform it to other energy commodities.

Thus, it is important to distinguish between the *input* of energy commodities into the particular production processes and the *throughput* of energy embodied in the energy commodities. Aggregating all inputs of energy in the economy results in double counting since the same energy is transformed from primary to secondary energy commodities (fuels) in the transformation sector (e.g., power and heat generation and fuel refining).

Eurostat and IEA conventions

Eurostat and IEA have different approaches to this. The key concept for the IEA statistical approach is the Total Primary Energy Supply (TPES) or domestic supply to the economy whereas the Eurostat focus on the Gross Inland Consumption (GIC). Whereas the EUROSTAT statistical approach is organised to reflect the throughput character of energy commodities, the IEA approach is organised to reflect supply and demand to a total energy market. In the EUROSTAT approach there is a clear distinction between primary and secondary production whereas in the IEA approach both contributes to the same supply.

The reader is referred to (OECD, IEA et al. 2005) for a more extensive description of these differences.

These two approaches are reflected in the two different approaches to energy statistics of the Danish Energy Agency and Statistics Denmark.

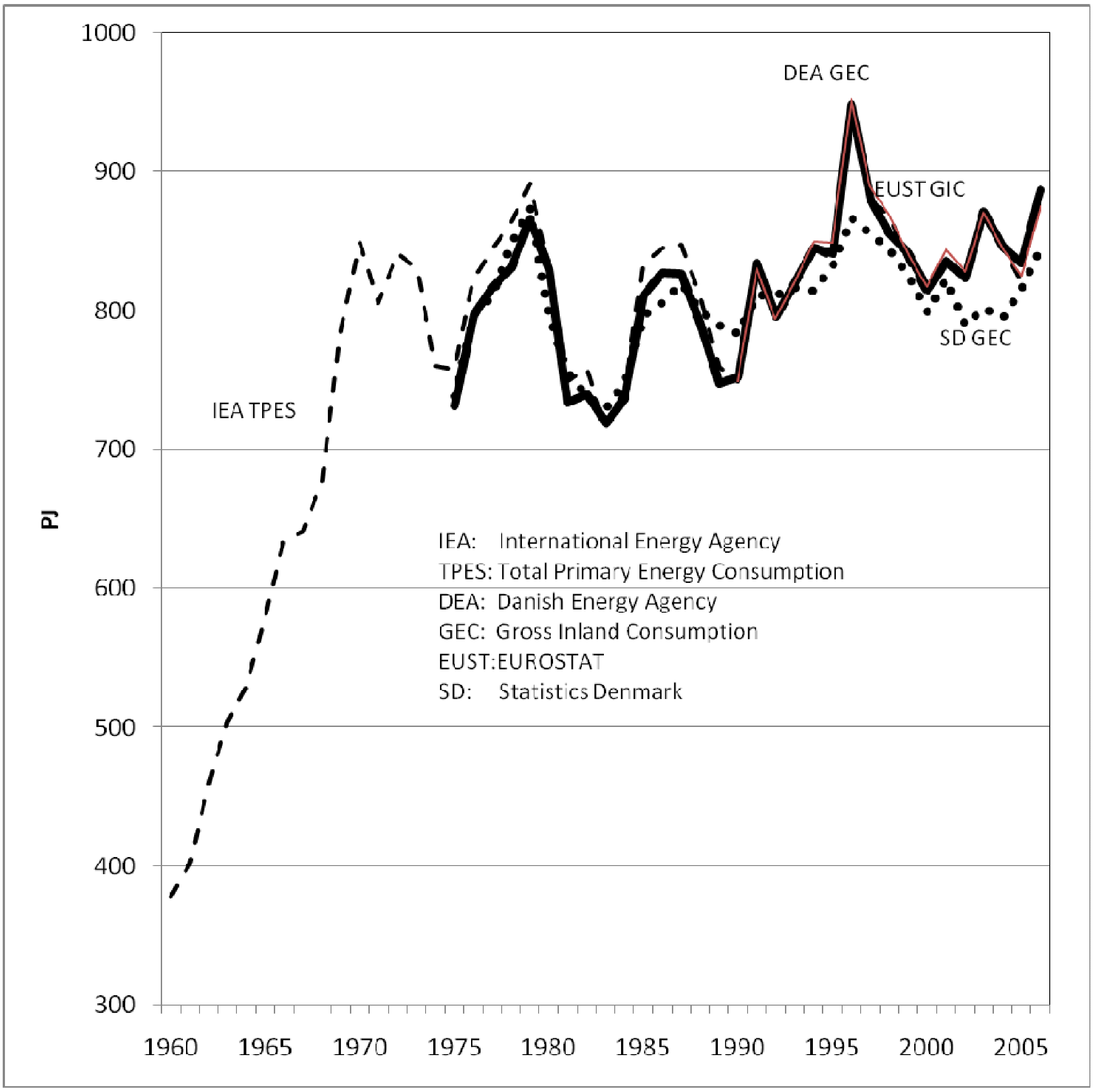

Figure 3. Energy consuymption in the Danish Economy 1975-2006 according to alternative statistical approaches.

Source: Online databases (IEA (19.05.08), EUROSTAT (19.05.08), Statistics Denmark (15.05.08), Danish Energy Agency (15.05.08)) and Author's calculations.

For a study of energy delinking and energy productivity, it is important to link the energy use to the economic activities, which it supports. This is what the approach applied by Statistics Denmark aims at and this approach will be pursued in this paper.

Therefore, there is no doubt that the foreign bunker fuel consumption is necessary for the value added in the Danish shipping and airline industries. Thus, any comparison between energy consumption and the value added of the total economy including the value added from these industries should also include the foreign bunker fuel consumption.

On the other hand, the activities of the other industries of the economy do depend on international transport, but not necessarily on the exact transport services delivered by Danish companies. The transport services that they actually depend on, do not have to be operated by Danish companies. Therefore, the transport enabled by the foreign bunker fuel consumption is not linked to the growth of the Danish economy in a necessary, technical sense as the inland energy consumption.

Consequently, it makes sense to consider the foreign fuel bunker consumption both as an integrated part of Danish energy consumption and separated from it.

Value added, GDP, and Consumption

Energy consumption is evaluated by relating it to the economic activities, it enables. In this study, they are measured in value added and private consumption. The statistical concept of value added is close to the concept of GDP in factor prices and these concepts can be used interchangeably. The concept of interest here, is the deflated value added or GDP and Statistics Denmark produces deflated series in constant 2000 prices as well as series deflated with chain index. The latter is preferred in this paper to avoid the bias that otherwise would occur when using constant prices over such long periods. It has the important weakness that the deflated figures in each industry cannot be aggregated to a total industry figure.

The figure below shows what difference it makes at the aggregate level.

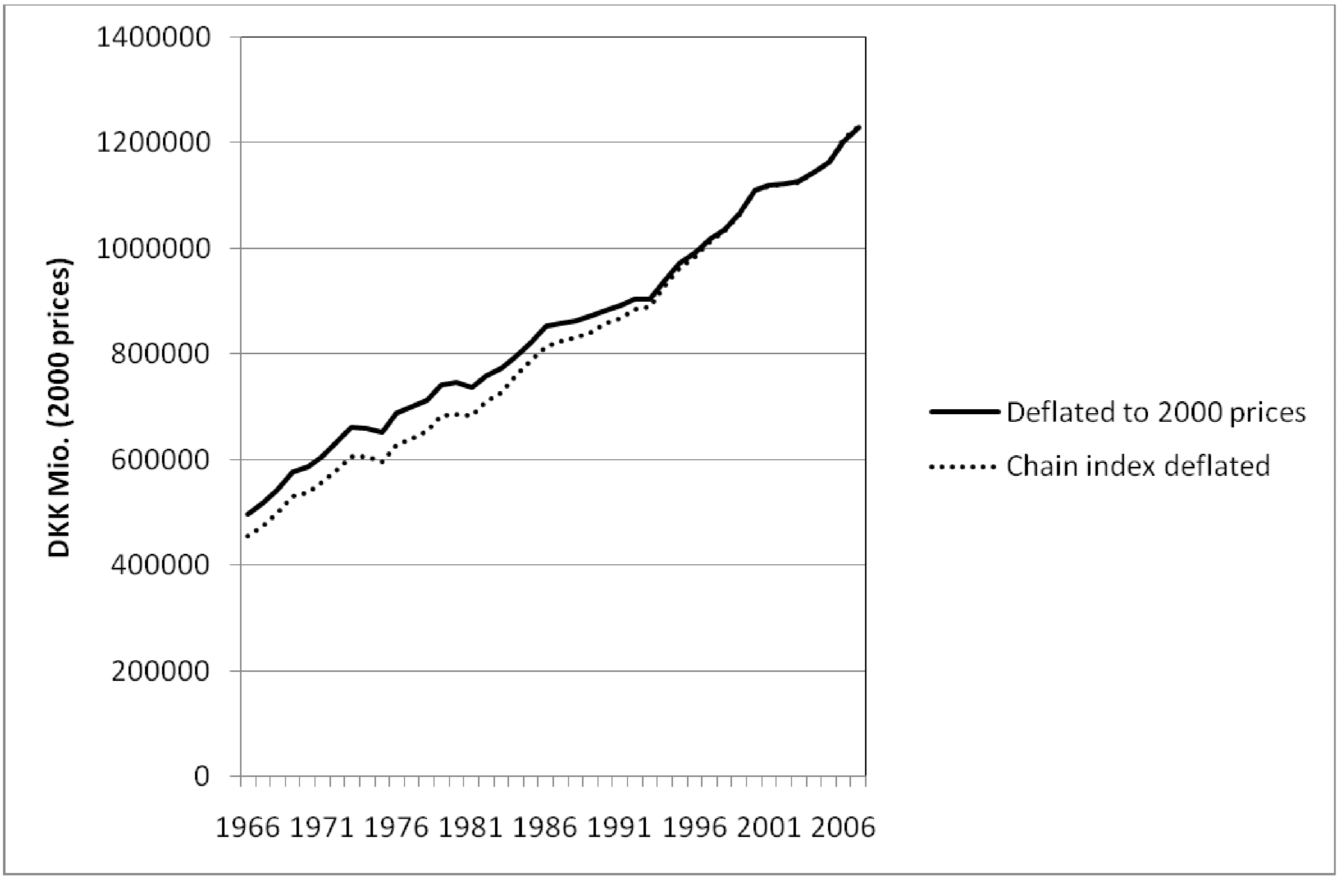

Figure 4. Gross Value Added of Danish Industries. 1966-2006. DKK 2000 Mio.

Energy Intensity in International Comparison

Energy Productivity based on EUROSTAT data

To get a deeper understanding of how special the Danish development is, it is useful to compare with the development of energy use in the countries that we usually compare with.

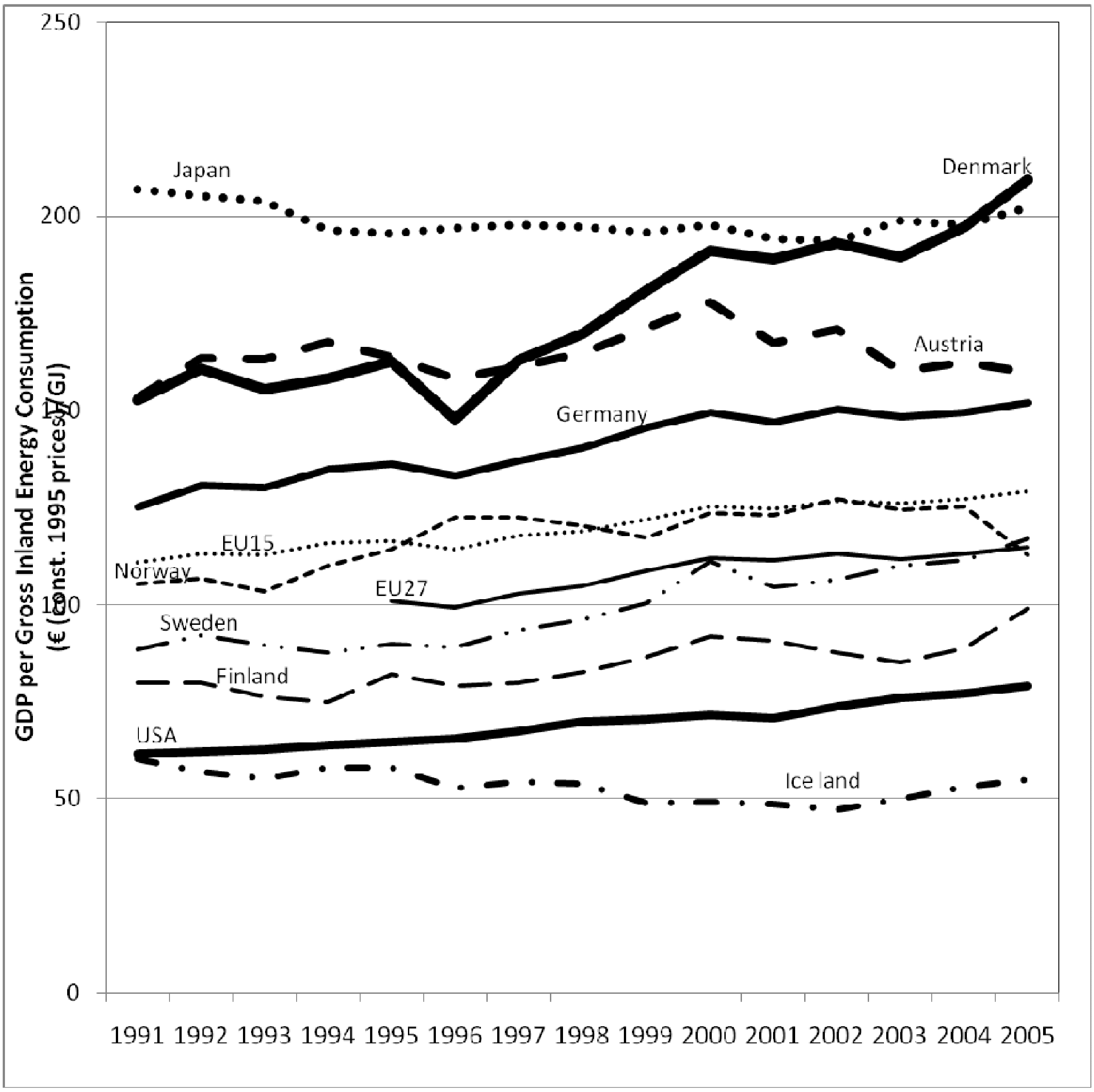

Figure 5. Energy productivity in USA, Japan, EU and the Nordic Countries (GDP per Gross Inland Consumption, €(1995-prices)/GJ).

Source: EUROSTAT online database (19.05.08) and Author's calculations.

The spectrum of energy productivities in the OECD economies, that use technologies comparable to those used in the Danish economy, is delimited by the low energy productivity of the US economy and the high energy productivity of the Japanese economy. The energy productivity of the European economy is in the middle.

The very low energy productivity of Iceland is an exception from this pattern. It follows from its abundant hydropower and geothermal sources resulting in large amounts of power and heat that are difficult to export. Thus, energy intensive industries, that is, industries with low energy productivity are preferred. Similar patterns can explain the relatively low energy productivities of Sweden, Finland, and Norway. Other European countries can also have more energy intensive industries, such as basic iron, steel, and chemicals, because they represent strategic industries on which other industrial activity is based.

In other words, low energy productivity can be, but are not necessarily always a sign of technological backwardness. It can as well be a result of energy priorities based on resource abundance. It can also be the result of the concentration of energy intensive industries that are basic to the entire European economy in few European countries. For instance, there is not much of the energy consuming manufacturing of paper in Denmark, but it is as fundamental to the functioning of the Danish economy as it is to the functioning of other economic activities in Sweden and Finland.

The energy productivity of the new member states is considerably higher than in the old member states ("EU15") resulting in a somewhat lower energy productivity of EU27 than of EU15. In this case, the technology factor is probably more likely to explain the differences.

The Danish economy had together with Austria in the beginning of the 90s the highest energy productivity in Europe. Whereas the Austrian economy remained at that level, the Danish economy took a remarkable upswing in energy productivity in the second half of the 90s and achieved the same level as Japan.

Germany as most of the other EU15 countries had a development in parallel with Denmark, but has an industrial structure that includes some of the very energy intensive industries, that Denmark don't have and therefore have energy intensities on a higher level.

Thus, the high and increasing Danish energy productivity can be partially explained by the fact that some of the very energy intensive industries on which all other industries depend simply are situated on the other side of the border. Nevertheless, the development of the energy intensity of Danish economic activities justifies a further investigation. Which factors are at work? How much can be devoted to the location of industries and how much to the technology factor? How important are exchange rates for these patterns? Are there any lessons to be learned for other countries? These are among the questions that arise and on which, we will seek answers in this paper.

Adjusting for Disparities in Purchasing Power with IEA data

Besides the minor differences in the definitions of energy consumption between the IEA and EUROSTAT, the IEA statistics also goes further back in time. The IEA series start in 1960. More importantly, the IEA statistics allows for adjusting according to purchasing power. The following figures show the energy productivity in international comparison for the OECD countries according to IEA statistics.

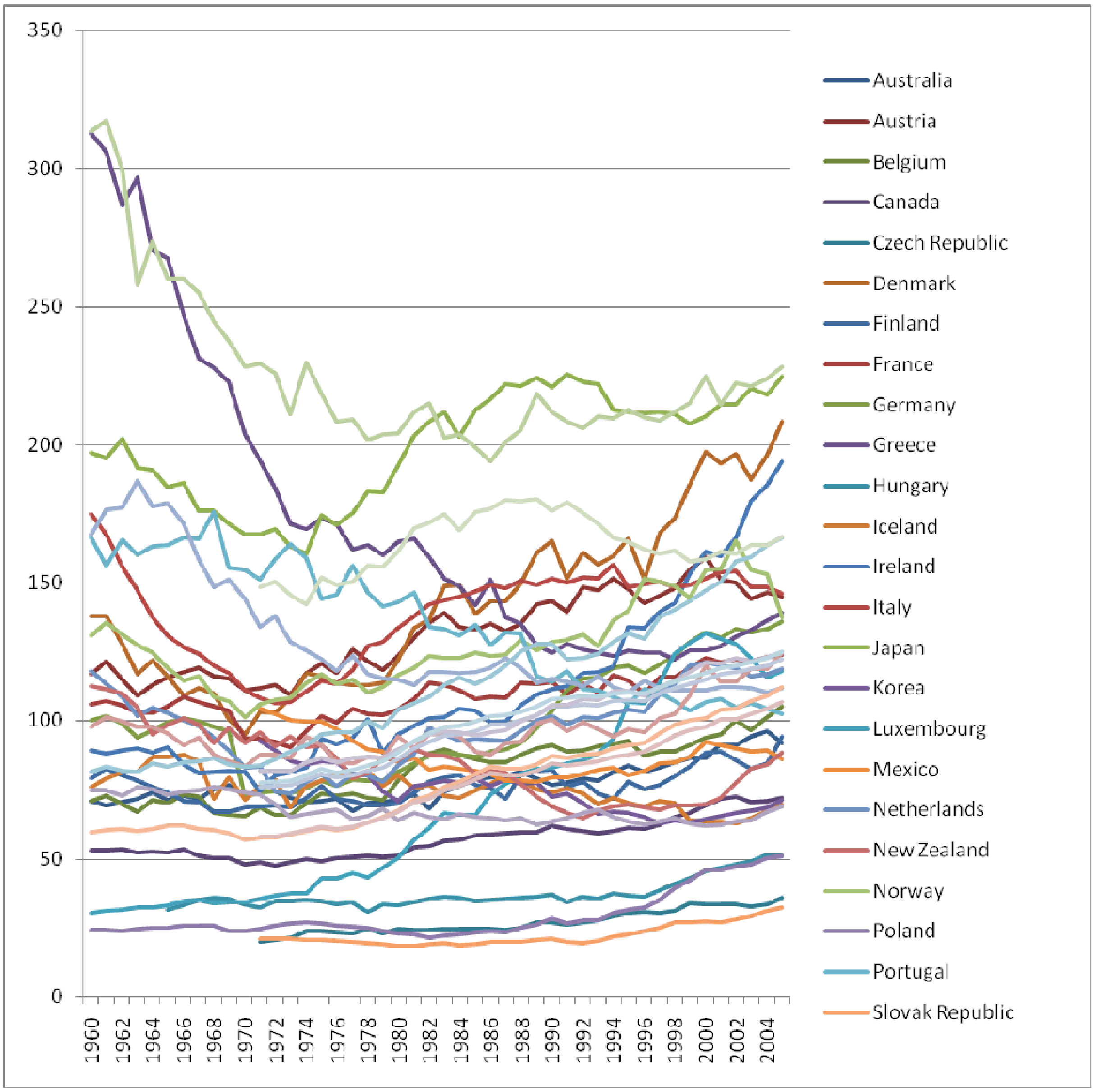

Figure 6. Energy productivity in OECD countries (GDP per TPES in USD (2000-prices)/GJ). 1960-2005.

Source: IEA/OECD Database 19.05.08. and Author's calculations.

This diagram confirms that not only the Japanese, but also the Swiss economy delivers the highest output per energy consumption. The Danish economy is approaching the same high level and so does, surprisingly, Ireland.

The figure also displays the long term decline in energy productivity in many countries until the 70s. After this, most economies have gradually improved their energy productivity, whereas some of the rapidly expanding economies in Southern Europe have continued the declining trend until the 90s.

The lowest energy productivities are found in the new member states of EU: The Slovak Republic, The Check Republic, Hungary, and Poland. Luxembourg is the economy that has improved its energy productivity most since the 70s, probably reflecting the dismantling of its energy intensive steel industry making way for expansion of the business service sector.

This statistics does, however, use the official exchange rates to calculate the GDPs in common currency. This method doesn't take account of the differences in purchasing power of the different currencies. For instance the, amount of Polish Zloty that you can get for a US dollar can buy a lot more in Poland than a dollar can by in the US. Since the ultimate goal of comparing these energy productivity indices is to find out where and when we get more goods and services out of the energy consumption, it is higly relevant to adjust for these differences in purchasing power. The following diagram is identical to the figure above except for it is in Purchasing Power Parities (PPPs).

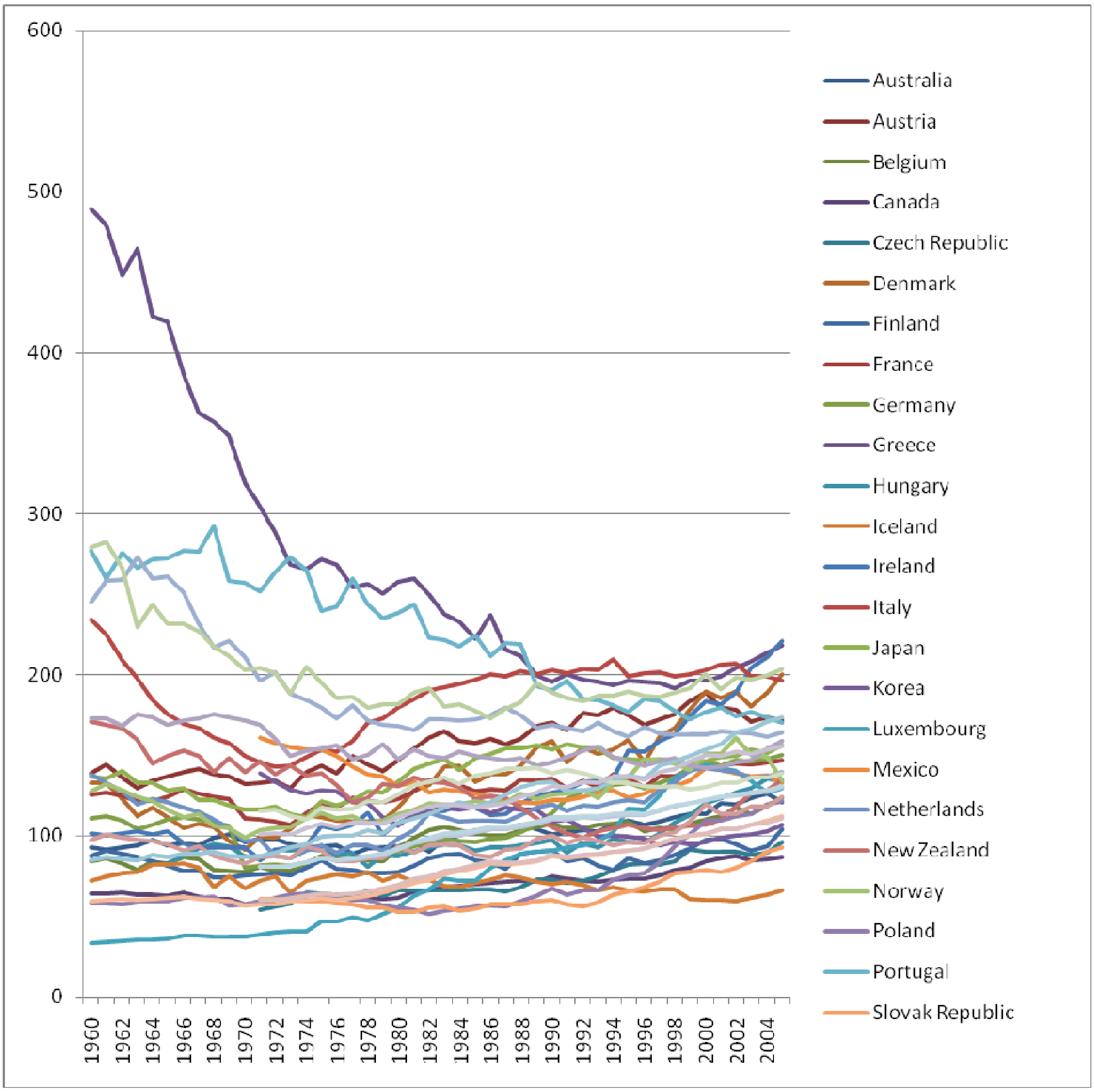

Figure 7. Energy productivity in OECD countries (GDP per TPES in USD (2000-prices and Purchasing Power Parities (PPP)))/GJ). 1960-2005.

Source: IEA/OECD Database 19.05.08. and Author's calculations.

The figure shows that adjusting for purchasing power narrows the spectrum of energy productivity to some extent because the currencies of some of the more energy productive economies have less purchasing power whereas the currencies of some of the less energy productive economies have more purchasing power. Moreover, some of the economies changes position, notably the Italian economy, which after purchasing power adjustment becomes one of the most energy productive economies.

The Danish economy does, however, still continuously improved its energy productivity after 1979 and remains one the top energy productive economies in OECD even aftger adjusting for the purchasing power of curriencies.

It is not easy to compare the individual countries on the basis of the figures above. The following figures compare Denmark with the spectrum of countries sharing similar technologies as used in Denmark.

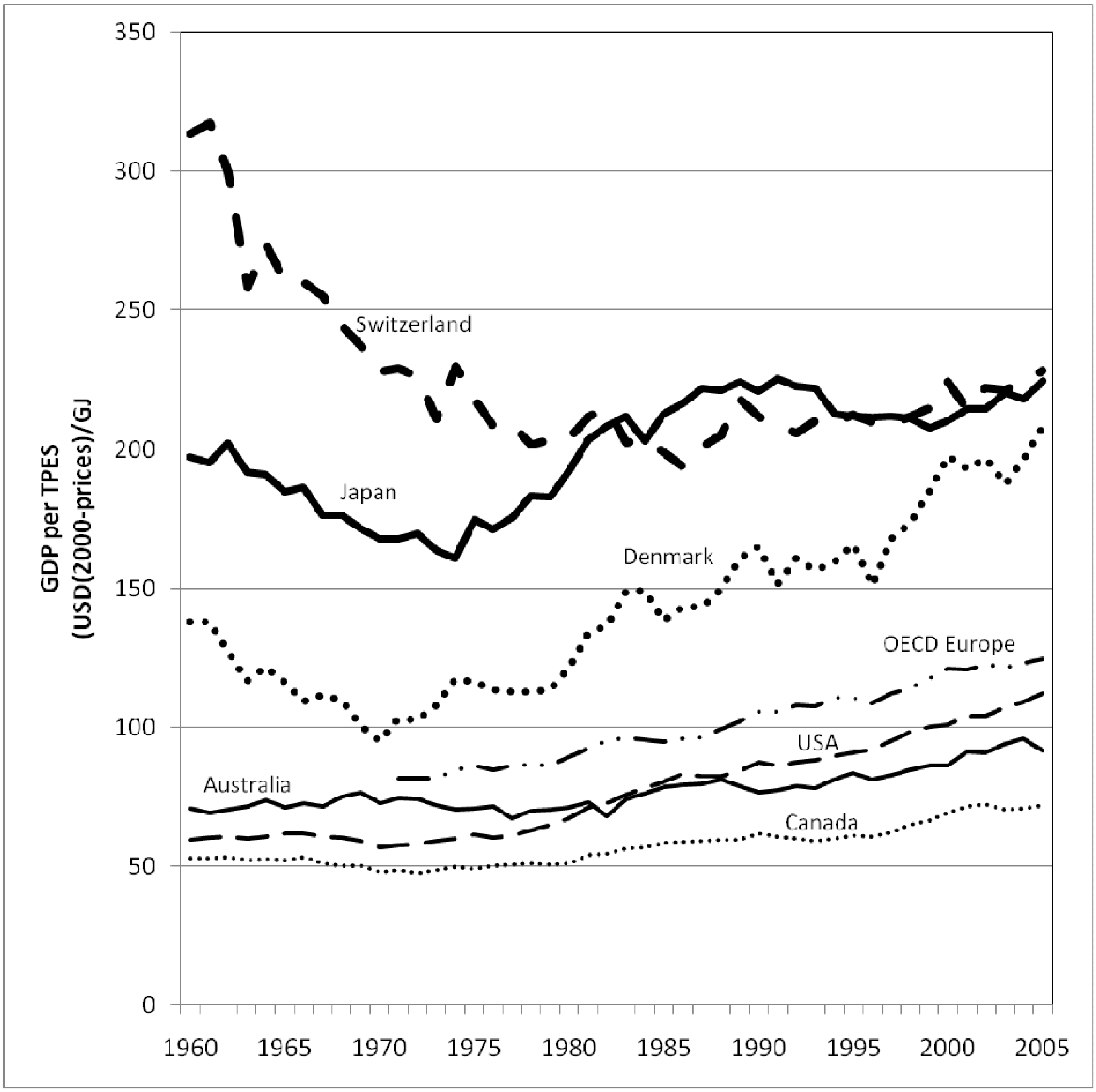

Figure 8. Energy productivity in selected OECD countries (GDP per TPES in USD (2000-prices)/GJ). 1960-2005.

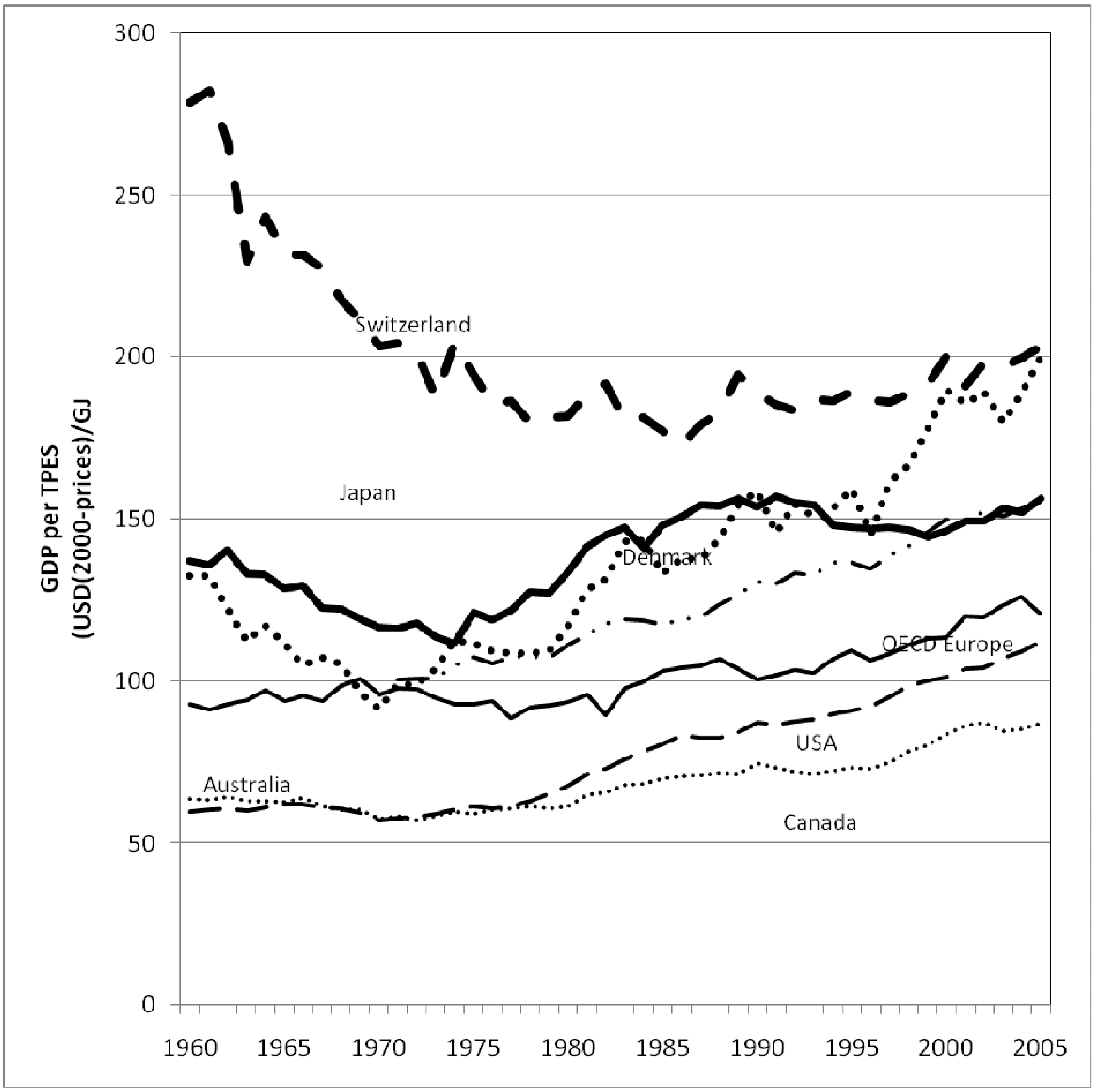

Figure 9. Energy productivity in selected OECD countries. GDP/TPES (USD in 2000 prices and Purchasing Power Parities (PPP)/GJ).

The figures without and with PPP adjustment shows fairly the same patterns except that the energy productivity of Japan was overtaken by Denmark already in the 90s.

The rest of OECD - again with the exception of Japan in the PPP case - all shows increasing energy productivity after the 70s, but Denmark also shifts to a significant higher level.

When comparing with the other high income OECD economies, the conclusion is that the Danish energy productivity has increased since the 70s from an average level to the top level among OECD economies. The details of this development are without doubt interesting to know in answering the question about how not only Denmark, but also other economies can delink their energy consumption from economic growth in the future.

Energy Productivity Development in the Danish Economy

Energy Productivity in Industries and Households

For industrial as well as household energy use, it can be useful to study the inputs of as well as the throughput of energy in energy commodities caused by the individual activities. As noted above, *input* of energy commodities into an economic activity means that the energy is consumed, that is, lost or transformed to energy commodities or something else. The energy *throughput* attributable to a given industry includes the energy used to produce the energy inputs, even if this energy is used in another industry, but not the inputs themselves. Except of cause the transformation industries where the use of energy throughput is only the inputs that are not transformed to new energy commodities.

The changes in the structure of the fuel chain will cause differences in the outcome of these two approaches. The ratio of output to input of energy in an industry could increase because of more careful optimisation of energy use, but it could also be a result of a shift from grid-supply to own supply ("auto-producer") of heat or power. Apparent progress in energy productivity could cover for the reverse shift. Thus, both perspectives are necessary to evaluate the development of energy productivity in each industry.

The gross value added figures of the individual industries are made comparable over time by chain index deflation because this method is more adequate than simple price index deflation for analysis over such long periods where the structure of economic activities unavoidably change.

The major sectors of the economy are the household sector and the industrial sector (including public sector services). The development of their energy productivities are shown in the figures below together with that of the primary industries. Household energy productivity may appear to be a very constructed concept, but households do produce energy services such as driven vehicle-kilometers, heated or lightened building space, etc. with the inputs of energy. The production of these services can be assumed to vary in proportion to the total private consumption.

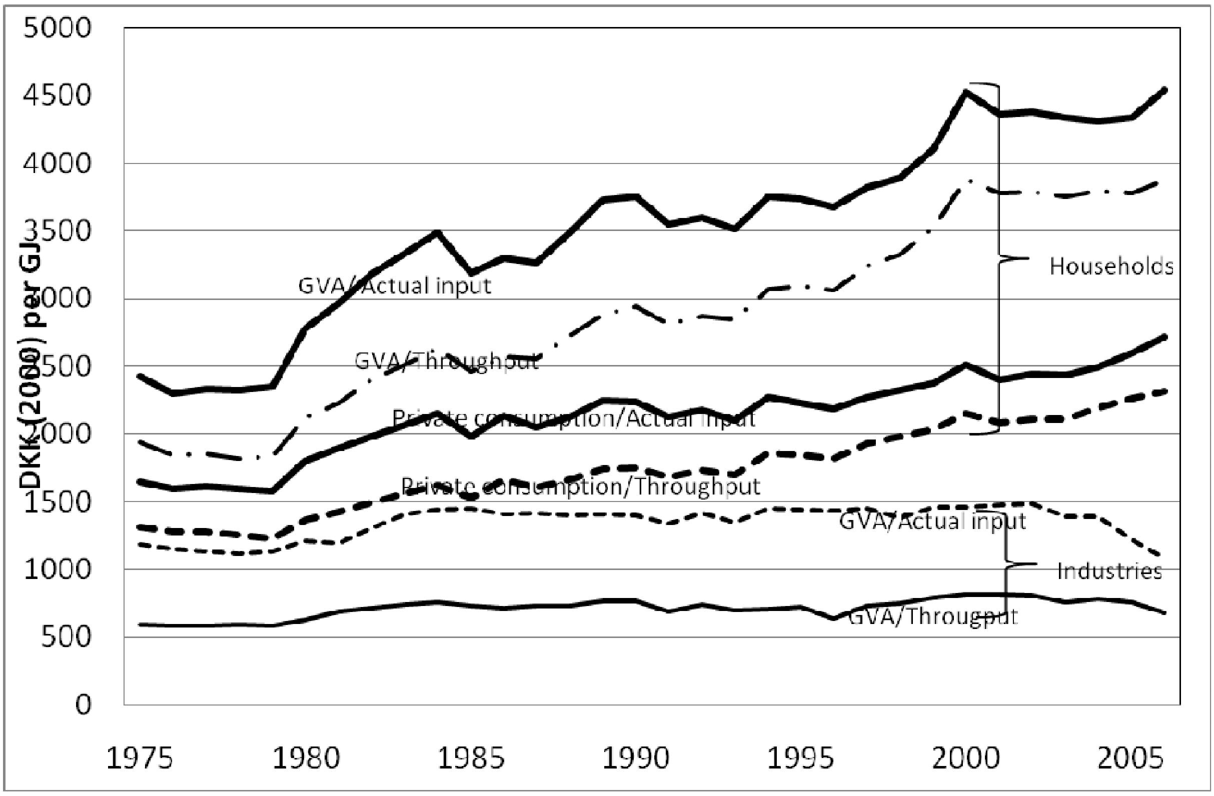

Figure 10. Energy productivity of households and industries in Denmark 1975-2006.

Source: Statistics Denmark, Statistikbanken, 15.05.08, and Author's calculations.

The difference between the productivity rates based on actual inputs and on throughputs of energy is demonstrated clearly in the figure above. The throughput indicator (dotted curves) means that when we add the energy used to produce the energy used by households, we get a smaller energy productivity than if we only use the actual energy consumed by households as denominator.

It could be argued that household energy consumption should be related to their income - that is, the value, GVA, they create in the industries – rather than the share of this income they actually spend on private consumption. In the above figure, productivity rates based on both numerators are shown.

For the energy productivity of households in their production of mobility, heating, lighting, and other energy services, this gives a total of four different productivity indicators, depending on the choice of denominator and nominator. The figure shows that irrespective of these choices

- Household energy productivity has increased considerably from the 70s to the 2000s
- Most of the increase occurred in the second half of the 80s and the second half of the 90s
- Irrespective of the choice of numerator, the conclusion is clear: It is the household use of energy – not the industrial use – that is responsible for the progress in energy productivity of the Danish economy.

Household energy productivity has increased remarkably in either case. Household energy use is

Progress in industrial use of energy seems to have stopped in 1985 and even reversed in recent years. Industrial energy productivity, however, followed the same increase as household energy productivity in the first half of the 80s, but has then remained constant until recently, after 2002, where it has dropped sharply.

This conclusion is, however, the kind of conclusions into which we have to introduce lights and shades. As shown in figure 2, the contribution of industrial activity to delinking depends heavily on whether consumption of foreign bunker fuel is included or not. In the following section, we will isolate energy use as well as value added in transport from other industrial activity.

Energy Productivity with and without Foreign Bunker Fuel Consumption

The following 4 figures show the patterns of industrial energy productivity development based on 4 different definitions of industrial energy productivity:

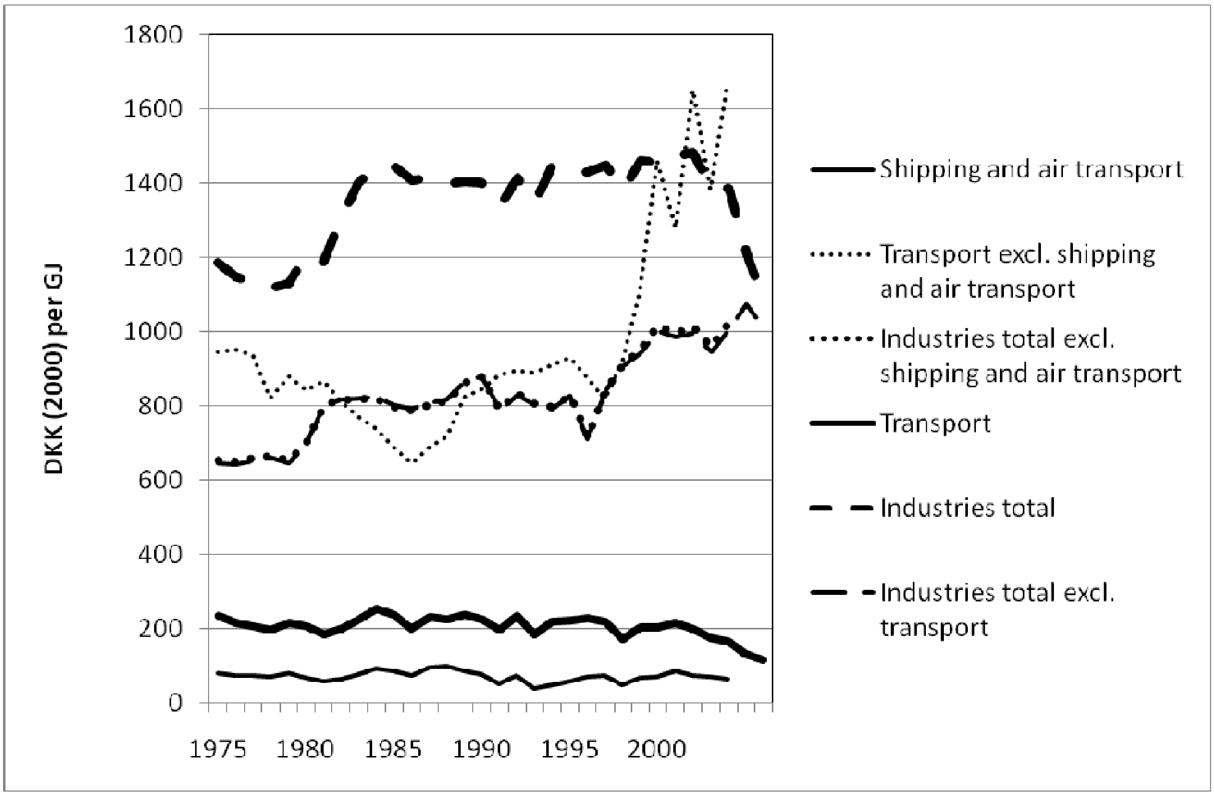

Figure 11. Energy productivity with and without shipping and air transport. Gross Value Added (chain index deflated) per Actual Energy Consumption (input).

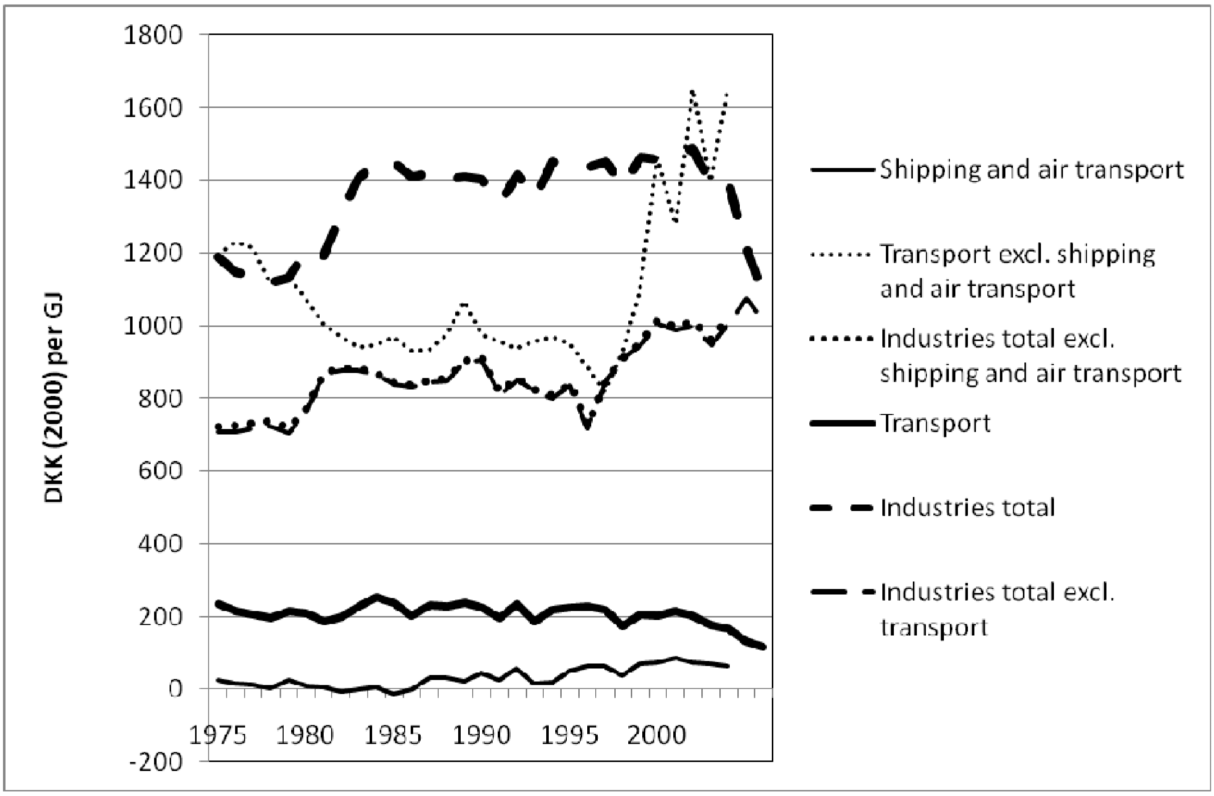

Figure 12. Energy productivity with and without shipping and air transport. Gross Value Added (deflated to 2000 prices) per Actual Energy Consumption (input).

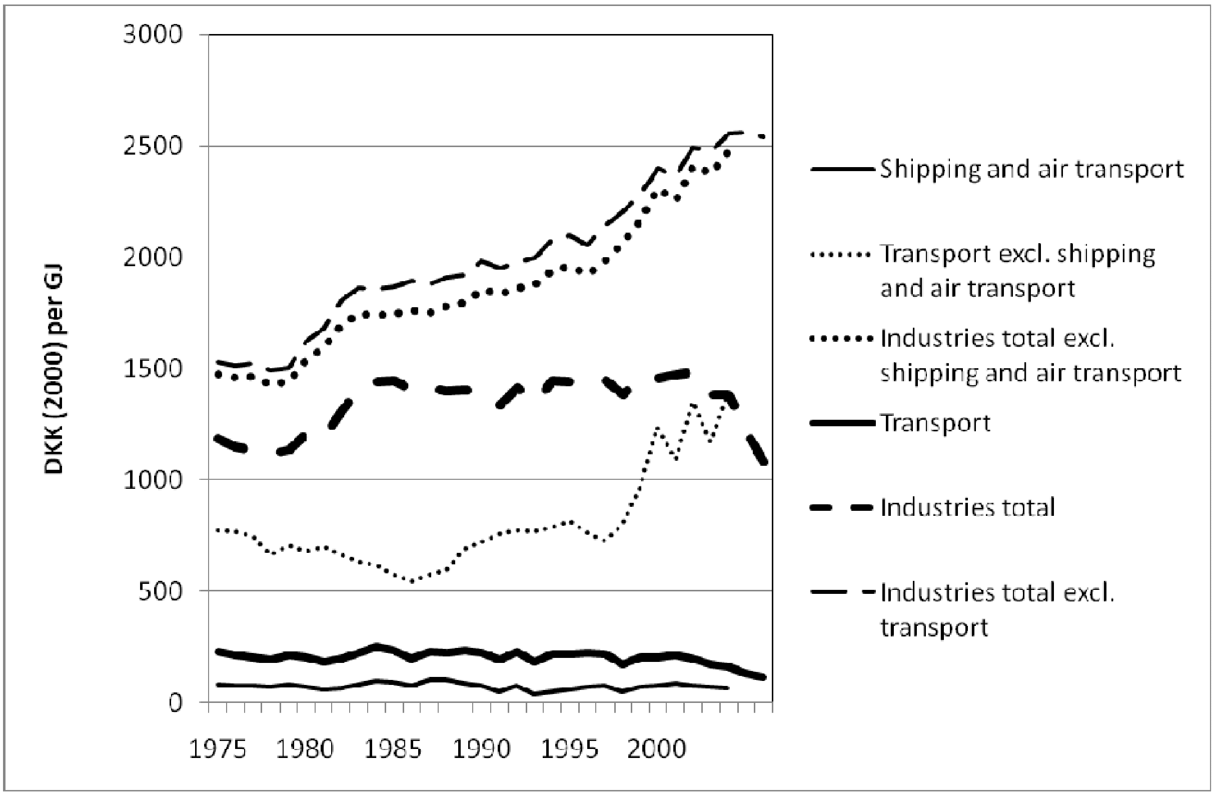

Figure 13. Energy productivity with and without shipping and air transport. Gross Value Added (chain index deflated) per Gross Energy Consumption (throughput).

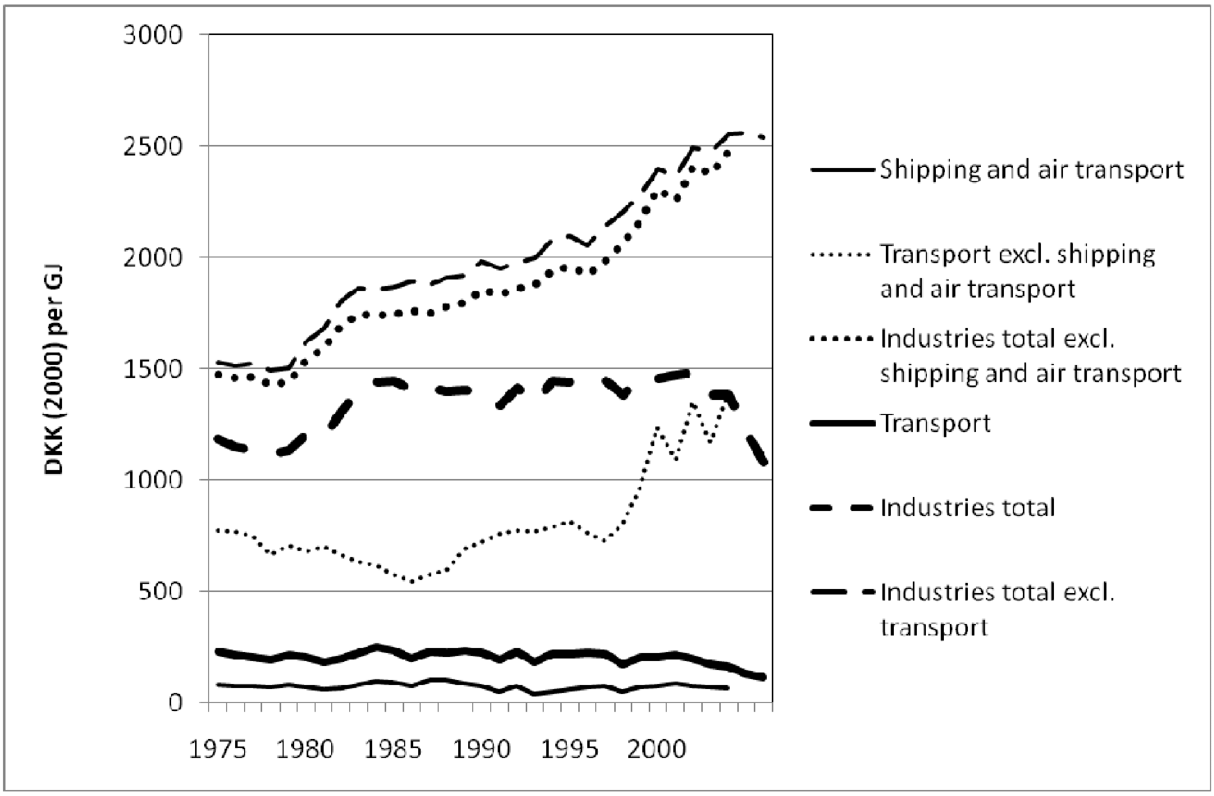

Figure 14. Energy productivity with and without shipping and air transport. Gross Value Added (deflated to 2000 prices) per Gross Energy Consumption (throughput).

The figures show that if shipping and air transport are excluded from the calculations, the energy productivity rate still takes a considerable upswing in the early 80s, but it doesn't stop in 1985. Rather it continues to increase at a more modest pace until the late 90s where it takes another spurt.

Energy productivity in the rest of the transport sector actually developed as a shadow image of the energy productivity of the industrial energy productivity as a whole. It declined until 1985, increased thereafter, and took a considerable jump after 1997. One possible explanation for the latter is that a natural gas pipeline from the natural gas fields in the North Sea to the Danish shore was taken into use after 1997 period and such a pipeline has a very high rate of energy productivity.

However, the development of energy productivity in the transport sector apart from shipping and air transport has very little effect on the rate of industrial energy productivity. Measured with the actual energy inputs, the two rates are identical, whereas measured with the throughput energy the differences are small and the development patterns identical.

The conclusion is that when we exclude shipping and air transport from the numerator as well as the denominator of the energy productivity rate, the energy productivity in industrial energy use has developed quite continuously since the late 70s.

Decomposing Industrial Energy Productivity Progress in the Danish Economy

The question is how important these changes in energy productivity really are to the overall delinking of energy demand from the growth of the Danish economy. Even if the energy productivity of the individual industries was unchanged, delinking could appear as a result of expansion of the most energy efficient industries and contraction of the least energy efficient industries. This could be an integrated part of the changes in the international division of labour and the trend towards a larger share of services in consumption taking place in the period.

To quantify the importance of the energy productivity gains of each industry to the overall delinking of energy demand from economic growth, several variance decomposition analyses have been conducted.

They find unanimously that increase in energy productivity is caused by increasing energy productiovity of eacbh in dustry (the technology factor) rather than by changing industrial structure. Hansen (2002), for instance, reported such findings based on ab analysis of the energy consumption 1966-91 of the Danish economy classified in 16 industries. According to this study the changes in industrial structure from 1966 to 1991 contributed slightly to a more energy efficient economy, whereas the main factor behind delinking of energy demand was the progress in energy productivity in the individual industries.

A similar study by (De Økonomiske Råd 2008) reached identical results for the period 1975 to 2006. From 1966 to 1975 changes in industrial energy productivity led to a higher industrial energy demand. From 1975 to 2006, however, increasing energy productivity helped to reduce industrial energy demand. Changes in industrial structure did, however not induce overall energy savings to any significant amount.

The result of the first decomposition analysis in this study is shown in table 1. It is performed on a 27 industry aggregation level comparing the average energy consumption in the industries in 1975-79 with their energy consumption in 2003. The first column shows what the change in the energy demand of each industry would have been in 2003, had it had the same energy productivity as in 1975-79. The second column shows the difference between this computed hypothetical energy consumption and the actual energy consumption in 2003. The third column shows the energy consumption of each industry if it had the same share of the total gross value added of the Danish economy as it had in 1975-79. That is, in this calculation, the energy productivity is a 2003 vintage, but the industrial structure is the average of 1975-79. The fourth column shows again the difference to the actual energy consumption as an indicator of the energy consumption avoided due to the stronger growth in energy productive industries than in energy intensive industries.

Table 1. Decomposed changes in industrial energy consumption from 1975-79 to 2002-06 assuming constant energy productivity and industrial structure. (PJ).

Computed Industrial Gross Energy Consumption 2003 assuming	1975-1979 energy prodtvt.	Saved (comp. - actual)	1975-1979 indust. structure	Saved (comp. - actual)
Sum of contributions	855	353	631	129
Agriculture, hortic. and forestry	146	96	127	77
Fishing	4	-5	36	27
Mining and quarrying	66	35	3	-28
Mfr. of food, beverages and tobacco	55	13	66	24
Mfr. of textiles and leather	3	0	13	9
Mfr. of wood prod., printing & publ	18	0	25	7
Mfr. of chemicals, plastic prod. etc.	123	81	28	-14
Mfr. of oth. non-metallic min.prod.	31	3	58	29
Mfr. of basic and fabr. metal prod.	53	21	35	3
Mfr. of furniture and mfr. n.e.c.	4	-3	9	1
Electr., gas and water supply	4	-1	4	-1
Construction	14	-5	24	5
Sale & rep. of motor veh. & fuel	5	-3	13	5
Wholesale exc. motor vehicles	59	35	26	3
Retail trade & rep. exc. mot veh.	23	4	31	12
Hotel and restaurants	8	0	8	0
Transport*	118	44	62	-11
Post and telecommunications	17	13	3	-2
Finance and insurance	9	6	3	0
Letting and sale og real estate	3	0	3	0
Business activities	20	5	7	-8
Public administration	18	10	10	1
Education	14	3	11	-1
Health care activities	9	2	7	0
Social institutions etc.	14	2	8	-4
Assoc., culture, refuse dispos.	16	0	12	-4

*Excl. foreign bunker fuel consumption.

The contributions from each industry displayed in table 1 do not sum to the industry total because of the built-in uncertainty in the computing method and very only the large contributions should be used as indicators of energy savings. It does, however, give some magnitudes that are suitable for comparison.

Agriculture has contributed surprisingly much to the delinking because the energy prodyuctivity has increased considerably. Still, agriculture has a relatively low energy productivity and thus the reduction of the share of agriculture in the total economy has improved the energy productivity of the economy as a whole.

Mining and quarrying is an energy intensive industry too, but has increased its energy productivity as the more valuable oil and gas extraction became dominating. Because the industry still is below average energy productive, its larger share of the Danish economy still results in higher energy consumption.

This story is the same for chemical industries as well, whereas the food, non-metallic minerals, and metal industries share the same story as agriculture.

Considerable contributions to the delinking phenomen was also found in the service industries: wholesale, transport, post and telecommunication, and public administration. The transport industry has, however, expanded too, which with its very low energy productivity has contributed to more energy consumption.

In sum, these results reaffirm that the observed delinking is more a result of energy productivity progress in the individual industries rather than of changes in industrial structure. Both trends have, however, contributed.

If foreign bunker fuel consumption had been included, transport would have contributed negatively in energy productivity as well as industrial structure effect. In that case, the energy productivity of transport would have declined since the late 70s and its share of the economy would have increased. Both trends countrer acted delinking.

Moreover, the major changes in the use of energy in the Danish economy seem to have taken place in the energy transforming industries.

Finally, the resulting effects of industry specific energy productivity progress depends on the level of aggregation. The finer the industry classification, the more of the change will be attributed to industrial structure.

For these reasons a decomposition study is undertaken on a 130 industry aggregation level below. This study focus on the effect of a changed industrial structure. The data and method are exactly the same as in the 27 industry analysis except that they are disaggregated into 130 industries.

Table 2. Impact on industrial energy consumption of changes in industrial structure from average of 1975-1979 to 2003 (PJ).

	Computed with 1975-79 industrial structure	**Saved compared to actual energy consumption**
Industry Total	**840**	**339**
Agriculture	106	71
Horticulture, orchards etc	20	11
Agricultural services, landscape gardeners etc	5	1
Forestry	1	0

	Computed with 1975-79 industrial structure	**Saved compared to actual energy consumption**
Fishing	36	27
Extr. of crude petroleum, natural gas etc	1	-26
Extr. of gravel, clay, stone and salt etc	10	5
Production etcof meat and meat products	10	2
Processing etcof fish and fish products	5	2
Processing etcof fruit and vegetables	3	1
Mfr. of vegetable and animal oils and fats	26	24
Mfr. of dairy products	12	5
Mfr. of starch, chocolate and sugar products	6	-1
Mfr. of bread, cakes and biscuits	2	0
Bakers' shops	3	2
Manufacture of sugar	9	5
Mfr. of beverages	12	7
Manufacture of tobacco products	0	0
Mfr. of textiles and textile products	6	3
Mfr. of wearing apparel, dressing etcof fur	3	2
Mfr. of leather and leather products	2	2
Mfr. of wood and wood products	7	1
Mfr. of pulp, paper and paper products	10	2
Publishing of newspapers	2	1
Publishing activities, excluding newspapers	2	0
Printing activities etc	5	2
Mfr. of refined petroleum products etc	126	110
Mfr. of industrial gases and inorganic basic chemicals	1	0
Mfr. of dyes, pigments and organic basic chemicals	2	-2
Manufacture of fertilizers etc	12	11
Mfr. of plastics and synthetic rubber	1	1
Mfr. of pesticides and other agro-chemical products	3	0
Mfr. of paints, printing ink and mastics	1	1
Mfr. of pharmaceuticals etc	1	-4
Mfr. of detergents and other chemical products	3	-1
Mfr. of rubber products and plastic packing goods etc	7	1
Mfr. of builders' ware of plastic	0	0
Manufacture of other plastic products n.e.c	1	-1
Mfr. of glass and ceramic goods etc	11	8
Mfr. of cement, bricks, tiles, flags etc	39	21
Mfr. of concrete, cement, asphalt and rockwool product	13	5
Mfr. of basic ferrous metals	22	21
First processing of iron and steel	1	0

	Computed with 1975-79 industrial structure	Saved compared to actual energy consumption
Mfr. of basic non-ferrous metals	1	0
Casting of metal products	1	-1
Mfr. of constructmaterials of metal etc	3	-2
Mfr. of hand tools, metal packaging etc	4	1
Mfr. af marine engines, compressors etc	3	0
Mfr. of other general purpose machinery	3	0
Mfr. of agricultural and forestry machinery	2	1
Mfr. of machinery for industries etc	2	0
Mfr. of domestic appliances n.e.c	1	0
Mfr. of office machinery and computers	0	0
Mfr. of other electrical machinery and apparatus	3	0
Mfr. of radio and communicatequipmetc	2	0
Mfr. of medical and optical instrumetc	1	-1
Manufacture of motor vehicles etc	2	1
Building and repairing of ships and boats	4	2
Mfr. of transpequipmexclships, motor vehicles etc	0	0
Mfr. of furniture	6	0
Mfr. of toys, gold and silver articles etc	3	2
Recycling of waste and scrap	0	0
Production and distribution of electricity	1	0
Manufacture and distribution of gas	0	0
Steam and hot water supply	1	-1
Collection and distribution of water	3	1
Construction of new buildings	13	6
Repair and maintenance of buildings	6	-2
Civil engineering	5	1
Construction materials		
Sale of motor vehicles, motorcycles etc	4	0
Repair and maintenance of motor vehicles	7	5
Service stations	2	1
Wsand commistrade, excof mvehicles	26	3
Retail trade of food etc	18	9
Department stores	4	1
Resale of phargoods, cosmetic artetc	1	0
Resale of clothing, footwear etc	3	1
Other retail sale, repair work	7	2
Hotels etc	2	0
Restaurants etc	6	0
Transport via railways	5	1

	Computed with 1975-79 industrial structure	**Saved compared to actual energy consumption**
Other scheduled passenger land transport	5	0
Taxi operation and coach services	2	0
Freight transport by road and via pipelines	19	-2
Water transport*	9	-1
Air transport *	35	11
Cargo handling, harbours etc., travel agencies	3	-3
Activities of other transport agencies	1	-1
Post and telecommunications	3	-2
Monetary intermediation	2	0
Other financial intermediation	0	0
Life insurance and pension funding	0	0
Non-life insurance	0	0
Activities auxiliary to finanintermediat	0	0
Real estate agents etc	0	0
Dwellings	1	0
Letting of non-residential buildings	1	0
Renting of machinery and equipment etc	0	0
Computer activexcsoftware consultancy and supply	0	0
Software consultancy and supply	0	-1
Research and development (market)	0	0
Research and development (other non-market)	1	0
Legal activities	1	0
Accounting, book-keeping, auditing etc	1	0
Consulting engineers, architects etc	2	-1
Advertising	1	0
Industrial cleaning	1	-1
Other business activities	1	-3
General (overall) public service activities	2	0
Regulation of public service activities excfor business	1	0
Regof and contribto more efficient operof business	2	1
Provision of services to the community	6	1
Primary education	8	0
Secondary education	1	0
Higher education	2	0
Adult and other education (market)	0	0
Adult and other education (other non-market)	0	0
Hospital activities	5	1
Medical, dental, veterinary activities etc	2	0
Social institutions etcfor children	2	-1

	Computed with 1975-79 industrial structure	Saved compared to actual energy consumption
Social institutions etcfor adults	6	-3
Sewage removal and disposal	1	-2
Refuse collection and sanitation	1	0
Refuse dumps and refuse disposal plants	0	-1
Activities of membership organizan.e.c	1	0
Recreational, cultural, sporting activities (market)	3	-2
Recreat., cultural, sporting activities (other non-market)	3	0
Service activities n.e.c	1	0

* Excl. foreign bunker fuel consumption

The analysis shown in table 2 leads to second thoughts about the distinction between the technology factor (change in energy productivity) and the industrial structure factor (change in the weight of the industries). The more detailed level of aggregation has the result that changes in industrial structure has saved the economy almost three times as much as was the case in the 27 industry analysis. What appeared to be energy productivity progress in the individual industry turns out to be change in the structure of the sub-industries or branches within each industry. Thus, the decomposition analysis shows, first of all, the level of aggregation on which it has been performed.

This doesn't mean that decomposition analysis cannot give any useful results, but one should be very cautious in what to infer from these results.

In this case, we can conclude that the delinking to some degree also is a result of the decline of agriculture and fisheries, organic oil, refineries, fertilizer, cement and brick, and basic iron and steel industries. These industries represent the past of an economy like the Danish, but their products are as necessary as before. Their production is just located somewhere else.

Concluding Remarks

The growth of the Danish economy has led to a proportional growth of inland energy consumption in most of the 20th century. This is not surprising since abundant energy use was the one of the indispensable technical prerequisites for the growth of the Danish and other industrialized or industrializing economies since the 18th century.

The surprising pattern is the sudden break of this link between economic growth and energy consumption in 1980.

This study has investigated the nature of this break with the use of energy productivity indices.

Other OECD economies have experienced similar trends with rising energy productivity since the energy price increases in the 1970s. A comparison of the these reaffirmed that the development of energy productivity in the Danish economy was more significant than what was found in other economies, even when adjusting for disparities in the purchasing power of currencies.

It also led to the notion that large differences in energy productivity do not have to be rooted in differences in the level of energy technology. Some of the differences are simply attributable to the fact that Denmark hosts very little of some of the more energy intensive industries, such as basic iron and steel, basic chemicals and paper industries. Obviously, all countries cannot achieve high energy productivity by not hosting the energy intensive industries on which all modern economies depend.

Another problem is, that the consumption of bunker fuels by ships and aircrafts in foreign ports and airports do not enter the international energy statistics as energy consumption nor in the economy to which the ships and aircrafts belong, or in the economy to which the harbor or airport belong. Including this energy consumption that was necessary to create the value added in the Danish transport industries, changes the picture of delinking fundamentally. This was in particular the case in the recent years where Danish shipping companies have expanded considerable in international transport. This additional energy consumption amounts to almost as much as the inland industrial energy consumption.

If sea and air transport is excluded from the economy (with respect to value added as well as energy consumption), the industrial and household energy productivity have been quite similar in the period from 1975 to 2006.

Earlier studies of the factors behind the delinking conclude unanimously that most of the increase in energy productivity can be explained by increasing energy productivity in the individual industries whereas only little of it can be explained by changes in industrial structure. This study showed, that if foreign bunker fuels are excluded from the economy, changes in industrial structure have a positive impact on overall industrial energy productivity albeit not as much as the energy productivity of each industry. This result, however, depends very much on the level of aggregation. The Danish industries were in this analysis classified into 27 broad industries. Doing exactly the same analysis on data that are classified into 130 industries produced twice as large energy savings resulting from changes in industrial structure towards less energy intensive industries and more industries with a higher than average energy productivity.

Moreover, a considerable share of the progress in energy productivity that seemingly took place in the individual industries, actually took place in the transformation industries.

One inescapable conclusion is that delinking of inland energy from economic growth is too narrow a focus for an energy delinking strategy. The delinking strategy is supposed to accommodate the economy to societal concerns about the vulnerability of the economy to international energy prices or downright energy supply interruptions as well as the environmental damage due to its growth. The close linkages between inland production and energy consumption outside the national territories, dictates that energy delinking strategies must have a strong lifecycle and international component to contribute to the corresponding societal goals.

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