ENERGY EFFICIENCY AND COMPETITIVENESS

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INTRODUCTION AND CONCLUSIONS

The main theme of this article is the relationship between the energy efficiency[1] of Danish industry and its international competitiveness. The analysis shows that Danish firms are among the most energy-efficient in the world – in both the industrial sector and the economy overall. This has required substantial investments in new technology.

Producer prices depend, inter alia, on the price of the energy consumed in production. The more energy-efficient the production in a country or an industry, the smaller the effect of a change in energy prices on producer prices, quite simply because energy accounts for a smaller share of total production costs (volume effect). Conversely, rising energy prices will, per se, expand the share of energy of total costs, meaning that a further increase in energy prices will have a stronger impact on producer prices, i.e. higher price sensitivity (price effect). The effect of rising energy prices on energy sensitivity has outpaced greater energy efficiency in the past 15 years, implying that price sensitivity has not only increased in Denmark but in most countries. One exception is the USA, which has benefited from the discovery of shale gas. This has resulted in a sharp downturn in energy prices in the USA and is boosting US welfare but not competitiveness, as the discovery of shale gas, all else being equal, will result in dollar appreciation.

High energy efficiency, and thus low energy price sensitivity, strengthens Denmark's competitiveness if energy prices rise because the pass-through to producer prices at a given composition of production is less pronounced in Denmark than in the competitor countries. Oil prices have nearly quadrupled over the past 10 years, boosting the wage competitiveness of Danish industry by approximately 9 per cent, equivalent to a reduction in hourly wages of kr. 27. This development has coincided with the Danish economic boom in the period 2005-08, and the higher rate of wage increase in Denmark than abroad during this period should be seen in the light of this competitive gain.

The calculations also support a subsiding effect on competitiveness. The reason is that foreign countries are slowly catching up with the high energy efficiency of Danish industry, as it is far easier and cheaper to invest in a proven technology than to develop a new one. Thus, it is increasingly difficult to maintain a competitive edge.

The calculated effect on competitiveness is a snapshot given the degree of energy efficiency. However, getting to that stage has required preceding investment in energy-saving technology, which may in itself have put pressure on firms' competitiveness. This aspect has not been allowed for in the analysis.

1 E.g. measured as the number of consumed energy units per unit of real GDP produced.

GLOBAL ENERGY EFFICIENCY

Global energy consumption has been increasing throughout history. In the past couple of decades, most of the increase has been attributable to medium-income countries, not least emerging economies such as China and India. These economies account for around 90 per cent of growth in global energy demand, and there are no signs of any considerable change in the years ahead.[2]

Energy consumption per capita is very unevenly distributed across countries, which not only masks pronounced variations in living standards but also considerable differences in the efficiency of energy utilisation in production, cf. Chart 1. Overall, production in advanced economies is more energy-efficient than in emerging economies. Iceland deviates from this pattern since its production is not very energy-efficient. This reflects the country's ample opportunities for using geothermal energy and its large energy-intensive aluminium production. This underscores the fact that country-specific factors may come into play, especially in less diversified economies. The highest energy consumption per output unit is found in iron and steel production and in the petrochemical and paper industries, which explains why Finland, with its substantial paper industry, comes in higher than the other Scandinavian countries.

Overall, the international focus on energy-efficient production has increased. For example, the energy intensity of Chinese industry has declined from four times the global average in 1990 to slightly more than two times today. Paradoxically, the greater the energy reduction in global production, the greater the probability of a downward pressure on energy prices which, viewed in isolation, will make energy investments less profitable. However, to the present, underlying economic growth, and hence higher demand for energy, has prevailed with a resultant surge in energy demand.

Over time, most countries have thus tended to increase the energy efficiency of their production. Improved energy efficiency can contribute to curbing emissions and pollution without having an adverse impact on economic growth. Moreover, the large differences across countries indicate that there is ample opportunity for increasing energy efficiency by spreading proven technologies to more countries and industries. However, since this requires substantial investments in new capital stock and a change of production methods, the development is fairly slow. In addition, there may be political barriers. It takes time for investments in environmental technology to become profitable. For the most energy-efficient countries, further improvements often call for the development of new technologies, which takes time.

It has required considerable investments in energy-saving technology for Danish firms to become so highly energy-efficient in an international context. These investments may have been prompted by Denmark's long-term focus on the problem and more extensive use of a variety of quantitative instruments than in foreign countries, such as emission restrictions, statutory requirements for technical standards, monitoring etc. On the other hand, energy taxes, on e.g. electricity, for industrial firms are not particularly high in Denmark by international standards, cf. Chart 2.

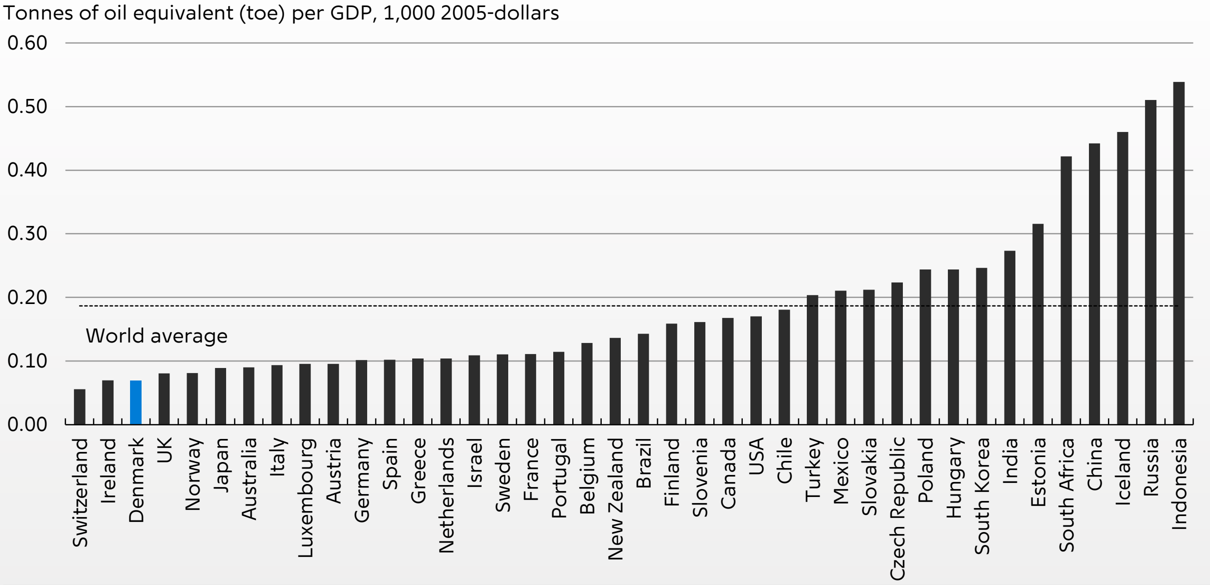
SENSITIVITY OF FINAL GOODS TO CHANGES IN ENERGY PRICES

The more sensitive producer prices are to changes in energy prices, the more vulnerable production and the country are to rising energy prices. It might be expected that the more energy-efficient the production of a country or an industry is, the smaller the effect of a change in energy prices will be on producer prices, quite simply because energy accounts for a smaller share of total production costs. However, the share of expenditure spent on energy, and hence price sensitivity, also depends on the level of energy prices, and in spite of energy being traded in a global market pronounced national differences may exist due to variations in prices of energy from different sources. Based on

2 Cf. International Energy Agency, World Energy Outlook, 2013

Energy intensity in production in a number of countries, 2011

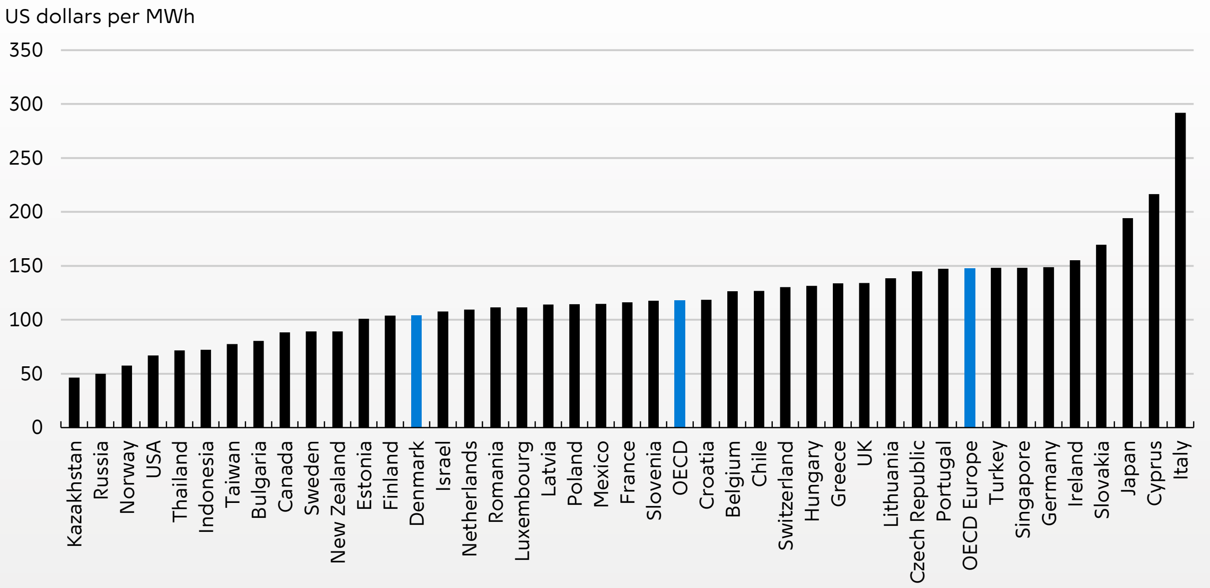
Chart 1



Note: The figures show the energy efficiency of the overall economy.
Source: OECD.

Electricity prices for firms, 2012

Chart 2



Note: Prices indicate the average price paid by firms in manufacturing industry. In Denmark, electricity prices vary from firm to firm due to variations in energy taxes.
Source: International Energy Agency.

Direct and indirect expenditure for primary energy in production, by sector Table 1

Per cent	GVA share in Denmark	Energy expenditure as percentage of output value, i.e. energy price sensitivity					
		Denmark			Abroad		
	2011	2000	2005	2011	2000	2005	2011
Agriculture	1.6	4.8	7.7	12.5	5.9	7.7	8.6
Mining and quarrying	4.2	0.8	1.1	2.1	7.0	8.7	8.7
Total industry	12.8	2.6	3.4	5.5	5.2	6.3	6.9
Including:							
Food	1.8	3.7	4.9	8.5	5.2	6.5	7.3
Textiles and leather	0.1	1.0	1.0	1.0	1.1	1.1	1.1
Wood	0.2	2.7	3.5	5.9	5.6	7.2	8.1
Paper and printing	0.9	2.1	2.9	4.3	5.2	6.6	7.5
Mineral oil	0.2	6.9	9.9	11.1	6.0	7.8	8.0
Chemical products	1.6	3.1	3.4	6.0	8.8	11.0	12.5
Rubber and plastics	0.5	3.0	3.9	5.7	6.3	8.2	9.4
Stone, clay and glass	0.4	4.8	5.8	10.8	7.8	9.5	10.6
Metals	1.2	2.7	3.3	5.6	6.8	8.3	8.9
Machinery	1.7	2.0	2.6	4.8	4.3	5.2	5.6
Electronical equipment	2.0	1.8	2.5	3.8	3.9	4.6	5.0
Transport equipment	1.4	1.1	1.1	1.2	1.2	1.3	1.3
Furniture, etc.	0.6	2.4	3.3	4.8	4.7	5.9	6.5
Energy and water supply	1.6	3.0	3.8	9.1	4.0	4.8	4.7
Construction	4.8	2.4	3.0	4.9	4.3	5.0	5.7
Transport	5.5	5.3	8.1	14.1	7.1	8.6	9.8
Service and public sectors	69.5	1.5	1.8	2.7	2.5	2.8	3.0
Economy overall	100.0	1.9	2.3	3.5	3.3	3.8	4.0

Note: GVA is gross value added and is a measure of total value creation in Denmark, split into industries. Direct and indirect energy expenditure comprises both domestically manufactured energy and imported energy. The coefficients also show the sensitivity of producer prices to energy prices. Energy expenditure relative to output value is calculated as column 6 in Table 7.E.1 in the publication Statistics Denmark (2009), Danish Input-Output Tables and Analyses 2009, based on the World Input-Output Database (WIOD). Adjustment has been made for the energy sectors' energy input to energy production by omitting energy input from one energy sector to the same energy sector. Abroad comprises the 27 countries included in the effective krone rate index, excl. Norway, Switzerland, Iceland, Hong Kong and New Zealand, and is weighted using the weights from here, cf. Table 2.
Source: World Input-Output Database and own calculations.

national accounts statistics such as input-output tables, price sensitivity can be calculated at both country and sector level[3], see the Appendix for details. Calculations are based on basic prices, i.e. exclusive of direct output taxes, so differences in national tax policies do not have a direct but probably an indirect impact.

Calculations show that in 2011 energy expenditure accounted for 5.5 per cent of the output value in Denmark against 6.9 per cent in competitor countries, cf. Table 1. In other words, producer prices increase by 5.5 per cent in Denmark and by 6.9 per cent abroad if energy prices double. These figures take into account not only direct energy consumption, but also indirect consumption from production of the intermediate goods used. Energy intensity of imports has also been accounted for. In consequence, if energy-intensive production is relocated from Denmark to, for instance, China and the output is imported in the form of intermediate goods, this will have an adverse impact on Danish energy accounts. However, imports of final goods will not entail any impact. If energy-intensive production is relocated to less energy-efficient countries with no subsequent decline in demand for the final goods, global energy efficiency will also decline even though, viewed in isolation, it increases in Denmark.

Danish production is more energy-efficient in almost all key industrial sectors, although the picture is slightly blurred in the most recent data from 2011. Thus, the high energy efficiency of the Danish industrial sectors is not only a result of firms in particularly energy-intensive industries having relocated abroad. However, the business structure does have a bearing on the result. Mature economies such as Denmark typically have a large, not very energy-intensive service sector. A standard calculation shows that if Denmark's business structure is applied to foreign countries, it would not significantly change the calculated coefficients for the overall economy as long as the krone rate weights are used. However, viewed in isolation, the overall energy intensity of a country such as China declines substantially, weighted by the Danish business structure.

Among Denmark's competitors, China and the Eastern European countries, for example, are most sensitive to energy prices, while Ireland is the least sensitive country, cf. Table 2. The USA and the UK are not very sensitive either. Both countries are advanced economies in which a not very energy-sensitive service sector plays a large role. Measured by industry alone, the USA also has a low level of sensitivity, and unlike most other countries the USA has managed to improve its energy efficiency in recent years. This may reflect the fact that energy prices are generally lower by virtue of, among other factors, the continually increasing production of shale gas, cf. below. Thus, two factors come into play: the business structure and the level of energy prices.

Historically, energy prices have been increasing, both in nominal and real terms, and often more than for other types of input. This has resulted in a higher energy share of total input costs even though energy efficiency has improved. At the same time energy prices are cyclically sensitive. Both factors are reflected in the calculated sensitivities which, since the mid-1990s, have increased both in Denmark and abroad and both in the industrial sector and in the overall economy, cf. Chart 3, left.

Basically, Danish production, including industrial production, is less sensitive to energy prices compared with foreign countries, but the gap has narrowed in the past 15 years, among other factors because the USA, China and the UK, which carry strong weights in the calculation of the effective krone rate, have managed to reduce their sensitivity to energy prices. This is largely explained by a "catching-up effect" with energy-efficient technology being spread globally. It is much cheaper to use proven technology than to develop new technology. In the past few years in particular, with Denmark struggling to emerge from the recession, the energy share of Danish production has increased. This is partly due to the low level of investment, including in energy technology, since the financial crisis, but the main reason is

3 Cf. Pedersen, Erik Haller and Johanne Dinesen Riishøj (2009), Energy efficiency and competitiveness, Danmarks Nationalbank, *Monetary Review*, 4th Quarter 2009.

Direct and indirect expenditure for primary energy in production, by country

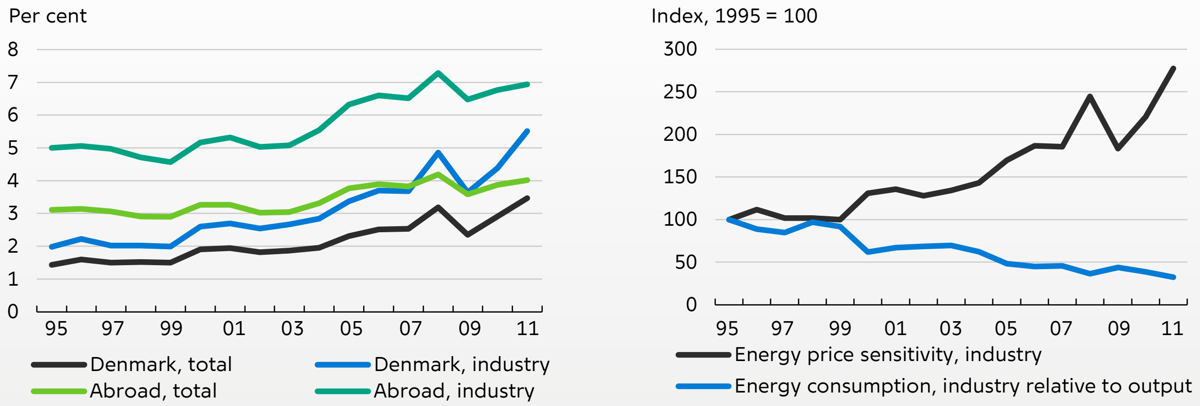
Table 2

Per cent	Weight in effective krone rate	Energy expenditure as percentage of output value, i.e. energy price sensitivity					
		Economy overall			Industry		
	2011	2000	2005	2011	2000	2005	2011
Germany	21.2	2.3	2.7	3.2	4.2	5.2	5.8
Sweden	10.2	2.7	3.2	3.4	3.2	4.1	4.6
USA	9.8	3.2	3.3	2.8	5.3	5.7	4.4
China	8.2	8.9	12.1	10.0	11.8	17.3	15.2
UK	7.3	2.0	2.4	2.1	3.6	5.2	4.9
France	5.8	2.4	2.5	3.0	4.3	5.0	7.0
Netherlands	5.5	2.6	3.1	4.2	4.3	5.6	7.5
Italy	5.1	3.1	3.4	4.0	5.9	6.7	8.2
Belgium	4.4	3.9	4.4	5.2	7.2	8.0	10.3
Japan	4.1	4.2	4.7	5.5	6.8	8.0	10.5
Spain	2.8	4.3	4.7	5.3	7.0	8.4	10.8
Poland	2.8	6.8	6.9	7.9	8.2	8.6	10.1
Finland	2.4	4.1	5.2	6.2	4.5	5.7	7.5
South Korea	1.9	7.3	8.1	11.5	10.9	13.0	17.9
Austria	1.7	3.1	3.6	4.5	3.9	5.2	6.6
Czech Republic	1.6	7.1	6.7	6.1	8.8	9.0	8.6
Ireland	1.4	2.2	2.7	2.8	2.4	3.4	3.2
Hungary	1.1	6.9	6.7	8.0	10.4	9.8	11.7
Canada	1.0	3.2	3.5	3.4	4.9	5.9	5.5
Portugal	0.6	3.7	4.7	4.5	4.8	6.8	6.7
Australia	0.7	3.3	3.3	3.1	5.1	5.1	4.9
Greece	0.4	3.9	4.3	3.7	6.9	8.8	8.7
Abroad, total	100.0	3.3	3.8	4.0	5.2	6.3	6.9
Denmark		1.9	2.3	3.5	2.6	3.4	5.5

Note: The weight calculation is based on the weights for the nominal effective krone rate. However, for data reasons, Norway, Switzerland, Iceland, Hong Kong and New Zealand have been left out. The weights have been re-standardised in order to adjust for this.
Source: World Input-Output Database and own calculations.

Energy price sensitivity (left) and energy consumption relative to output value in Danish industry (right)

Chart 3



Note: Left-hand chart: Energy price sensitivity is determined as expenditure for the energy used for production relative to the output value. Both are measured by basic prices, i.e. exclusive of direct production taxes.
Source: World Input-Output Database, Statistics Denmark and own calculations.

the rise in energy prices since 2010. Thus, Denmark's underlying energy efficiency is still being improved, cf. Chart 3, right.

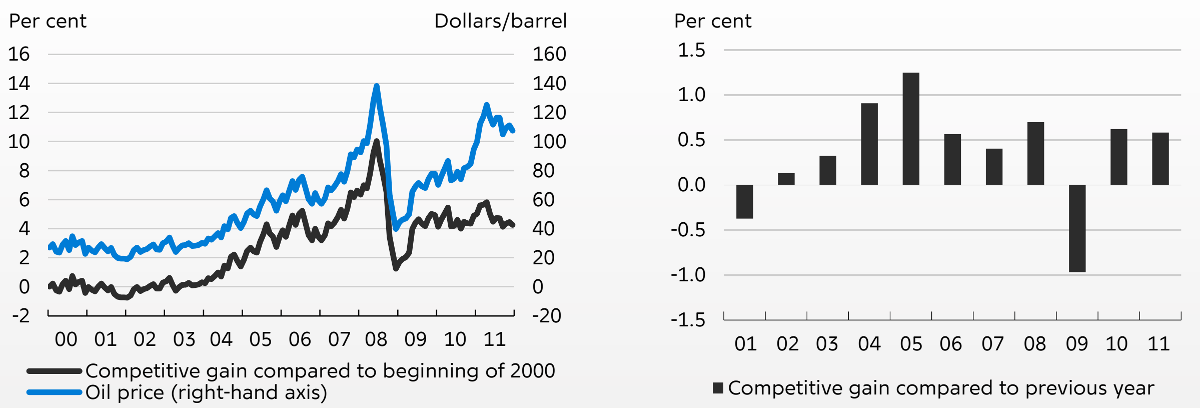
ENERGY EFFICIENCY AND COMPETITIVENESS

Higher energy prices have a smaller impact on producer prices in Denmark than in competitor countries due to the high energy efficiency of Danish production. In other words, Denmark's competitiveness improves when energy prices rise. In 2011, the energy content of industrial production was 5.5 per cent. This means that the firms' input costs increase by 5.5 per cent if energy prices rise by 100 per cent. Therefore, producer prices rise by a similar rate if volume effects are disregarded. For Denmark's foreign competitors, the figure is 6.9 per cent, entailing that prices of foreign goods increase 1.4 per cent (6.9 – 5.5) more than Danish goods when energy prices double.

The effect on competitiveness is potentially appreciable, cf. Chart 4, left and right. If calculated using the above method, the improve-

Competitiveness and oil price (left) and annual competitive gain (right)

Chart 4



Note: "Competitive gain compared to beginning of 2000" has been calculated by multiplying the increase since January 2000 by the annual difference in energy price sensitivities between Denmark and abroad. In "Competitive gains compared to previous year", the oil price increase over the past year has been multiplied with the difference in energy price sensitivity.
Source: Reuters EcoWin for oil prices and own calculations.

ment was 4.3 per cent in the period up to 2011 when oil prices nearly quadrupled, while foreign countries in the same period caught up with Denmark's energy efficiency. Wages and profit account for 48 per cent of producer prices in the economy while the remainder is input of raw materials, intermediate goods, imports and producer taxes. With an hourly cost of kr. 300 in the industrial sector, the reduction in hourly wages at an unchanged profit ratio is calculated at kr. 27 per hour (0.043*300/0.48), corresponding to a gain of 9 per cent measured by wage competitiveness.

The effect on competitiveness of rising energy prices has eased in recent years, due to a narrowing of the gap in energy intensity between Denmark and abroad.

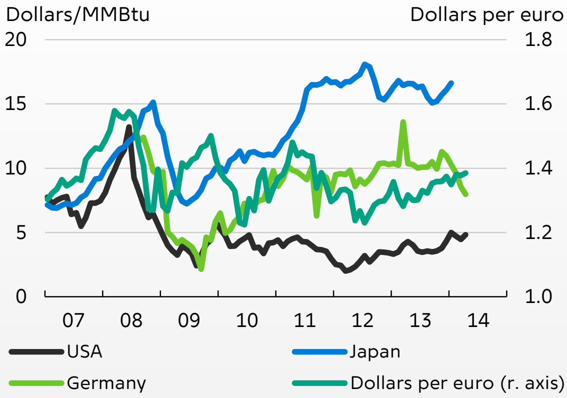
Denmark's export of energy technology has grown to slightly more than kr. 60 billion in 2013, half of which is green energy technology such as renewable energy plants.[4] In the past 10 years, Denmark has experienced the strongest export growth in this field in the EU, implying that Danish industry has been able to exploit the growing international demand in the area. It should be noted, however, that the government has granted substantial subsidies to this area.

In recent years, the USA has started to exploit a new source of energy on a large scale: shale gas. This supply shock has resulted in US gas prices falling to a considerably lower level than in the EU and Japan, cf. Chart 5. One of the reasons why prices have not been cancelled out is that US energy exports are subject to fairly stringent restrictions.

At first glance, the new energy resource seems to boost US welfare; however, viewed in isolation, it will erode US competitiveness. There is a risk that the new resource will merely increase the consumption of cheap energy rather than translate into investments with long-term benefits. The dollar will tend to appreciate, in nominal as well as real terms, in step with increased purchasing power of the economy as a consequence of the shale gas. This will result in a tighter labour market and

4 Cf. Danish Energy Agency, www.ens.dk.

Gas prices and dollar rate versus euro Chart 5



Note: MMBtu is an energy measure. The left-hand axis shows gas prices in dollars per energy unit. Prices are stated as the spot price at the end of each month. The following indices have been used: USA: Henry Hub, Japan: LNG Japan Corp and Germany: NCG Hub.
Source: Bloomberg.

higher wage increases. Such real appreciation will impede other competitive industries. This phenomenon is also called "Dutch disease" and is known in many resource economies, for instance Norway. It should be noted that the US economy is too large and diversified to be categorised as a resource economy. Add to this the dollar's status as the world's reserve currency, the exchange rate of which is largely determined by movements in the capital account and, to a lesser extent, in the trade balance. Thus, the relationship between energy prices and the dollar rate may be quite blurred, masking the fact that the dollar, all else being equal, appreciates as a result of the shale gas.

The Danish economy has also been impacted by oil extraction. Oil production really took off in the 1990s and has contributed to the large current account surpluses and thereby an accumulation of foreign assets. The return on foreign assets has contributed to growth in purchasing power in the economy, entailing a Danish rate of wage increase that, for a period of time, exceeded that abroad with a resultant erosion of wage competitiveness.

The energy intensity of the economy is of significance to the pass-through of energy price rises to consumer prices. In Denmark, the direct and indirect energy content of private consumption was 5.61 per cent in 2007, which is the most recently published figure.[5] The figure is based on current prices including direct and indirect taxes. A tripling of the energy price, corresponding to an increase of 200 per cent, would, all else being equal, imply that prices of private consumption measured by the consumption deflator would rise by more than 10 per cent (2*5.61). A number of assumptions have been made to arrive at the coefficient of 5.61, including that the same technology is used in Denmark and abroad and thereby in imports, i.e. that the energy share of the manufacture of a product is identical for all countries.

APPENDIX

AN INPUT-OUTPUT PRICE MODEL

An input-output table shows the inputs to production for all industries in the economy and how the inputs are used for production of final output. Based on such a table, a price model may be developed showing the direct and indirect energy consumption in the production of the industries. The model allows for energy consumption in the production of intermediate goods which end up as final output through the value chain.

In practice, a matrix representation is used in a model based on the method developed by Wassily Leontief.[6] In the World Input-Output Database, the production sector is split into 35 industries and the input-output table is therefore a (35x35) square matrix, Z, with $z_{k,j}$ being industry k's input to industry j:

$$\mathrm{Z} = \begin{pmatrix} z_{1,1} & \cdots & z_{1,35} \\ \vdots & \ddots & \vdots \\ z_{35,1} & \cdots & z_{35,35} \end{pmatrix} \qquad (1)$$

The value of final output in industry j, x_j, is created on the basis of intermediate goods from other industries, including energy, v_j, which is made up of input from mineral oil and electricity, i.e. industries 8 and 17 in the input-output table. The calculations take the energy used to manufacture intermediate goods into account. This is expressed in matrix form where final output and value added for all industries are gathered in vectors[7]:

$$x_j = \sum_{k=1}^{35} z_{k,j} + v_j \Rightarrow \mathrm{x}' = \mathrm{i}'\mathrm{Z} + \mathrm{v}' \qquad (2)$$

In relation (2) x' is a vector consisting of the final output in each industry, and v' is a vector with the use of energy input in each industry. Now the (35x35) square matrix, A, is introduced where the elements, $a_{k,j}$, show industry k's input to industry j as a share of industry j's final output. Since input to production is a share of final output in each industry, we arrive at the relation, $\mathrm{Z} = \mathrm{A}\hat{\mathrm{x}}$, where $\hat{\mathrm{x}}$ is a diagonal matrix[8] with the industries' final output in the main diagonal, and v'_c is a vector with shares of energy input in the production for each industry so that we get the following relation:

$$\mathrm{x}' = \mathrm{i}'\mathrm{A}\hat{\mathrm{x}} + \mathrm{v}' \Leftrightarrow \mathrm{x}'\hat{\mathrm{x}}^{-1} = \mathrm{i}'\mathrm{A}\hat{\mathrm{x}}\hat{\mathrm{x}}^{-1} + \mathrm{v}'\hat{\mathrm{x}}^{-1} \Leftrightarrow \qquad (3)$$

$$\mathrm{i}' = \mathrm{i}'\mathrm{A} + \mathrm{v}'_c \qquad (4)$$

A technical operation is required in order not to double count the energy sectors' input to production. In the article we have decided to assume that the energy sectors do not supply energy for own production. In this way we allow for country-specific and year-specific differences, which is the main focus of the article. However, it is likely that a minor energy share appears several times and that the individual energy sectors are not assigned the right energy consumption of own production.

In relation (4) the right-hand side shows input costs per unit of final output. It is assumed that prices can basically be standardised to ensure that the prices of final output are identical

5 Cf. Statistics Denmark (2009), Danish Input-Output Tables and Analyses 2009, p. 126

6 Blair, Peter D. and Ronald E. Miller (2009), Input-Output analysis - foundations and extensions, *Cambridge University Press.*

7 i' is a vector containing the number 1 on each coordinate.

8 With the dimension (35x35).

with the total production costs in the individual industries. In other words, the relationship between producer prices and input costs is 1, which is used to create a vector with a price index for the industries, so that $p' = i'$. Thereby, a price index is achieved showing how much the prices of the final output in each industry increase when energy prices and/or volumes rise:

$$p' = p'A + v'_c \Leftrightarrow p' = v'_c(I - A)^{-1} \qquad (5)$$

Tables 1 and 2 in the article show the energy sensitivities of the various industries in Denmark and abroad. With energy sensitivities of 5.5 and 6.9 in industry in Denmark and abroad, respectively, in 2011, Danish producer prices of industrial products increase 1.4 per cent less[9] in Denmark than abroad when energy prices – approximated by oil prices in the article – rise. This is considered a competitive gain.

In several cases, the industries are composed of several sub-industries. To obtain overall goals for the main industries based on a definition that is consistent with Statistics Denmark's breakdown, the energy sensitivity of the main industries is a geometric average of the sub-industries' energy sensitivity where the sub-industries' shares of gross value added in the main industry are used as weights.

Similarly, the energy sensitivity abroad is calculated as a geometric average of the 27 countries included in the krone rate index, in which the re-standardised krone rate weights[10] are used as weights. The weighting has been made to obtain the best comparable measure of Danish competitive gains.

9 6.9 less 5.5.

10 Norway, Switzerland, Iceland, Hong Kong and New Zealand have been excluded for data reasons.