Spillovers of R&D Expenditure on Energy Use in the EU-countries: Empirical Modelling of Energy Demand[1]

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Abstract. This paper explores sets of equations explaining demand of energy in the framework of a large-scale annual E3 model for the EU, the E3ME. The equations are estimated for 17 fuel users in each EU member country using cointegration and error correction method. The estimation period is 1970-95. Use of energy in Th.toe/output at costant prices in a fuel user (17) is explained by real energy price, R&D variables, and by investment in a fuel user. R&D variables take into account following factors: (1) Own R&D expenditures and (2) Rent spillovers from the industrial and office machines as well as electrical goods producing industries in the whole EU; in the case of transportation from transport equipment producing industry. It is assumed that R&D in those capital goods producing industries has main spillovers for energy saving in the 17 fuel user sectors.

Keywords: energy demand, R&D expenditure spillovers

Executive Summary

The main features, conclusions and recommendations of this paper concern impacts of research and development activities on energy efficiency.

The causal chain starting from R&D incentives for energy efficiency and going through R&D expenditures, patents, technological progress, and finishing in unit energy savings is considered to be a vital impact channels in evaluating economic policy measures to improve energy efficiency and to decrease GHG-emissions. A crucial problem is to have rational classifications and available data for the study. Statistics on R&D expenditures and on energy efficiencies in industries are then determining factors.

R&D expenditures are available by fuel users in the E3ME, but they refer to total R&D expenditures and those expenditures used for energy efficiency improvements are only a part of those expenditures. Much of the potential for changing the production process through unit energy consumption is dependent on the availability of advanced technology embodied in machinery and equipment. These capital goods are manufactured only to a small amount within the industry using energy. Most of capital goods are produced in a few industries, which supply them to all sectors of the economy. The energy saving potential is then dependent very much on the results of external R&D expenditures, which is incorporated in capital goods. They are purchased by investing sectors, which innovate their production processes. The amount of investment in advanced technologies has an impact on the input structure and the efficient use of resources.

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[1] Paper will be presented at the XIII International Conference on Input-Output Techniques at University of Macerata, Italy August 21-25th, 2000.

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In many areas of activity energy saving technology is not in the focus but a side effect, even if energy is a noteworthy input factor for the production. Therefore beside R&D on energy saving total investment must be taken into account when we try to explain a reduction of the specific energy consumption.

The innovations of the products of capital goods industries have turned out to be major importance on unit energy consumption. The spillovers of innovation can be revealed by a converter matrix, which quantifies the supplier-buyer-relationship. However, this approach could not be used because of data difficulties, but econometric estimation of energy demand equations was used. The approach provides an explanation of the reduction of the unit energy consumption induced by investment in advanced machinery and equipment.

An industry's upstream linkages to suppliers of intermediate inputs also contribute to a reduction of the unit energy consumption. The individual decrease in energy consumption might then be small and difficult to identify. The impact of the innovation of intermediary inputs on the specific energy consumption is more or less a steady flow of improvements that results in a trend of reduction over time.

Public action and oil prices follow each other rather closely. Average oil prices changes are often followed by the corresponding changes in public economic measures. It is then difficult to separate the influence of these two factors on energy efficiency. The problem is relevant also when we want to separate the effects of research and development costs on improvements of energy efficiency.

Energy saving explaining factors have more significant effects in long-term than in short-term. This is natural because particularly research and investment has long-term characteristics. Real energy price long-term effects are significant in as many cases as other variables indicating long-term characteristics, too. However, they have most significant effects among short-term ones showing their short-term sense, too.

Fuel users' own research and development contributes to energy saving in long-term. Spillovers of R&D expenditures in industrial and office machines and also in electrical goods producing industries on unit energy use are mostly positive This indicates that research and development work in these industries is probably directed into inventions of new products without paying attention to energy saving characteristics of machines. However, negative impacts, indicating energy saving properties, are more common when the estimates by region are analysed. It seems that energy saving characteristics have been considered more while developing new models in transport equipment producing industries. The spillovers have energy saving impacts on the following fuel user sectors: rail transport, road transport, and households. Long-term estimates for investment demonstrate energy saving impacts in most cases. We can then conclude that investment and new technology used will save energy for the most fuel users. When new machines substitute old ones energy per output is usually saved but if they compensate labour, use of energy per output might increase.

Accuracy of the estimates is affected by the operational choice of explaining variables. Real energy price is a good and accurate operational equivalent for showing relation between costs of energy and other inputs. Own R&D expenditures include also other costs than those related to energy inputs. These costs may be used to develop new products or improving quality of old products without taking into account use of energy input. This concerns also the measures used for describing spillovers of R&D expenditures. Investment includes all kinds of capital goods. All these deficiencies affect the accuracy and reliability of the estimates. These reservations concern also the policy conclusions based on the results of the estimates.

1. Background for analysis

1.1 Purpose of the Paper[3]

Objectives of the paper are to assess the links between R&D expenditure and energy efficiency in the context of energy demand. The task of the paper is then to generate an econometric test of the correlation between the use of energy and real energy price, R&D expenditures, and investment. Measuring technology spillovers and deficiencies in measuring will then be a main problem to be dealt with.

1.2 Spillovers of R&D expenditures

There are several rather general reasons for research and development expenditures concerning also development of energy efficiency:

- Firms have to invest in research and development in order to stay in business
- Subsidies are available for research and development expenses.
- Relative prices of inputs are changing, in particular fuel prices are increasing
- Restrictions have been placed for emissions

Information on reasons for R&D incentives is mostly based on theoretical considerations. Empirical studies are scarce, so it seems reasonable to write only some general opinions on this issue based on literature.

The main driving force for technological progress, considered as endogenous factor in new growth theory, is research and development expenditures. The externalities connected with an innovation are important when the impacts of R&D expenditures on other industries are analysed. Two kinds of spillovers are usually separated (distinction developed by Grilichers (1979)):

> Rent spillovers occur when an industry i purchases goods (intermediate or capital) from an industry j, which produces goods, and have invested in R&D while developing the goods. The quality improvements of these goods offer possibilities to improve productivity growth in industry i. R&D expenditures are only partly included into quality-to-price ratio of the good because of competition between enterprises in the industry j. Rent spillovers occur because the inputs purchased by sector i from sector j are not prised at their user value. To the extent that the quality improvements in the purchased capital goods and intermediate inputs result from the R&D in sector j the total factor productivity growth in sector i depends on the R&D expenditures on the accumulated R&D stock available in sector j.
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> Knowledge spillovers refer to the transmission of knowledge. They are more directly than rent spillovers related to the knowledge embodied in the innovation, and not necessary to the economic transaction. An invention may give a new idea to different innovators.

Rent spillovers are easier to analyse than knowledge spillovers, and it is difficult to separate their impacts from each other. The two types of spillovers are difficult to dissociate because knowledge flows are often concomitant with user-producer transactions and the capture of rents and knowledge

[3] This paper is based on the working paper written by Forssell and Vierweg (1999) for the project: Industrial Benefits and Costs of Greenhouse Gas Abatement Strategies: Applications of E3ME, supported by the Commission of the European Communities, Directorate-General XII for Science, Research and Development, under the Workprogramme Non-Nuclear Energy (JOULE-THERMIE) 1994-1998, Project Reference JOS3-CT97-019. The project is coordinated by Cambridge Econometrics Ltd, United Kingdom.

gains can be used to reap economic rents. Spillovers have been widely examined by several economists over 40 years. Various authors have reviewed this work (Griliches 1992; Mohnen 1996).

The econometric estimation of R&D spillovers consists of connecting a performance measure (output growth, the total factor productivity, profitability, exports) in one industry to the R&D knowledge accumulated in other industries. Soete and Verspagen (1991) discuss the usefulness of the different indicators. Input-output models are also a useful tool to examine the knowledge flows and the transmission of economic rents between industries. A special issue of Economic Systems Research, Number 1 March 1997, describes well the state-of art in the field.

Following conclusions are drawn from analysis:

- Both R&D and productivity spillovers determine total factor productivity growth rates in other sectors of the economy (Wolf 1997 p. 20)
- The sector´s own R&D, the knowledge spillovers and the pure rent spillovers all play significant roles in total productivity growth. High-tech industries rely more on their own R&D, whereas other industries rely primary on R&D generated elsewhere. Knowledge spillovers are the second most important R&D source in high-tech industries, and rent spillovers incorporated in capital goods are the most important source of growth in the services. (van Meijl 1997 p. 42)
- Finnish manufacturing firms seem to have benefited more from the technology embodied in imported capital goods, from domestic R&D spillovers and from their own R&D than from other sources of knowledge. (Vuori 1997 p.78)
- The relative importance of the various spillovers varies across countries, across industries and over time. Interindustrial R&D spillovers have a higher return than own R&D, and imported R&D dominates domestic spillovers. R&D spillovers do in services, especially in the information and communications sectors, coming from computers and airplanes. (Sakurai et al. 1997 p.103-104)
- Chemicals represent the spillover source in electrical machinery, metal products in transport machinery and in general machinery. (Odagiri and Kinukawa 1997 p.139)

An industry´s or a plant´s production process is an activity where intermediate inputs and other production factors such as labour and capital services are combined for manufacturing an output. The proportion of different inputs is dependent on the utilization of inputs and their efficient combination. This means above all the quality of inputs, the applied technology, the organisation, the control of production process, and the relative prices. The innovations concerning all these elements have impacts on use of energy per unit of output or energy efficiency and its changes. The innovation of a plant´s or an industry´s production process is carried out by managerial decisions on the quality of the applied inputs and the kind of their combination.

Much of the potential for changing the production process is dependent on the availability of advanced technology incorporated in machinery and equipment. These capital goods are manufactured only to a small amount within the company or even within the industry. Most of these capital goods are produced in a few industries that deliver them to most other sectors of the economy. Thus for most sectors much of the energy saving potential is dependent on the results of external R&D expenditures and is incorporated via investment projects

Energy saving technology is a side effect in many other areas, even if energy is an important factor for the production as for instance in the case of steel production. The development of highly integrated flexible steel works during the mid 1980's has made available a technology that enabled companies to save enormous amounts of capital and energy. Nevertheless, it must be assumed that in areas of technology only few innovations have a noteworthy impact on energy consumption per unit of output.

An industry's upstream linkages to suppliers of intermediate goods also contribute to a reduction of the unit energy consumption to a certain extent. The transformation of new materials and a smaller number of machine operations affect the amount of unit energy input. The individual increase of energy efficiency might be small but the total amount of energy savings might be important. However, a distinct area of technology cannot identify it.

The energy savings discussed above are more related to external than internal innovation. However, the selection of a particular factor combination and the structuring of a production process are more dependent on an industry's internal conditions, such as the ability of companies to create an efficient organization and to optimize the process control by the application of adequate hardware and software. Most of these activities are part of a permanent effort to increase the overall efficiency of companies.

Although there are many areas of activity that have an impact on unit energy consumption of industries, the innovations of products of the capital good industries have turned out to be major importance. This kind of innovation has seldom a steady effect on the unit energy consumption. The availability of new, advantageous technologies incites an investment push that leads to a reduction of the specific energy consumption within a few years only. A converter matrix that quantifies the supplier-buyer-relationship will reveal the spillovers of innovation. This approach provides an explanation of the reduction of the unit energy consumption induced by investment in advanced machinery and equipment.

Economists have been trying to quantify the amount, the direction, the channels of transmission and the effects of R&D spillovers. The two approaches have been used

- The econometric estimation of R&D spillovers consists of connecting a performance measure in one sector to the R&D knowledge accumulated in other sectors.
- Input-output analysis is used to model the knowledge flows and transmission of economic rents that arise from R&D. IO matrices are used to aggregate the R&D expenditures.

Most studies have focused on one particular channel such as producer-user relationships in the trade of goods and services, the potential exchange of patents, the manufacturer and use of innovations or patent citations. The spillovers are assumed to be proportional to these flows or embodied to them. Another approach builds on proximity measures between the same kind of classes: patents, researchers. The econometric estimation of R&D spillovers connecting a performance measure of energy use in one sector to the R&D knowledge and other economic factors is applied in this study.

2. Elasticities for energy saving

Aggregate energy demand equation follows the corresponding equation used in the previous version of the E3ME (Version 2.1, Users' Manual p.8-4—8.6). R&D variables and separate investment variable substitute now technological progress, temperature variable is left away. Sum of research and development expenditures for all industrial and office machines, and electrical goods producing EU industries measures spillover effects of these goods on fuel users, except in transport related sectors 12-15. Spillover effects are measured in these sectors by sum of R&D expenditures for all transport equipment producing EU industries.

THE AGGREGATE ENERGY DEMAND EQUATION

Co-integrating long-term equation:

LN(FR0(.)		Total fuel used by fuel users	
	=	BFR0(.,1)	
	+	BFR0(.,2)*LN(FRY(.))	Activity measure
	+	BFR0(.,3)*LN(PREN(.))	Real price ratio
	+	BFR0(.,4)*LN(ORD(.))	Own R&D
	+	BFR0(.,5)*LN(MRD(.))	Spillover of R&D
	+	BFR0(.,6)*LN(TRD(.))	Spillover of R&D
	+	BFR0(.,7)*LN(K(.))	Investment
	+	ECM	Error

Co-integrating dynamic equation:

DLN(FR0(.))		Total fuel used by fuel users	
	=	BFR0(.,8)	
	+	BFR0(.,9)*DLN(FRY(.))	Activity measure
	+	BFR0(.,10)*DLN(PREN(.))	Real price ratio
	+	BFR0(.,11)*DLN(ORD(.))	Own R&D
	+	BFR0(.,12)*DLN(MRD(.))	Spillover of R&D
	+	BFR0(.,13)*DLN(TRD(.))	Spillover of R&D
	+	BFR0(.,14)*DLN(K(.))	Investment
	+	BFR0(.,15)*DLN(FR0(-1))	Lagged change in fuel use
	+	BFR0(.,16)*ECM(-1)	Lagged error correction

Definitions:

BFR0	Is a matrix of parameters
FR0	Is a matrix of total fuel used by 17 fuel users for 18 regions, thousand tonnes of oil equivalent
FRY	Is a matrix of output for 17 fuel users and 18 regions, m ecu at 1990 constant prices
PREN	Is a matrix of real price ratios, total energy price/output price
ORD	Is a matrix of research and development expenditures for 17 fuel users and 18 regions, m ecu at 1990 constant prices
MRD	Is a sum of research and development expenditures for all industrial and office machines, and electrical goods producing EU industries, m ecu at 1990 constant prices
TRD	Is a sum of research and development expenditures for transport equipment producing EU industries, m ecu at 1990 constant prices
K	Is a matrix of investment for 17 fuel users and 18 regions, m ecu at 1990 constant prices
(.)	Indicates that a matrix is defined across industries
LN	Indicates natural logasrithm
D	Indicates change in variables in front of a term
ECM	Is a matrix of error terms for 17 fuel users and 18 regions

The unit total energy demand per output is more stable than its individual components, different kinds of fuels that can substitute each other. However, it is also subject to changes in relative prices of energy and in technical progress. The equation considers the total fuel used (11 fuel types) in thousand tonnes of oil equivalent by 17 fuel users of the E3ME. The demand of energy by a fuel user is dependent on the level of activity for the fuel user. Gross output is chosen to describe the level of activity for most sectors. Household fuel demand is a function of total consumers' expenditure.

The real price of energy describes the effect of changes in the cost of energy relative to other inputs. A restriction is imposed so that relative price increases cause demand to fall but relative price decreases have no effect. It is supposed that savings in energy use due to increased energy prices are not reversed when energy prices fall again.

Three measures for technological progress capture different aspects of new ways of energy saving and energy conservation as more efficient techniques replace the old use of energy. Own R&D expenditures measure direct impacts on use of energy inputs in the production process. These changes may be due to improved use of energy input or development of less energy intensive products. Sum of R&D expenditures for all industrial and office machines, and electrical goods producing EU industries measures spillover effects for capital goods in fuel users. Sum of R&D expenditures for transport equipment producing EU industries measures spillover effects of these capital goods. Investment in fuel user sectors describes utilization of new technologies.

Parameters of equations were estimated for the period 1970-1995[4]. The aim in the specification and estimation is for a coherent economic explanation, with consistent long-term properties, robustness in equation behaviour and parsimony in their specification. The previous E3ME principles are then followed (Version 2.1, Users' Manual p.8-1). Cointegration and error-correction methodology was used in estimation. The equations were changed for estimation so that unit energy use per output was the dependent variable when the output variable is one. The estimated parameters can then be interpreted as elasticities indicating the change in energy intensity of output due to relative change in the explaining variable. The parameters for real energy price indicate for instance how many percentages energy use per output will change when real energy price change one percent.

The estimated long-term parameters are presented for real energy price, own R&D expenditures, sum of R&D expenditures for all industrial and office machines, and electrical goods, sum of R&D expenditures for transport equipment, and investment in the following pages. The equations were estimated also for four fuels: coal, heavy fuel oil, natural gas, and electricity. The specification of the equations follows similar lines to the aggregate energy equations. The equations contain the same variables, but total fuel use describes now the activity level and the real price term is a ratio of the price for the particular fuel in question to that of the aggregate fuel. The estimated parameters are not presented here because saving of total energy is a focus in this analysis.

[4] I am very grateful to Neil Jennings from Cambridge Econometrics, who did the estimation work. Possible errors and deficiences are due to my misunderstanding.

ELASTICITY OF REAL ENERGY PRICE

A Long-term

	Belgium	Denmark	Germany	Greece	Spain	France	Ireland	Italy north	Italy south	Lugen-bourg
1 Power Generation	-0.980	-1.009	-0.150	-0.150	-1.797	-0.150	-0.370	-0.703	-0.692	-0.892
2 Iron & Steel	-0.569	-0.250	-0.250	-0.999	-0.640	-0.250	-0.250	-0.250	-0.250	-0.250
3 Non-ferrous Metals	-0.250	-0.250	-1.700	-1.700	-1.671	-0.541	-0.627	-0.250	-0.250	-0.250
4 Chemicals	-0.250	-1.644	-0.250	-1.700	-0.250	-1.153	-1.064	-0.250	-0.250	-0.250
5 Mineral Products	-1.358	-0.200	-0.200	-0.200	-1.475	-0.452	-1.700	-0.200	-0.200	-0.200
6 Ore-extraction	-1.334	-0.200	-1.700	-1.399	-1.128	-0.200	-0.641	-0.200	-0.200	-1.563
7 Food, Drink & Tobacc	-0.397	-0.696	-0.898	-0.506	-0.200	-0.332	-0.598	-0.200	-0.200	-1.700
8 Tex., Cloth. & Footw	-0.291	-1.090	-1.700	-0.433	-0.751	-1.140	-0.200	-0.200	-0.200	-1.323
9 Paper & Printing	-0.200	-1.255	-1.188	-1.700	-0.736	-0.465	-0.406	-0.200	-0.200	-0.200
10 Engineering etc	-0.617	-0.200	-0.252	-1.349	-0.200	-0.528	-1.700	-0.237	-0.200	-0.200
11 Other Industry	-0.200	-0.200	-0.200	-0.872	-0.200	-0.925	-1.700	-0.353	-0.405	-1.700
12 Rail Transport	-0.200	-0.200	-1.332	-0.200	-0.574	-0.200	-1.645	-0.200	-0.200	-1.262
13 Road Transport	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700
14 Air Transport	-0.477	-0.501	-1.342	-0.400	-0.413	-0.400	-0.563	-0.400	-0.400	0.000
15 Inland Navigation	-0.200	-0.200	-0.200	-0.200	-0.362	-0.200	-0.200	-0.200	-0.200	0.000
16 Households	-0.288	-0.200	-0.200	-0.720	-0.200	-0.210	-0.618	-0.200	-0.200	-0.445
17 Other Final use	-0.928	-1.700	-1.309	-0.608	-0.332	-0.200	-0.902	-0.200	-0.200	-0.391
Wtd. ave. sectoral	-0.687	-0.809	-0.398	-0.479	-1.006	-0.320	-0.634	-0.429	-0.542	-0.560
Count of sig. t-stat	8.000	8.000	8.000	1.000	6.000	4.000	3.000	2.000	2.000	8.000

A Long –term, continuation

	Nether-lands	Portu-gal	United Kingdom	Austria	Finland	Sweden	Norway	Switzer-land	Weigh-ted average
1 Power Generation	-0.150	-0.150	-0.150	-1.177	-0.150	-0.409	-0.150	0.000	-0.393
2 Iron & Steel	-0.324	-0.690	-1.173	-0.250	-0.250	-0.250	-0.654	-0.250	-0.444
3 Non-ferrous Metals	-1.700	-1.700	-0.250	-1.700	-0.250	-0.250	-0.648	-0.250	-0.967
4 Chemicals	-1.700	-0.250	-0.250	-0.508	-0.250	-0.250	-0.250	-0.250	-0.521
5 Mineral Products	-0.269	-0.733	-0.969	-0.720	-0.200	-0.200	-1.700	-0.452	-0.543
6 Ore-extraction	-0.200	-1.700	-0.200	-0.200	-1.700	-0.200	-0.315	0.000	-0.824
7 Food, Drink & Tobacc	-0.200	-0.200	-0.368	-0.200	-0.775	-1.700	-0.200	-0.220	-0.448
8 Tex., Cloth. & Footw	-0.200	-0.979	-0.201	-0.200	-0.246	-0.200	-0.240	-0.200	-0.634
9 Paper & Printing	-0.200	-0.595	-0.504	-0.938	-1.008	-0.200	-0.200	-0.200	-0.621
10 Engineering etc	-0.536	-0.200	-0.200	-0.200	-0.501	-0.200	-0.763	-0.554	-0.336
11 Other Industry	-0.200	-0.200	-0.887	-0.200	-0.779	-1.179	-0.200	-0.358	-0.631
12 Rail Transport	-0.200	-0.200	-0.313	-1.033	-0.200	-0.200	-0.200	-0.200	-0.531
13 Road Transport	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700	-0.700
14 Air Transport	-0.400	0.326	-0.400	-0.515	-0.400	-0.400	-0.400	-0.400	-0.422
15 Inland Navigation	-0.599	-0.532	-0.200	-0.200	-0.200	-0.200	-0.200	-1.067	-0.281
16 Households	-0.200	-0.200	-0.200	-0.200	-0.200	-0.200	-0.200	-0.200	-0.218
17 Other Final use	-0.200	-0.200	-0.200	-0.200	-0.434	-0.200	-0.274	-0.200	-0.500
Wtd. ave. sectoral	-0.391	-0.351	-0.347	-0.534	-0.364	-0.396	-0.325	-0.363	-0.448
Count of sig. t-stat	3.000	4.000	6.000	6.000	1.000	3.000	5.000	5.000	83.000

LASTICITY OF OWN RESEARCH AND DEVELOPMENT EXPENDITURES

A Long-term

	Belgium	Denmark	Germany	Greece	Spain	France	Ireland	Italy north	Italy south	Lugen-bourg
1 Power Generation	-0.668	-2.000	0.462	-0.175	-2.000	-0.064	-0.428	-0.169	-0.421	-0.233
2 Iron & Steel	-0.173	-0.336	-0.099	0.237	-0.479	-0.050	-0.822	0.053	-0.338	-0.271
3 Non-ferrous Metals	-0.500	2.000	0.491	-0.118	-0.577	0.057	0.582	-0.248	-0.345	-2.000
4 Chemicals	-1.827	-0.183	-0.854	0.340	-0.100	-0.364	-0.871	-0.773	-0.565	-1.011
5 Mineral Products	-0.079	1.924	0.118	-0.321	-0.240	-0.316	-0.278	-0.302	-0.237	-0.430
6 Ore-extraction	0.251	-2.000	-0.327	0.340	0.266	0.367	-0.435	-0.282	-0.150	-1.213
7 Food, Drink & Tobacc	-0.909	-0.790	-0.308	0.362	0.152	0.029	-0.299	0.168	-0.077	1.451
8 Tex., Cloth. & Footw	-0.198	-0.095	-0.042	-0.065	0.001	-0.141	-0.254	0.013	0.037	-0.724
9 Paper & Printing	-0.132	-0.041	0.116	-0.053	-0.270	-0.025	-0.271	0.318	0.456	-2.000
10 Engineering etc	0.261	-0.252	-2.000	-0.186	0.624	-1.109	-1.216	-0.337	-0.419	0.056
11 Other Industry	1.023	0.201	0.609	-0.322	0.287	0.454	-1.031	0.167	-0.113	-2.000
12 Rail Transport	-0.164	0.000	0.797	0.564	0.036	0.088	-0.552	-0.056	-0.042	-0.268
13 Road Transport	-0.392	0.000	0.207	1.361	0.279	-0.123	-0.417	0.029	0.135	-0.384
14 Air Transport	0.527	0.000	-0.397	-1.390	-1.529	-0.599	0.172	-0.264	0.049	0.000
15 Inland Navigation	0.461	0.000	-1.840	1.604	-1.486	0.749	0.620	-1.263	-1.127	0.000
16 Households	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17 Other Final use	-0.261	-0.004	0.469	0.511	0.120	-0.053	0.117	-0.067	-0.082	0.591
Wtd. ave. sectoral	-0.385	-0.725	0.177	0.161	-0.764	-0.080	-0.243	-0.087	-0.223	-0.348
Count of sig. t-stat	2.000	2.000	8.000	4.000	5.000	6.000	4.000	5.000	5.000	7.000

A Long-term, continuation

	Nether-lands	Portu-gal	United Kingdom	Austria	Finland	Sweden	Norway	Switzer-land	Weigh-ted average
1 Power Generation	-0.264	-2.000	-0.105	0.000	-0.354	-0.185	0.000	0.000	-0.215
2 Iron & Steel	-0.505	0.140	-0.876	-0.056	-1.497	0.513	0.000	-0.537	-0.253
3 Non-ferrous Metals	-1.656	1.264	-1.138	0.455	-0.211	1.771	0.000	0.189	-0.104
4 Chemicals	0.211	-0.751	0.302	-0.107	0.092	-1.269	0.000	-2.000	-0.507
5 Mineral Products	-1.212	-0.018	-0.529	0.320	-0.214	1.023	0.000	-0.337	-0.152
6 Ore-extraction	-0.054	0.037	-0.679	-0.072	-1.077	0.709	0.000	0.000	-0.059
7 Food, Drink & Tobacc	-0.324	-0.069	0.360	0.295	-0.743	1.931	0.000	-0.050	-0.002
8 Tex., Cloth. & Footw	-0.957	-0.176	-0.202	0.878	0.439	1.795	0.000	-0.329	-0.052
9 Paper & Printing	-0.692	-0.575	2.000	-0.430	-0.206	-0.517	0.000	0.126	0.157
10 Engineering etc	-2.000	0.266	-0.514	0.532	-1.190	-2.000	0.000	0.000	-0.924
11 Other Industry	-1.490	-0.095	0.187	-0.646	-0.053	1.071	0.000	0.367	0.309
12 Rail Transport	0.000	-0.853	-0.231	0.000	0.080	-0.461	0.000	0.000	0.093
13 Road Transport	0.000	-0.750	-0.237	0.000	0.206	0.329	0.000	0.000	0.024
14 Air Transport	0.000	-0.833	0.114	0.000	0.013	1.813	0.000	0.000	-0.259
15 Inland Navigation	0.000	-1.670	-2.000	0.000	0.222	-0.171	0.000	0.000	-0.684
16 Households	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17 Other Final use	0.175	-0.071	0.094	-0.403	-0.195	0.068	0.000	-0.148	0.099
Wtd. ave. sectoral	-0.134	-0.847	-0.087	-0.032	-0.236	0.024	0.000	-0.111	-0.111
Count of sig. t-stat	4.000	6.000	4.000	3.000	7.000	8.000	0.000	2.000	82.000

ELASTICITY OF RESEARCH AND DEVELOPMENT EXPENDITURE IN MACHINES, OFFICE AND ELECTRICAL GOODS PRODUCING INDUSTRIES OF THE WHOLE EU

A Long-term

	Belgium	Denmark	Germany	Greece	Spain	France	Ireland	Italy north	Italy south	Lugen-bourg
1 Power Generation	1.535	2.000	0.324	2.000	2.000	0.210	-0.456	-1.044	-1.112	-0.521
2 Iron & Steel	0.165	0.874	-0.691	-0.403	0.159	-0.348	2.000	0.185	1.651	-0.036
3 Non-ferrous Metals	0.209	-2.000	0.001	0.430	0.957	0.070	2.000	0.492	1.558	-2.000
4 Chemicals	1.398	1.335	0.003	0.455	-0.049	0.711	1.497	0.312	0.094	0.435
5 Mineral Products	0.985	-0.318	-0.452	0.488	0.663	0.091	0.028	-0.044	0.005	-0.269
6 Ore-extraction	1.035	1.219	0.476	-0.023	0.087	-0.754	-0.408	-0.059	-0.007	0.925
7 Food, Drink & Tobacc	-0.064	0.967	-0.101	-1.179	0.159	-0.406	-1.314	-0.793	0.125	1.047
8 Tex., Cloth. & Footw	0.099	1.217	0.322	0.119	0.677	0.501	-1.206	-0.001	-0.087	0.982
9 Paper & Printing	0.633	1.525	0.164	0.130	-0.150	-0.169	-0.464	1.616	1.326	-2.000
10 Engineering etc	-0.133	-0.251	1.801	0.584	-2.000	0.718	1.781	0.208	-0.188	1.625
11 Other Industry	-0.571	0.099	-1.292	0.618	0.429	0.700	-0.391	0.859	1.231	2.000
12 Rail Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13 Road Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14 Air Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15 Inland Navigation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16 Households	-0.066	-0.167	0.041	0.767	-0.078	0.228	0.739	-0.394	0.535	-0.171
17 Other Final use	-0.025	1.539	0.364	0.191	0.294	0.000	0.583	0.659	0.551	0.320
Wtd. ave. sectoral	0.601	0.948	0.135	0.927	0.769	0.153	0.120	-0.235	-0.373	0.115
Count of sig. t-stat	3.000	8.000	3.000	4.000	2.000	4.000	6.000	6.000	4.000	8.000

A Long-term, continuation

	Nether-lands	Portu-gal	United Kingdom	Austria	Finland	Sweden	Norway	Switzer-land	Weigh-ted average
1 Power Generation	-0.288	1.928	0.100	2.000	1.137	-0.106	-0.017	0.000	0.374
2 Iron & Steel	0.567	-0.453	-0.390	0.064	1.806	0.097	0.288	0.850	-0.115
3 Non-ferrous Metals	1.260	-1.626	-0.501	-0.433	0.110	0.028	0.227	-0.803	0.251
4 Chemicals	0.444	0.572	-0.309	-0.554	-0.499	0.638	-0.307	1.716	0.252
5 Mineral Products	-0.127	-0.334	0.356	0.833	-0.258	0.209	0.948	-0.017	0.073
6 Ore-extraction	1.610	0.856	-0.589	-0.528	1.554	0.256	-0.212	0.000	0.097
7 Food, Drink & Tobacc	-0.273	-0.308	-0.415	-0.088	1.214	0.453	-0.498	-0.173	-0.241
8 Tex., Cloth. & Footw	0.167	1.484	-0.533	-0.321	-0.661	-0.416	0.045	0.853	0.196
9 Paper & Printing	0.042	-0.202	0.052	0.931	0.437	-0.032	0.071	0.041	0.289
10 Engineering etc	1.621	-1.497	-0.246	-1.916	1.755	1.530	0.231	1.052	0.593
11 Other Industry	0.369	-0.258	0.550	0.620	0.437	-0.136	0.025	1.085	0.174
12 Rail Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13 Road Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14 Air Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15 Inland Navigation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16 Households	0.298	1.135	0.012	-1.118	-0.317	0.300	0.236	0.518	0.022
17 Other Final use	0.091	0.549	0.131	-0.205	0.669	0.387	-0.251	1.820	0.298
Wtd. ave. sectoral	0.067	0.799	0.030	-0.017	0.573	0.082	0.024	0.649	0.184
Count of sig. t-stat	6.000	8.000	6.000	4.000	8.000	3.000	7.000	4.000	94.000

ELASTICITY OF RESEARCH AND DEVELOPMENT EXPENDITURES IN TRANSPORT EQUIPMENT PRODUCING INDUSTRIES OF THE WHOLE EU

A Long-term

	Belgium	Denmark	Germany	Greece	Spain	France	Ireland	Italy north	Italy south	Lugen-bourg
1 Power Generation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 Iron & Steel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Non-ferrous Metals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Chemicals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5 Mineral Products	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 Ore-extraction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7 Food, Drink & Tobacc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8 Tex., Cloth. & Footw	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9 Paper & Printing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10 Engineering etc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11 Other Industry	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12 Rail Transport	0.518	-0.196	-0.313	-0.981	0.385	-0.320	-1.311	-0.049	-0.138	0.680
13 Road Transport	0.317	0.276	0.022	-1.592	-0.410	-0.049	-0.284	-0.121	-0.311	0.874
14 Air Transport	0.445	-0.934	-2.000	2.000	0.633	0.502	-0.187	0.165	0.286	0.000
15 Inland Navigation	1.273	0.957	-0.669	-0.684	1.839	-0.842	2.000	1.647	1.632	0.000
16 Households	0.238	-0.272	-0.331	-0.495	0.464	-0.385	-1.040	0.167	-0.165	-0.444
17 Other Final use	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wtd. ave. sectoral	0.016	-0.035	-0.069	-0.275	0.019	-0.066	-0.254	0.023	-0.064	0.221
Count of sig. t-stat	3.000	4.000	2.000	0.000	2.000	3.000	1.000	1.000	2.000	3.000

A Long-term, continuation

	Nether-lands	Portu-gal	United Kingdom	Austria	Finland	Sweden	Norway	Switzerland	Weigh-ted average
1 Power Generation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 Iron & Steel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Non-ferrous Metals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Chemicals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5 Mineral Products	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 Ore-extraction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7 Food, Drink & Tobacc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8 Tex., Cloth. & Footw	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9 Paper & Printing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10 Engineering etc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11 Other Industry	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12 Rail Transport	-0.013	1.587	-0.444	0.051	1.090	-0.578	0.021	-0.212	-0.226
13 Road Transport	-0.492	1.469	0.187	-0.377	0.341	0.022	0.022	-0.861	-0.074
14 Air Transport	0.570	2.000	-0.530	0.790	0.014	-2.000	0.223	-0.892	0.016
15 Inland Navigation	-2.000	1.546	0.737	-2.000	0.689	-0.977	-0.047	-0.889	0.278
16 Households	-0.890	-0.994	-0.235	0.400	0.128	-0.926	-0.252	-0.524	-0.253
17 Other Final use	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wtd. ave. sectoral	-0.221	0.249	-0.030	0.057	0.021	-0.180	-0.031	-0.427	-0.057
Count of sig. t-stat	4.000	2.000	5.000	3.000	1.000	2.000	0.000	4.000	42.000

ELASTICITY OF OWN INVESTMENT

A Long-term

	Belgium	Denmark	Germany	Greece	Spain	France	Ireland	Italy north	Italy south	Lugen-bourg
1 Power Generation	-0.735	2.000	-0.815	-0.365	2.000	0.414	0.038	2.000	2.000	-0.772
2 Iron & Steel	0.087	0.000	-0.628	-1.158	-0.217	-0.342	-0.853	-0.222	1.500	-0.005
3 Non-ferrous Metals	0.114	0.000	1.208	-0.116	-0.468	-0.049	-1.623	-0.067	1.022	-2.000
4 Chemicals	0.468	0.000	0.568	-0.544	-0.061	-0.615	0.208	0.014	0.068	0.056
5 Mineral Products	-0.923	0.095	0.256	-0.503	-0.754	0.066	0.319	0.341	0.069	0.433
6 Ore-extraction	-0.586	0.017	0.529	-0.201	-2.000	-0.226	-0.019	0.511	-0.061	0.164
7 Food, Drink & Tobacc	0.668	0.239	0.236	1.260	-0.184	0.893	0.448	0.958	-1.045	0.190
8 Tex., Cloth. & Footw	0.180	-0.142	-0.111	0.037	-0.052	-0.318	0.114	-0.280	-0.070	0.028
9 Paper & Printing	-0.229	-0.794	-0.583	0.207	-0.054	0.155	0.190	-1.250	-0.638	2.000
10 Engineering etc	-0.239	0.000	0.036	-0.548	0.039	-0.160	0.026	-0.503	1.104	-0.263
11 Other Industry	1.114	0.151	0.000	-0.248	-0.954	-0.408	1.103	-0.089	-0.481	2.000
12 Rail Transport	0.105	0.000	-1.423	0.610	-0.243	-0.466	0.940	-0.026	0.085	-0.268
13 Road Transport	0.377	0.000	0.002	0.309	-0.346	-0.262	0.410	0.008	0.301	0.232
14 Air Transport	-0.091	0.000	-0.030	-0.126	0.931	0.144	0.497	1.342	0.981	0.000
15 Inland Navigation	-0.518	0.000	-2.000	-0.491	0.766	-0.253	-1.689	0.608	0.731	0.000
16 Households	-0.483	-0.027	-0.125	-0.307	-0.337	-0.807	-0.448	-0.013	-0.268	0.000
17 Other Final use	0.427	-0.918	-0.341	0.036	0.207	0.113	0.177	-1.750	-0.285	-0.686
Wtd. ave. sectoral	-0.203	0.626	-0.365	-0.172	0.614	-0.007	0.031	0.344	1.012	0.169
Count of sig. t-stat	5.000	3.000	2.000	4.000	5.000	5.000	4.000	6.000	2.000	5.000

A Long-term, continuation

	Nether-lands	Portu-gal	United Kingdom	Austria	Finland	Sweden	Norway	Switzerland	Weigh-ted average
1 Power Generation	0.232	2.000	-0.300	2.000	-0.066	0.729	-0.175	0.000	0.263
2 Iron & Steel	0.825	-0.036	0.027	0.396	0.004	0.300	0.139	1.052	-0.145
3 Non-ferrous Metals	-1.245	-0.248	0.052	0.810	0.033	-0.095	0.107	0.676	0.153
4 Chemicals	0.159	0.034	-0.480	-0.105	-0.206	1.183	0.001	-0.929	0.065
5 Mineral Products	-0.373	0.293	-0.762	-0.816	0.075	0.264	-0.259	0.399	-0.093
6 Ore-extraction	0.180	-0.087	-0.644	1.011	0.363	0.336	-0.219	0.000	-0.073
7 Food, Drink & Tobacc	-0.218	0.005	0.103	0.609	-0.693	-0.408	0.584	0.414	0.319
8 Tex., Cloth. & Footw	-0.384	-0.753	0.030	-0.214	-0.068	-1.101	-0.077	0.517	-0.176
9 Paper & Printing	0.375	-0.295	-0.413	0.497	-0.157	-0.160	0.046	0.064	-0.284
10 Engineering etc	0.797	0.679	-0.298	-0.213	0.011	0.059	0.558	-0.366	-0.090
11 Other Industry	-0.392	0.090	-0.538	0.609	-0.593	-0.297	-0.311	-0.073	-0.214
12 Rail Transport	0.000	0.048	0.404	-0.608	-0.344	1.662	-0.016	0.435	-0.252
13 Road Transport	0.000	-0.071	0.001	-0.137	-0.149	-0.697	0.037	1.166	-0.044
14 Air Transport	0.000	-0.153	-0.416	-1.634	-0.302	-1.360	-0.029	1.803	0.117
15 Inland Navigation	0.000	-0.212	1.249	-2.000	-1.627	0.444	-0.060	-0.712	0.166
16 Households	-0.883	-0.598	-0.171	0.435	-0.488	-0.551	-0.263	-0.805	-0.321
17 Other Final use	0.097	0.356	-1.044	1.234	-0.368	0.273	0.433	-2.000	-0.335
Wtd. ave. sectoral	-0.041	0.509	-0.285	0.525	-0.204	0.154	-0.027	-0.231	-0.010
Count of sig. t-stat	4.000	1.000	4.000	3.000	8.000	6.000	8.000	7.000	82.000

The estimates for the parameters vary remarkably among regions and industries as well as between long-term and short-term. Count of significant t-statistics is clearly greater for the long-term estimates than for the short-term ones. This was expected because particularly research and investment has long-term characteristics. Real energy price long-term estimates are significant in as many cases as other variables indicating long-term characteristics, too. However, they have most significant estimates among short-term ones showing their short-term sense, too.

Weighted average of the estimates for the whole region, short-term

		Real energy price	Own R&D	Machinery R&D	Transport R&D	Investment
1	Power Generation	-0.168	0.133	0.166	0.000	-0.196
2	Iron & Steel	-0.174	-0.285	0.378	0.000	0.039
3	Non-ferrous Metals	-0.340	-0.396	0.652	0.000	0.119
4	Chemicals	-0.166	-0.232	0.043	0.000	-0.028
5	Mineral Products	-0.222	-0.288	0.329	0.000	0.149
6	Ore-extraction	-0.289	-0.507	0.406	0.000	0.091
7	Food, Drink & Tobacc	-0.226	-0.141	-0.195	0.000	0.162
8	Tex., Cloth. & Footw	-0.251	-0.037	-0.845	0.000	-0.208
9	Paper & Printing	-0.309	0.021	0.156	0.000	-0.133
10	Engineering etc	-0.285	-0.461	0.590	0.000	-0.099
11	Other Industry	-0.142	-0.639	0.779	0.000	-0.033
12	Rail Transport	-0.115	0.075	0.000	0.277	-0.428
13	Road Transport	-0.215	0.105	0.000	0.145	-0.089
14	Air Transport	-0.255	-0.171	0.000	0.108	0.074
15	Inland Navigation	-0.204	-0.474	0.000	0.393	0.000
16	Households	-0.184	0.000	-0.001	0.137	0.008
17	Other Final use	-0.186	0.203	0.396	0.000	-0.135
	Wtd. ave. sectoral	-0.191	0.024	0.142	0.055	-0.092
	Count of sig. t-stat	40	30	20	11	11

The short-term and long-term estimates for real energy price have minus sign in every case because positive signs were not accepted in the estimation process. The impacts of real energy price are more energy saving in long-term than in short-term for every fuel user.

Fuel users' own research and development contributes to energy saving in most cases in long-term. Spillovers of R&D expenditures in industrial and office machines and also in electrical goods producing industries on unit energy use are mostly positive when all the regions are taken into account. This indicates that research and development work in these industries is probably directed into inventions of new products without paying attention to energy saving characteristics of machines. However, negative impacts, indicating energy saving properties, are more common when the estimates by region are analysed. It seems that energy saving characteristics have been considered more while developing new models in transport equipment producing industries. The estimates have negative signs in the following fuel user sectors: rail transport, road transport, and households. These parameters have also significant estimates in the most of the cases under consideration. Long-term estimates for the parameters of investment are in 11 cases among 17 fuel users negative. We can then conclude that investment will save energy for the most fuel users. When new machines substitute old ones energy per output is usually saved but if they substitute labour, use of energy per output may increase.

Weighted average of the estimates for the whole region, long-term

	Real energy price	Own R&D	Machinery R&D	Transport R&D	Investment
1 Power Generation	-0.393	-0.215	0.374	0.000	0.263
2 Iron & Steel	-0.444	-0.253	-0.115	0.000	-0.145
3 Non-ferrous Metals	-0.967	-0.104	0.251	0.000	0.153
4 Chemicals	-0.521	-0.507	0.252	0.000	0.065
5 Mineral Products	-0.543	-0.152	0.073	0.000	-0.093
6 Ore-extraction	-0.824	-0.059	0.097	0.000	-0.073
7 Food, Drink & Tobacc	-0.448	-0.002	-0.241	0.000	0.319
8 Tex., Cloth. & Footw	-0.634	-0.052	0.196	0.000	-0.176
9 Paper & Printing	-0.621	0.157	0.289	0.000	-0.284
10 Engineering etc	-0.336	-0.924	0.593	0.000	-0.090
11 Other Industry	-0.631	0.309	0.174	0.000	-0.214
12 Rail Transport	-0.531	0.093	0.000	-0.226	-0.252
13 Road Transport	-0.700	0.024	0.000	-0.074	-0.044
14 Air Transport	-0.422	-0.259	0.000	0.016	0.117
15 Inland Navigation	-0.281	-0.684	0.000	0.278	0.166
16 Households	-0.218	0.000	0.022	-0.253	-0.321
17 Other Final use	-0.500	0.099	0.298	0.000	-0.335
Wtd. ave. sectoral	-0.448	-0.111	0.184	-0.057	-0.010
Count of sig. t-stat	83	82	94	42	82

The estimated parameters of fuel users are related to rather much aggregate sectors in some cases. Other final use includes agriculture, construction, several market services, and non-market services. These kinds of fuel users are heterogenous in their use of energy and the parameter estimates are then complicated and hard for explanation. Fortunately their use of energy is small compared to such fuel users as Power Generation, Iron & Steel, Chemicals, Paper & Printing, and all Trasnsport sectors.

Iron &Steel is the only fuel user that has negative signs for all estimated long-term parameters. It has then used very much energy saving technologies in the past. Mineral products, ore-extraction, engineering, rail and road transport as well as households are other examples of energy saving behaviour in long run. Other fuel users have at least one estimated parameter, in addition to real energy price, indicating energy saving impact (minus sign) when the explaining variable is increased. The estimated long-term parameters by region vary much more in their impacts on energy saving.

Accuracy of the estimates is affected by the operational choice of explaining variables. Real energy price is a good and accurate operational equivalent for showing relation between costs of energy and other inputs. Own R&D expenditures include also other costs than those related to energy inputs. These costs may be used to develop new products or improving quality of old products without taking into account use of energy input. This concerns also the measures used for describing spillovers of R&D expenditures. Investment includes all kinds of capital goods. All these deficiencies affect the accuracy and reliability of the estimates.

3 Conclusions and Policy Implications

We have at least three questions when incentives for energy efficiency are analyzed:

1. What kinds of things have impacts on energy efficiency?
2. What kinds of instruments are available?
3. What kinds of impact channels can be used?

Energy efficiency and factors having impacts on its development are the starting points when the questions above are answered. Energy is supplied with production technology and consumption of energy is mainly determined by the technology used in production of different products. Technology is developed mainly with research that produces patents in order to ensure the rights of developing firm to the innovation. Market forces behind supply and demand of energy determine its price, and government uses taxes and regulations as instruments to effect on energy price. Management of energy systems and level of knowledge affects on supply and demand of energy in addition to hard technology. Research is again the main force behind these factors.

R&D is clearly the major driving force behind energy efficiency beside relative price of energy. Taxes and regulations on energy production and use are policy instruments that can be used to promote energy efficiency. R&D expenditures are usually financed by the industry itself, but government often subsidizes these expenditures. R&D is also a driving force behind economic growth and considered as an important economic and economic policy instrument for stimulating economic growth. We have focused in our study on technology and R&D as forces encouraging industries to energy efficiency and considered also some other factors behind these forces.

Public action and oil prices follow each other rather closely. Average oil prices changes are often followed by the corresponding changes in public economic measures. It is then difficult to separate the influence of these two factors on energy efficiency. The problem is relevant also when we want to separate the effects of research and development costs on improvements of energy efficiency.

The main driving force for technological progress, considered, as endogenous factor in new growth theory, is research and development expenditures. The externalities connected with an innovation, spillovers, are important when the impacts of R&D expenditures on other industries are analyzed.

Energy saving explaining factors have more significant effects in long-term than in short-term. This is natural because particularly research and investment has long-term characteristics. Real energy price long-term effects are significant in many cases indicating long-term characteristics, too. However, they have most significant effects among short-term ones showing their short-term sense, too.

Fuel users' own research and development contributes to energy saving in long-term. Spillovers of R&D expenditures in industrial and office machines and also in electrical goods producing industries on unit energy use are mostly positive This indicates that research and development work in these industries is probably directed into inventions of new products without paying attention to energy saving characteristics of machines. However, negative impacts, indicating energy saving properties, are more common when the estimates by region are analysed. It seems that energy saving characteristics have been considered more while developing new models in transport equipment producing industries. The spillovers have

energy saving impacts on the following fuel user sectors: rail transport, road transport, and households. Long-term estimates for investment demonstrate energy saving impacts in most cases. We can then conclude that investment and new technology used will save energy for the most fuel users. When new machines substitute old ones energy per output is usually saved but if they are substitutes for labour, use of energy per output might increase.
The estimated parameters of fuel users and conclusions based on them are related to rather much aggregate sectors in some cases. Other final use includes agriculture, construction, several market services, and non-market services. These kinds of fuel users are heterogenous in their use of energy and the parameter estimates are then complicated and hard for explanation. Fortunately their use of energy is small compared to such fuel users as Power Generation, Iron & Steel, Chemicals, Paper & Printing, and all Trasnsport sectors.
Iron &Steel is the only fuel user that has negative signs for all estimated long-term parameters. It has then used very much energy saving technologies in the past. Mineral products, ore-extraction, engineering, rail and road transport as well as households are other examples of energy saving behaviour in long-term. Other fuel users have at least one estimated parameter, in addition to real energy price, indicating energy saving impact (minus sign) when the explaining variable is increased. The estimated long-term parameters by region vary much more in their impacts on energy saving reflecting varying conditions by region.
Accuracy of the estimates is affected by the operational choice of explaining variables. Real energy price is a good and accurate operational equivalent for showing relation between costs of energy and other inputs. Own R&D expenditures include also other costs than those related to energy inputs. These costs may be used to develop new products or improving quality of old products without taking into account use of energy input. This concerns also the measures used for describing spillovers of R&D expenditures. Investment includes all kinds of capital goods. All these deficiencies affect the accuracy and reliability of the estimates. These reservations concern also the policy conclusions based on the results of the estimates.

References

Barker T.-Gardiner B.-Milas C. Cambridge Econometrics (1998*): E3ME Users´ Manual, Version 2.1*, January 1998.
Bosseboeuf D.-Chateau B.-Lapillone B. (1997): Cross.country comparisons on energy efficiency indicators: the on-going European effort towards a common methodology*, Energy Policy, Special Issue, Cross-country comparisons of indicators of energy use, energy efficiency and CO2 emissions,* Volume 25 Numbers 7-9, June/July 1997, pp. 673-682.
Capros P.-Mantzos L.- Kokkolakis E. et al. (1997): Evaluation of Policies and Measures and their Costs for the EU to meet the Kyoto Target of –15% CO2 Emissions, Summary of Analysis with PRIMES for "Climate Technology Strategy" Project of Joule-II (DG-XII/F1*, Draft written on 5-Oct-97, National Technical University of Athens.*
Economic Systems Research, *Journal of the International Input-Output Association*, Volume 9 Number 9 March 1997.
Energy Policy, Special Issue (1997*): Cross-country comparisons of indicators of energy use, energy efficiency and CO2 emissions,* Volume 25 Numbers 7-9, June/July 1997.
Forssell O. & Vierweg H. G. (1999): Research and development expenditures and patents for developing energy saving technologies**,** *Working Paper No 5.1***,** *Task 5: Incentives for industrial energy efficiency,* December 1999. Industrial benefits and costs of greenhouse gas abatement strategies: applications of E3ME, The E3ME project is supported by the Commission of the European Communities, Directorate-General XII for Science, Research

and Development, under the Workprogramme Non-Nuclear Energy (JOULE-THERMIE) 1994-1998, Project Reference JOS3-CT97-019.

Griliches Z. (1979): Issues in assessing the contribution of research and development to productivity growth, *Bell Journal of Economics*, 10, pp. 92-116.
Griliches Z. (1992): The search for R&D spillovers, *The Scandinavian Journal of Economics*, 94 (Supplement), pp.29-47.
Meijl H. (1997): Measuring Intersectoral Spillovers, *Economic Systems Research, Journal of the International Input-Output Association,* Volume 9 Number 9 March 1997, pp. 25-47.
Mohnen P. (1996): R&D externalities and productivity growth, *STI Review*,18, pp.39-66.
Odagiri H. – Kinukawa S. (1997): Contributions and Channels of Interindustry R&D Spillovers: An Estimation for Japanese High-Tech Industries, *Economic Systems Research, Journal of the International Input-Output Association,* Volume 9 Number 9 March 1997, pp. 127-142.
United Nations Environment Programme (1994): UNEP Greenhouse Gas Abatement Costing Studies, Phase Two Appendix: Guidelines, *UNEP Collaborating Centre on Eneergy and Environment, Riso National Laboratory, Denmark,* May 1994.
Verspagen B. (1997): Measuring Intersectoral Technology Spillovers: Estimates from the European and US Patent Office Databases, *Economic Systems Research, Journal of the International Input-Output Association,* Volume 9 Number 9 March 1997, pp. 47-65.
Vuori S. (1997): Interindustry Technology Flows an Productivity in Finnish Manufacturing, *Economic Systems Research, Journal of the International Input-Output Association,* Volume 9 Number 9 March 1997, pp. 67-80.
Wolf E.N. (1997): Spillovers, Linkages and Technical Change, *Economic Systems Research, Journal of the International Input-Output Association,* Volume 9 Number 9 March 1997, pp. 9-23.
Sakurai N.-Papaconstantinou G. – Ionnidis E. (1997): Impact of R&D Diffusion on Productivity Growth: Empirical Evidence for 10 OECD Countries, *Economic Systems Research, Journal of the International Input-Output Association,* Volume 9 Number 9 March 1997, pp. 81-109.
Soete L. & Verspagen B. (1991): Recent comparative trends in technology indicators in the OECD area, *Technology and Productivity. The Challence for Economic Policy*, Paris, OECD.