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Operational and Investment Response to Energy Prices in the OECD Manufacturing Sector

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Keywords energy efficiency, energy prices, investment, vintage capital model

JEL Classification D24, E22, Q41, Q43

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EPRG WORKING PAPER

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This paper estimates the vintage capital model of energy demand and examines operational and investment responses to energy prices at disaggregate level using data from five OECD manufacturing industries. Applying the model to less aggregate level data helps avoid the distortions from exogenous structural shifts and measurement errors. The results confirm the previous findings that including capital stock vintages significantly improves the econometric model's goodness of fit. Estimated own-price elasticities of energy demand vary between 0.26 and 1.00 and are economically sound. Estimated own-price investment elasticities of energy efficiency of capital stock vary between 0.03 and 0.9. The investment response to energy prices thus varies significantly across manufacturing industries, being significant in some of them and negligible in other. The results of policy simulations for the U.K. petrochemical industry (the most energy-intensive industry in the sample) indicate that total (operational and investment) own-price elasticity of energy demand is close to one.

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1 Introduction

This working paper builds upon an earlier EPRG working paper by Steinbuks, Meshreky, and Neuhoff (2009), which attempts to address the limitations of current econometric models of energy demand in reflecting the adaptation of the capital stock to energy price changes.[1] Their econometric model explicitly incorporates the capital stock, and separately accounts for operational and investment choices in different sectors. Specifically, traditional estimation of energy, materials, and labour responses to input price changes is expanded by including

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[1] For a more detailed explanation of this problem, see Griffin and Schulman (2005, p.5), Steinbuks, Meshreky, and Neuhoff (2009), and refrences therein.

vintages of the capital stock. Each vintage has its own energy efficiency, which is a function of input prices at the time of investment, and the exogenous technological change. In this vintage capital model, rational cost-minimizing firms choose both the optimal input quantities and the efficiency of new capital stock. The model therefore is able to separate the flexibility of substitution between input factors to production (labour, energy and materials), and the potential for more efficient use of these inputs by choosing more efficient technologies at the time of investment.

Steinbuks, Meshreky, and Neuhoff (2009) estimate their econometric model for four sectors (agriculture, commerce, manufacturing, and transport) in 23 OECD countries between 1990 and 2005. They find that vintage representation of capital stock significantly improves the explanatory value of the model at the sector level. The results for all sectors indicate that rising energy prices result in a substantial decline in long-run energy use, and affect both the operation (input substitution) and the investment (energy efficiency of capital stock) components of energy demand. However, some of the estimated parameters cannot be reconciled with the economic intuition. Interpretation of these results are plagued by exogenous structural shifts within and across sectors, regulatory distortions, and measurement error.

This paper attempts to evaluate the robustness of the results of Steinbuks, Meshreky, and Neuhoff (2009) by applying their model to less aggregate data, thus reducing the distortions from exogenous structural shifts and measurement errors. The model is estimated for five manufacturing industries in 19 OECD countries between 1990 and 2005. Our results confirm that including capital stock vintages significantly improves the econometric model's goodness of fit. Estimated own-price elasticities of energy demand vary between 0.26 and 1.00 and are economically sound. Estimated own-price investment elasticities of energy efficiency of capital stock vary between 0.03 and 0.9. This result indicates that the investment response to energy prices varies significantly across manufacturing industries, being significant in some and negligible in others.

An important finding of this paper is that energy and climate policies aimed at reductions in fossil fuel emissions can result in a substantial reduction of energy use in energy intensive sectors. The results of policy simulations for the U.K. petrochemical industry (the most energy-intensive industry in the sample) indicate that a 17 percent increase in energy prices from a 30 dollar carbon tax results in a 19 percent decline in energy use. That is total (operational and investment) own-price elasticity of energy demand is close to one.

The rest of this paper is structured as follows. The second section outlines the vintage capital model and resulting stochastic specification. The third section describes the dataset. The fourth section presents the main findings of the research. The fifth section presents the results of policy simulations. The final section concludes, and suggests policy recommendations.

2 Empirical Model

We adopt the vintage capital model of Steinbuks, Meshreky, and Neuhoff (2009) that separately accounts for firms' investment and operational (production) decisions. In this model firms first make investment decisions and choose the optimal level of factor efficiency of their new production technology given their expectations of future input costs. The firms then make production decisions, so to minimize realized input costs and produce the desired output level given the level of input efficiency of installed production technology. The stochastic specification of the model is based on a system of four equations to be estimated:

$$S_{i,t}^{j} = \alpha_{ij} + \beta_{Yj} \log Y_{i,t} + \sum_{j} \beta_{ij} \log w_{i,t}^{j} \gamma_{i,t}^{j} + \varepsilon_{it}^{j}, \tag{1}$$

where $S_{i,t}^{j}$ is the share of each input j in country's i total cost at the time t, α_{ij} are country-specific fixed effects, $Y_{i,t}$ is the gross output, β_{Yj} are the elasticities of factor shares with respect to gross output, $w_{i,t}^{j}$ are the input prices, $\gamma_{i,t}^{j}$ is the index of input efficiency of capital stock, and ε_{it}^{j} is the error term.

We calculate the index of input efficiency of capital stock as

$$\gamma_{i,t}^{j} = (1-\delta)^{t} x_{i,0}^{k} \left(\frac{w_{i,0}^{j}}{\overline{w}^{j}} \right)^{-\phi^{j}} + \sum_{q=1}^{t} (1-\zeta)^{q} \left(\frac{w_{i,q}^{j}}{\overline{w}^{j}} \right)^{-\phi^{j}} \frac{I_{i,q} (1-\delta)^{t-q}}{x_{i,t}^{k}}, \tag{2}$$

where δ is the rate of economic depreciation of capital stock, $x_{i,t}^{k}$ is the value of capital stock, $\overline{w}^{j}$ is the average price of input j across countries and all time periods, ϕ^{j} is the elasticity of input efficiency of capital stock with respect to input price changes, ζ is the rate of exogenous Hicks-neutral technological change[2], and $I_{i,q}$ is the vintage investment in period q.[3]

The system of equations (1) is a conditionally linear seemingly unrelated regression[4], which is efficiently estimated by full information maximum likelihood (FIML). Because the share equations in the model (1) add to one, only 3 share equations are estimated. Following Griffin and Gregory (1976, p. 849) we treat input prices as purely exogenous, because the small sample bias from a set of constructed instrumental variables is not necessarily smaller

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[2] While there is an evidence that technological change responds endogenously to energy prices (see e.g. Popp 2002), endogenizing technological change is precluded by the numerical complexity of the model. Given this, our results should be interpreted as the lowest boundary of the effect of energy prices on energy efficiency of the capital stock.

[3] For derivation and detailed discussion of the model, see Steinbuks, Meshreky, and Neuhoff (2009).

[4] e.g. we still need to obtain the values of ζ and ϕ^{j} before estimating the model (1) as a linear problem.

than that obtained from actual prices.

The values of parameters ζ and ϕ^j are estimated to maximize the value of the model's goodness-of-fit criterion, and are obtained by grid search. To minimize the computational burden of a multidimensional grid search, based on earlier empirical findings (e.g. Jorgenson and Fraumeni 1981; Raff and Summers 1987; Baltagi and Griffin 1988; Newell, Jaffe, and Stavins 1999; Li, Von Haefen, and Timmins 2008; and Sue Wing 2008) we restrict the exogenous technological change, ζ, to lie between -0.02 and 0.04, and the elasticity of input efficiency of capital stock with respect to input price changes, ϕ^j, - between 0 and 1.5.

While the system (1) forms our basic empirical model we also estimate a restricted model, assuming that the input efficiency of capital stock does not change, so $\gamma_{i,t}^j$ is set to 1 (or both ζ and ϕ^j are set to zero). Under this restriction the model becomes a conventional translog model of input demand of Berndt and Wood (1975) and Griffin and Gregory (1976). We then use the likelihood-ratio test to evaluate the significance of input efficiencies of capital stock in the models of energy demand.

To quantify factor response to current price changes holding all previous prices constant, we compute own-price and cross-price elasticities of substitution.[5] These elasticities are given by

$$\eta_{jj} = \frac{\partial \ln x_{i,t}^j}{\partial \ln w_{i,t}^j} = \frac{\beta_{jj} + \left(S_{i,t}^j\right)^2 - S_{i,t}^j}{S_{i,t}^j}, \; j = k, l, e, m. \tag{3}$$

and

$$\eta_{pj} = \frac{\partial \ln x_{i,t}^j}{\partial \ln w_{i,t}^p} = \frac{\beta_{pj} + S_{i,t}^p S_{i,t}^j}{S_{i,t}^j}, \; p, j = k, l, e, m, \; p \neq j. \tag{4}$$

Because analysis is based on panel data across countries, the estimated elasticities have a standard interpretation of the long-run equilibrium effects (Griffin and Gregory 1976). Inclusion of capital vintages does not affect this interpretation of computed elasticities, because capital stock adjusts fully to equilibrium in the long run.

3 Data

The vintage capital model is estimated using the panel data of 19 OECD countries between 1990 and 2005 separately for five manufacturing industries - food, beverages and tobacco (ISIC sectors 15 and 16), pulp, paper products, paper, and publishing (ISIC sectors 21 and

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[5] We have also estimated Allen's and Morishima's partial elasticities of substitution. Because these elasticities have less straightforward interpretation (Frondel 2004), and can be directly inferred from estimated cross-price elasticities, their estimates are not reported and available from authors upon request.

22), chemical, rubber, plastics, and fuel products (ISIC sectors 23, 24, and 25), basic metals, and fabricated metal products (ISIC sectors 27 and 28), and electrical and optical equipment (ISIC sectors 30, 31, 32, and 33).[6] The use of disaggregated data reduces measurement error and improves the quality of the estimates, as different sectors use energy for different purposes, which affects their ability to substitute between energy and other inputs. Because of data limitations the analysis was not possible at less aggregate level. The main data source for empirical analysis is the EU KLEMS database, which is constructed based on the methodology of Jorgenson, Gollop, and Fraumeni (1987) and Jorgenson, Ho, and Stiroh (2005).[7] The EU KLEMS database comprises data on production inputs, labor and capital input prices[8], and output at the industry level for the European Union, the United States, Korea, and Japan. We exclude four Eastern Europian countries, which have experienced large structural shifts in their economies during the period of the study.[9] Full list of variables, countries and the descriptive statistics for the final dataset are shown in Tables 1-3 (Appendix 2).

In the EU KLEMS dataset we only have data for capital stock $x^k_{i,t}$ and do not observe actual investment. The methodology of Jorgenson, Gollop, and Fraumeni (1987) and Jorgenson, Ho, and Stiroh (2005) assumes geometric mortality distribution, (e.g. replacement is proportional to actual capital stock) and a time-invariant rate of economic depreciation. Under these assumptions we can calculate the vintage investment in period q is as

$$I_{i,q} = x^k_{i,q} - (1-\delta)x^k_{i,q-1}. \tag{5}$$

Based on the estimates from Timmer, O Mahony, and van Ark (2007, Appendix 1) we set economic depreciation rates as 11 percent in food processing industry, and 10 percent in other industries.

To avoid the problem of endogeneity of input prices and cost shares at the industry level, we use their average estimates for the manufacturing sector. The EU KLEMS dataset does not include information on energy and materials input prices. We obtain the end-use energy price data from the International Energy Agency database, and construct the average energy

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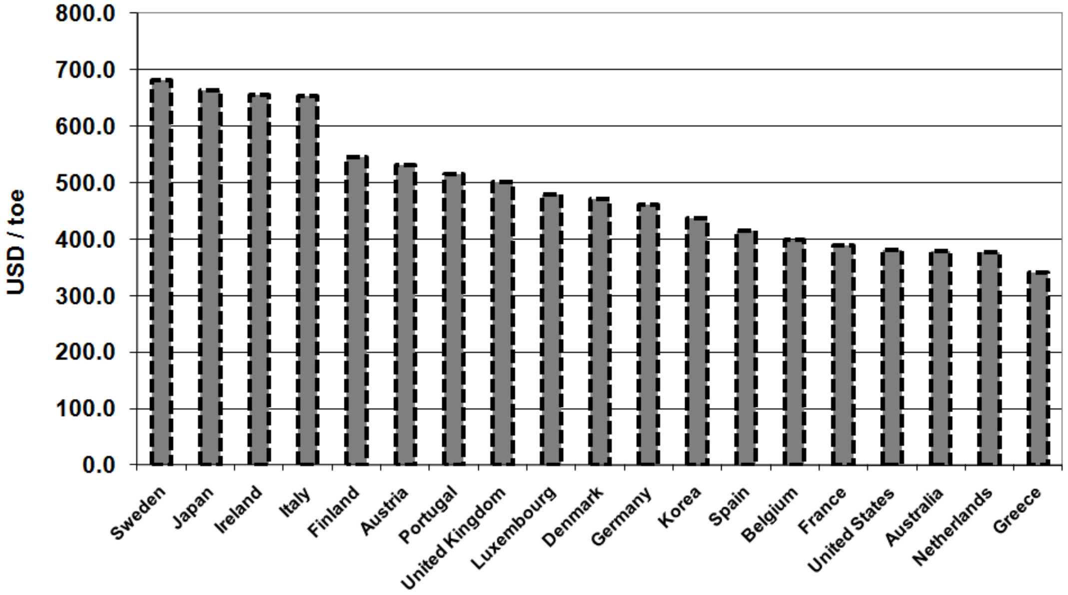
[6] To preserve space further in the text these industries are referred as food processing, pulp and paper products, petrochemical, metals, and electrical industries.

[7] For more details, see Timmer, O Mahony, and van Ark (2007).

[8] Data on the price of capital services were not available for some countries. For these countries following Andrikopoulos, Brox, and Paraskevopoulos (1989) and Cho, Nam, and Pagán (2004) we computed the capital input prices (available from IMF International Financial Statistics Database) as a sum of the nominal interest rate on short-term government papers, and capital depreciation rate.

[9] The data for these countries were available from 1995, making the panel unbalanced. An attempt to estimate the vintage capital model with these countries included resulted in unexpectedly large values of estimated parameters. The results are available from authors upon request.

Figure 1: Average Real Energy Prices in OECD Manufacturing Sector in 2005.



Note. Real energy prices are calculated using 1995 as a base year.

price for the manufacturing sector by weighting energy carriers' prices by the consumption of each energy carrier in the manufacturing sector.[10] We construct the price of materials by weighting international commodity prices (from IMF International Financial Statistics database) by sector consumption of each commodity (from UNIDO Industrial production database). The data series for labor, energy, and material costs, and for the values of output and capital stock are all deflated to their real values based on the industry deflators using 1995 as a base year, and converted into the United States dollars.

Figure 1 shows the average energy prices in OECD manufacturing sector across countries in 2000. The highest energy prices are in Italy, Ireland, Japan and Sweden, and the lowest are in Australia, Netherlands, Greece, and the United States. These differences in energy prices across OECD countries are because of variation in energy taxes, the types of fuels used in the production process, and local distribution costs. Energy taxes are the major factor explaining the energy price differences - for example, in 2008 gasoline tax accounted for nearly 60 percent of final energy price in Sweden, Germany and the United Kingdom, compared to just 13 percent in the United States (International Energy Agency 2008). However, variation in industrial energy prices across the OECD manufacturing industry is relatively small

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[10] Specifically, we consider the following energy products - oil and petrolium products (high- and low-sulphur fuel oil, light fuel oil, automotive diesel, and gasoline), natural gas, coal, and electricity. Consumption of each product is measured in British thermal units (BTUs). More details are available in the technical appendix, available from authors upon request.

compared to other sectors, such as commerce or transportation (Steinbuks, Meshreky, and Neuhoff 2009). This may reflect constraints on national energy tax policies in the manufacturing sector, posed by countries' concerns to maintain their international competitiveness (Brack, Grubb, and Windram 2000).

4 Results of Estimation of the Vintage Capital Model

The regression results for the five industries analyzed in this study are presented in Tables 4a-4e (Appendix 2). We present the results for both the vintage capital model, and the standard translog model of energy demand, in which the indices of input efficiency of capital stock are set to 1. Tables 1, 2 and 3 present estimated own-price elasticities of input demand, cross-price elasticities of energy demand, and own-price elasticities of input efficiency of capital stock from the vintage capital model. Tables 5a-5e, Appendix 2 demonstrate the variation of estimated elasticities across countries. Estimated cross-price elasticities of other input demands are presented in Table 6, Appendix 2. Figures 1a-1e, Appendix 3 show the values of the calculated indices of input efficiency of capital stock.

Table 1. Estimated Own-Price Elasticities of Input Demand in OECD Manufacturing Sectors

Sector	η_{LL}		η_{KK}		η_{EE}		η_{MM}	
	VCM	TL	VCM	TL	VCM	TL	VCM	TL
Chemical, Rubber, Plastics and Fuel Products	-0.46***	-0.82***	-0.71***	-0.77***	-0.41***	-0.57***	-0.43***	-0.36***
	(0.05)	(0.04)	(0.08)	(0.06)	(0.11)	(0.10)	(0.03)	(0.03)
Electrical and Optical Equipment	-0.62***	-0.49***	-0.58***	-0.81***	-0.26***	-0.26***	-0.45***	-0.49***
	(0.03)	(0.03)	(0.09)	(0.08)	(0.09)	(0.09)	(0.03)	(0.03)
Food Products, Beverages, and Tobacco	-0.55***	-0.56***	-1.08***	-1.08***	-0.37***	-0.40***	-0.31***	-0.30***
	(0.03)	(0.03)	(0.03)	(0.02)	(0.12)	(0.12)	(0.01)	(0.01)
Basic Metals and Fabricated Metal Products	-0.31***	-0.41***	-0.78***	-0.84***	-1.00***	-0.93***	-0.44***	-0.40***
	(0.05)	(0.05)	(0.02)	(0.03)	(0.10)	(0.08)	(0.03)	(0.03)
Pulp, Paper, Paper Products, Printing and Publishing	-0.38***	-0.44***	-0.41***	-0.94***	-0.43***	-0.41***	-0.33***	-0.34***
	(0.03)	(0.03)	(0.08)	(0.07)	(0.15)	(0.15)	(0.05)	(0.05)

Note. VCM - Vintage Capital Model, TL - Translog Model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The regression results show that the vintage capital model generally provides a better explanation of energy demand. The R-squared are higher for the vintage capital model (Tables 4a-4e, Appendix 2). The likelihood ratio test indicates that the translog restriction of input efficiencies of capital stock being equal to 1 is rejected at the 1 percent level of significance for four out of five industry estimates. However, for the food processing industry the translog model can be rejected only at a 10 percent level of significance.

Overall, the estimates of own-price and cross-price elasticities of input demand are consistent with their economic interpretation. Table 1 demonstrates that all of the estimated own-price elasticities of input demands across different sectors have the expected signs and reasonable magnitudes.[11] The vintage capital model and the translog model yield comparable estimates of the input demand elasticities in four out of five industries, except for the elasticities of capital demand. The estimated elasticities of capital demand based on the translog model are higher, except for the food processing industry. The estimated elasticities of input demand based on the translog model are also higher for the petrochemical industry. The results from both the vintage capital model and the translog model indicate that long-run energy demand is inelastic in all sectors, except for the metals industry, where the long-run energy demand is close to unit-elastic.

Table 2. Estimated Cross-Price Elasticities of Energy Demand in OECD Manufacturing Sectors

Sector	η_{LE}		η_{KE}		η_{ME}	
	VCM	**TL**	**VCM**	**TL**	**VCM**	**TL**
Chemical, Rubber, Plastics and Fuel Products	0.39***	0.39***	0.16	0.09	0.07**	0.14***
	(0.05)	(0.05)	(0.11)	(0.10)	(0.03)	(0.03)
Electrical and Optical Equipment	0.24***	0.25***	0.12	0.05	-0.13***	-0.12***
	(0.03)	(0.03)	(0.13)	(0.14)	(0.03)	(0.03)
Food Products, Beverages, and Tobacco	0.02	0.04*	0.10	0.09	-0.01	-0.01
	(0.03)	(0.02)	(0.06)	(0.06)	(0.01)	(0.01)
Basic Metals and Fabricated Metal Products	0.15**	0.16***	-0.10*	-0.15**	0.03	0.03
	(0.05)	(0.05)	(0.05)	(0.05)	(0.02)	(0.02)
Pulp, Paper, Paper Products, Printing and Publishing	0.07**	0.03	-0.001	0.05	-0.005	-0.001
	(0.03)	(0.03)	(0.12)	(0.13)	(0.04)	(0.04)

Note. VCM - Vintage Capital Model, TL - Translog Model. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 2 shows estimated partial cross-price elasticities of energy demand. As expected, labor is a substitute for energy across all industries. Capital and energy inputs are substitutes in petrochemical, electrical, and food processing industries. Capital and energy are complements in the metals industry. The vintage capital model suggests that capital and energy are also complements in the pulp and paper industry. Estimated cross-price elasticities for capital and energy, however, are not statistically different from zero. The translog model indicates that capital and energy are the substitutes in the pulp and paper products industry. Materials and energy inputs are substitutes in the energy-intensive petrochemical industry, and are complements in the materials-intensive electrical industy. Estimated cross-price elasticities for materials and energy demand are close to zero and not statistically significant in food processing, metals, or the pulp and paper products industries. These results indicate that estimated differences in cross-price elasticities of input demand from previous empirical studies (Thompson and Taylor 1995) can be attributed to the aggregation bias.

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[11] Estimated elasticities did not have the expected sign in some countries (see Tables 5a-5e, Appendix 2, for details). However, they were not statistically different from zero.

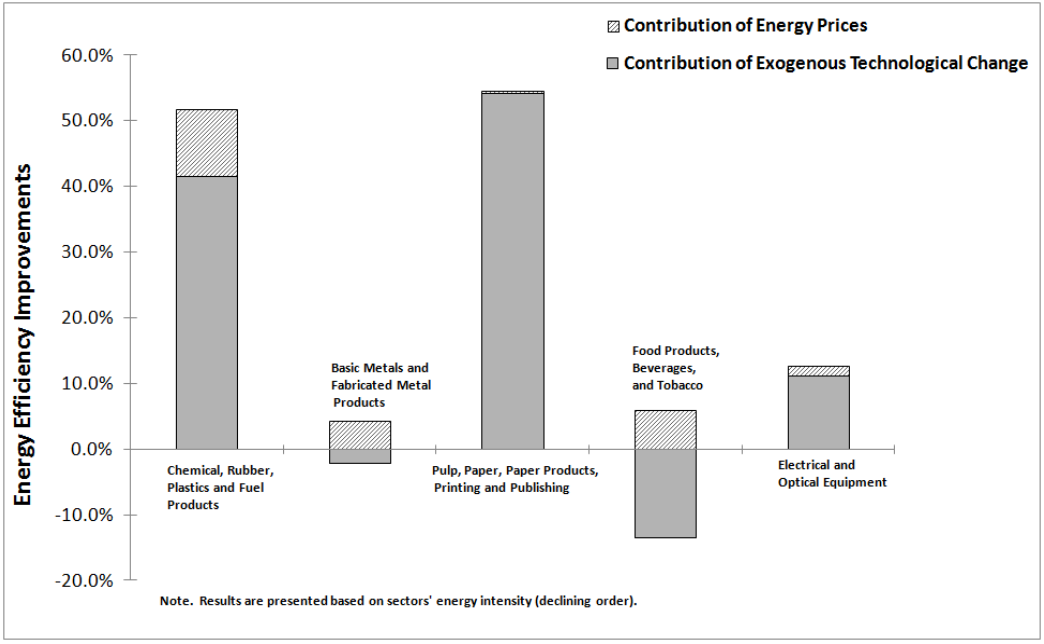
Table 3. Own-Price Elasticities of Input Efficiency of Capital Stock, Real Input Price Changes, and the Rate of Exogenous Technological Change in OECD Manufacturing Sectors, 1990-2005

Sector	**Own-Price Elasticities of Input Efficiency of Capital Stock**			**Exogenous Technological Change**
	Labor	**Energy**	**Materials**	
Chemical, Rubber, Plastics and Fuel Products	0.71	0.89	0.01	0.032
Electrical and Optical Equipment	0.88	0.05	0.04	0.027
Food Products, Beverages, and Tobacco	0.30	0.72	0.03	-0.017
Basic Metals and Fabricated Metal Products	0.77	0.30	0.90	-0.002
Pulp, Paper, Paper Products, Printing and Publishing	0.41	0.03	0.42	0.045
% Change in Factor Price in OECD Manufacturing, 1990-2005	22.33	16.4	-6.29	

Table 3 illustrates the estimated elasticities of input efficiency of capital stock, the estimated rate of exogenous technological change, and real input price changes in OECD manufacturing sector between 1990 and 2005. Estimated elasticities have reasonable magnitudes, and vary significantly across sectors. Estimated own-price elasticity of labor efficiency of capital stock varies from 0.3 to 0.9 with the highest investment response in electrical, petrochemical and metals industries. Estimated own-price elasticity of energy efficiency of capital stock ranges between 0.3 and 0.9 in petrochemical, food processing and metals industries. The investment response to energy prices is close to zero in pulp and paper products and electrical industries. Estimated own-price elasticity of materials efficiency of capital stock varies from 0.4 to 0.9 in pulp and paper products and metals industries. The investment response to materials prices is close to zero in petrochemical, electrical and food processing industries. Table 3 shows that the real price of materials has fallen in all sectors. Weak investment response to falling materials prices in petrochemical, electrical and food processing industries can be supportive to the hypothesis of asymmetric demand response to input prices (Borenstein, Cameron, and Gilbert 1997; Peltzman 2000; Gately and Huntington 2002). The parameter ζ is positive in petrochemical, electrical, and pulp and paper products industries, indicating that autonomous technological change increases the input efficiency of capital stock. The parameter ζ is negative in food processing and metals industries, indicating that autonomous technological change increases the input intensity of capital stock.

Figure 2 shows the estimated effect of energy prices and the exogenous technological change on the energy efficiency of capital stock in OECD manufacturing industries. Between 1990 and 2005 the energy efficiency of capital stock has increased in all sectors, except for the food processing industry, where it has fallen by 7.5 percent. The increase in the

Figure 2: Contribution of Energy Prices and Exogenous Technological Change to Energy Efficiency of Capital Stock in OECD Manufacturing Industries, 1990-2005.

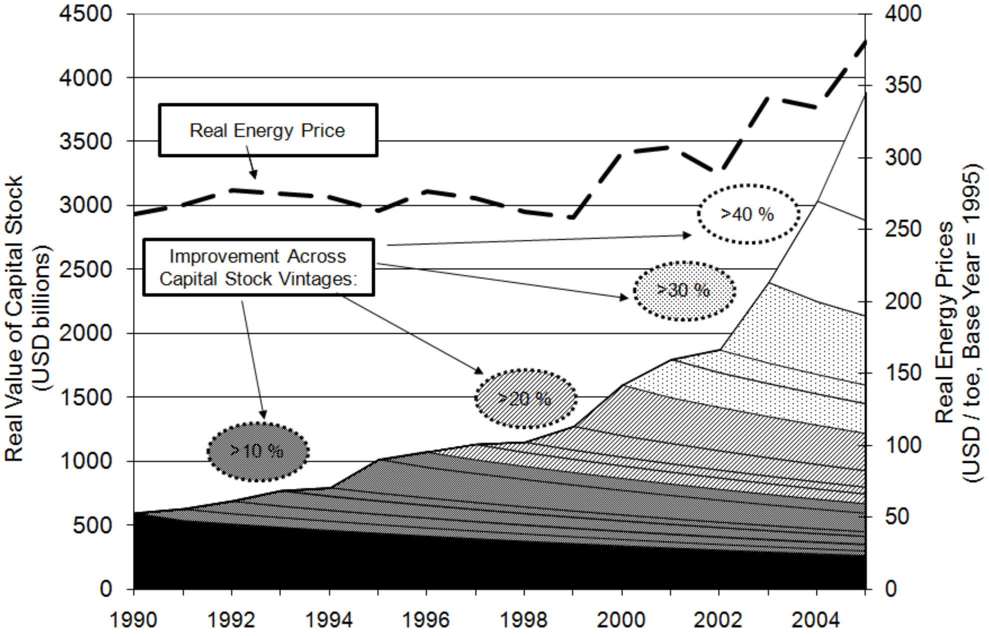


Note. Results are presented based on sectors' energy intensity (declining order).

energy efficiency varies from 2 percent in the metals industry to more than 50 percent in petrochemical and pulp and paper products industries. In less energy-intensive sectors (see Tables 3a - 3e, Appendix I), such as pulp and paper products, and electrical industries, more than 90 percent of energy efficiency improvements is attributable to exogenous technological change. In more energy-intensive industries the contribution of energy prices is larger. In the petrochemical industry, energy prices account for 20 percent (or 10 percent out of overall 50 percent) of total improvements in energy efficiency of capital stock. In the metals industry, energy prices account for all improvements in energy efficiency of capital stock, offsetting the negative effect of exogenous technological change.

Figure 3 illustrates the effect of energy prices on energy efficiency of capital stock, by showing the estimated rate of improvement in energy efficiency in petrochemical sector across capital vintages in the United States in 1990-2005. The vintage capital model predicts that between 1990 and 2005 the energy efficiency of capital stock in the U.S. manufacturing sector has improved by 52 percent. Real energy prices did not change much before 2000, and most improvements in the energy efficiency of capital stock were driven by exogenous energy-saving technological change. The major price-induced improvement in energy efficiency came between 2000 and 2005, following a sharp rise in real energy prices.

Figure 3: Real Energy Prices and Energy Efficiency Improvements in the U.S. Petrochemical Industry

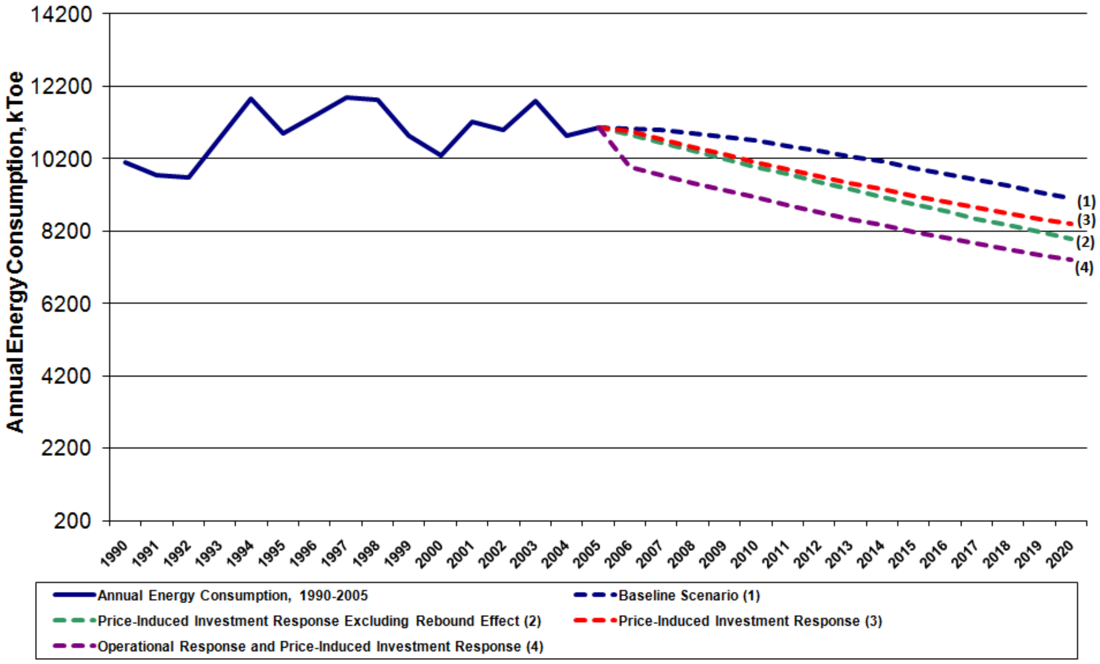


5 Simulated Effects of Greenhouse Gas Emissions Tax

The results of the vintage capital model indicate that energy-price induced improvements in capital stock are significant in determining the future energy efficiency of production in three out of five industries analyzed in this study. These findings imply that energy and climate policies that provide incentives for early investment in energy efficient capital stock may reduce future energy (including fossil fuel) input consumption. To illustrate the outcome of such policies we use the vintage capital model predictions to evaluate the effect of a greenhouse emissions tax on energy consumption. Specifically, we simulate the effect of the greenhouse gas (carbon dioxide, CO_2) emissions tax implemented in 2005 in the U.K. petrochemical industry.

We assume that all input prices except for the energy price and output remain at their 2005 levels (e.g. $\Delta Y_{i,t} = \Delta w_{i,t}^{j=k,l,m} = 0, t > 2005$). The capital stock stays constant, and the vintage investment offsets capital stock depreciation (e.g. $x_{i,t>2005}^{k} = x_{i,2005}^{k}$, $\Delta I_{i,l>2005} = (1-\delta)\, x_{i,2005}^{k}$). Based on the results of the vintage capital model (see Table 3 and Table 5d, Appendix 1) we assume the rate of exogenous technological change $\zeta = 0.032$, the own-price elasticity of energy efficiency of capital stock $\phi^{e} = 0.89$, and the own-price elasticity of energy demand for the U.K. petrochemical industry $\eta_{ee} = -0.58$. Because EU KLEMS dataset does

Figure 4: Simulated Effect of $30 Carbon Tax on Energy Consumption in the U.K. Petrochemical Industry



not have data on sector energy consumption we obtain this data from U.K. Department of Energy and Climate Change.

Figure 4 illustrates the simulation results. In the baseline scenario, we assume there is no greenhouse emission tax, and the energy price does not change. The change in the energy input consumption in the baseline scenario is determined by two factors. The first factor is the improvement in the energy efficiency of capital stock due to exogenous technological change. To quantify this effect we use the assumptions above to compute an index of energy efficiency of the capital stock for the simulation sample based on equation (2). The second factor is the change in the share of energy service due to the substitution effect between labor, energy, and materials services.[12] We compute the change in the share of energy service using the results from regression (1) for the manufacturing sector (see Table 4d, Appendix 2), and convert this change into energy units (*toe*). Our calculations show that in the baseline scenario, these factors account for a 22 percent decline in energy input consumption by 2020.

In the counterfactual scenario, we assume there is $30 tax per ton of emitted greenhouse

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[12] Given the assumptions above, the equation (1) implies that $\Delta S^E_{i,t} = \sum_{j=k,l,e,m} \beta_{ij} \Delta \log \left(w^j_{i,t} \gamma^j_{i,t} \right) = \sum_{j=k,l,e,m} \beta_{ij} \Delta \log(w^j_{i,t}) + \sum_{j=l,e,m} \beta_{ij} \Delta \log \gamma^j_{i,t} = \sum_{j=l,e,m} \beta_{ij} \Delta \log \gamma^j_{i,t} \neq 0.$

gas. Using the data for the UK petrochemical industry, we find that one ton of the fuel mix emits 2.4 tons of the CO_2 (computation details are available in Table 7, Appendix 2).[13] Then, a \$30 tax per ton of greenhouse gas corresponds to \$73 per *toe*, or (given that the average real energy price in the U.K. petrochemical industry in 2005 was \$433 per *toe*) to a 17 percent increase in energy input price. We assume that energy-using capital stock in manufacturing sectors is idiosyncratic in fuel mix, so no interfuel substitution is possible.[14]

The change in energy input consumption in the counterfactual scenario relative to the baseline scenario depends on two factors. The first factor is price-induced change in the energy efficiency of the capital stock (or the price-induced investment response). As in the baseline scenario, we compute the index of energy efficiency of the capital stock for the simulation sample, now assuming a 17 percent increase in the energy input price. Our calculations show that the price-induced investment response results in 12 percent less energy consumption relative to that in the baseline scenario by 2020. This analysis, however, excludes the rebound effect[15]. To quantify the rebound effect, we predict an increase in the share of energy service consumption $S_{i,t}^{j}$ due to greenhouse tax induced improvements in energy efficiency of capital stock (holding other factors constant), and convert these changes in level terms. The rebound effect is the difference in price-induced energy consumption with and without adjustments for changes in the share of energy service. Our calculations show a long-run rebound effect of 36 percent.[16] In the presence of the rebound effect, energy efficiency improvements result in 8 percent less energy consumption relative to the baseline scenario by 2020.

The second factor is the long-run change in the energy demand due to input substitution (or the operational response). Because prices of other inputs are assumed constant, the decline in long-run energy demand depends solely on the own-price elasticity of energy demand. Our calculations show that the operational response to the greenhouse emissions

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[13] The data on fuel mix composition in the U.K. petrochemical industry is obtained from the U.K. Department of Energy and Environment database. The greenhouse emission coefficients per type of fuel (in million of British Thermal Units, BTU) are obtained from the US Department of Energy Voluntary Reporting of Greenhouse Gases Program website (http://www.eia.doe.gov/oiaf/1605/coefficients.html) and converted to tons of oil equivalent (*toe*, 1 *toe* $\approx 40 \times 10^6$ BTU).

[14] To test the restrictiveness of this assumption we estimated the econometric model of interfuel substitution for 12 energy-intensive UK manufacturing sectors between 1990 aand 2005, and found very small cross-price elasticities of fuel demand in both short- and the long- run. This finding is consistent with earlier studies of interfuel substitution in manufacturing based on disaggregated data (Woodland 1993, Bjorner and Jensen 2002).The results are available from authors upon request.

[15] In this context the "rebound effect" is defined as a direct increase in demand for an energy service whose supply has increased as a result of improvements in technical efficiency in the use of energy (Khazzoom 1980; Greening, Greene, and Difiglio 2000; Sorrell and Dimitropoulos 2008).

[16] For a survey of empirical studies on rebound effect, see Small and Van Dender (2007) and references therein.

tax results in 11 percent less energy consumption than in the baseline scenario by 2020.

Bringing all effects together, a 17 percent increase in the energy input price due to the greenhouse gas tax lowers energy consumption by 19 percent relative to the baseline scenario, or energy demand is approximately unit-elastic. Price-induced efficiency improvements lower long-run energy consumption by 12 percent relative to the baseline scenario. However, 36 percent of these price-induced efficiency improvements (or 4 percent of energy consumption in the baseline scenario) are reverted due to the rebound effect. The remaining 11 percent decline in long-run energy consumption relative to the baseline scenario is due to a reduction in the long-run energy demand. These results indicate that energy and climate policies that increase energy costs result in significant reductions in energy use in the long-run.

6 Concluding Remarks

This paper examines the robustness of the econometric vintage capital of Steinbuks, Meshreky, and Neuhoff (2009) using less aggregate data. This allows us to test model results abstracting from the distortions from exogenous structural shifts and measurement errors. The model is estimated for five manufacturing industries in 19 OECD countries between 1990 and 2005. The results confirm the previous findings of Steinbuks, Meshreky, and Neuhoff (2009) that including capital stock vintages significantly improves the econometric model's goodness of fit. The conventional translog model of energy demand is rejected for all sectors but one. Estimated own-price elasticities of energy demand vary between 0.26 and 1.00 and are economically sound. Estimated own-price investment elasticities of energy efficiency of capital stock vary between 0.03 and 0.9. This result indicates that the investment reponse to energy prices varies significantly across manufacturing industries, being significant in some of them and negligible in other.

An important finding of this paper is that energy and climate policies aimed at reductions in fossil fuel emissions can result in substantial reductions in energy use in energy intensive sectors. The results of policy simulations for the U.K. petrochemical industry (the most energy-intensive industry in the sample) indicate that a 17 percent increase in energy prices from 30 dollar carbon tax results in a 19 percent decline in energy use. That is total (operational and investment) own-price elasticity of energy demand is close to one.

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Appendix I - Tables

Table 1

List of Variables

Variable	Desctiption	Units
S_L	Share of Labor in the Total Cost	Percent
S_K	Share of Capital in the Total Cost	Percent
S_E	Share of Energy in the Total Cost	Percent
S_M	Share of Materials in the Total Cost	Percent
Y	Real Sector Output	Real USD million
w_L	Real Average Wage	Real USD / hour
w_K	Rate of Return on Capital	Percent
w_E	Real Average Price of Energy	Real USD / toe
w_M	Real Average Price of Materials	Real USD / metric ton
INT	Sector Energy Intensity	Toe / real USD thousand

Table 2

List of Countries

Country ID	Country	Data Availability
1	Australia	1990-2005
2	Austria	1990-2005
3	Belgium	1990-2005
4	Denmark	1990-2005
5	Finland	1990-2005
6	France	1990-2005
7	Germany	1990-2005
8	Greece	1990-2005
9	Ireland	1990-2005
10	Italy	1990-2005
11	Japan	1990-2005
12	Korea	1990-2005
13	Luxembourg	1990-2005
14	Netherlands	1990-2005
15	Portugal	1990-2005
16	Spain	1990-2005
17	Sweden	1990-2005
18	United Kingdom	1990-2005
19	United States	1990-2005

Table 3a. Descriptive Statistics (1995)

Chemical, Rubber, Plastics and Fuel Products

Country	S_L	S_K	S_E	S_M	Y	w_L	w_K	w_E	w_M	INT
Australia	0.18	0.12	0.23	0.46	22689	15.0	0.13	332.7	842.1	0.59
Austria	0.25	0.16	0.10	0.49	14163	23.7	0.11	406.7	1153.1	0.22
Belgium	0.20	0.15	0.15	0.49	42620	32.7	0.11	327.5	1221.2	0.39
Denmark	0.25	0.16	0.17	0.42	10480	26.4	0.12	354.5	1048.7	0.42
Finland	0.18	0.17	0.25	0.40	10145	25.2	0.13	411.4	1064.0	0.52
France	0.19	0.14	0.19	0.48	143280	26.5	0.12	314.2	1219.7	0.50
Germany	0.30	0.13	0.16	0.41	238281	32.1	0.10	432.9	1394.4	0.30
Greece	0.19	0.11	0.38	0.32	7076	7.6	0.21	354.2	1182.9	0.95
Ireland	0.12	0.46	0.04	0.39	12382	14.8	0.12	372.6	1709.9	0.08
Italy	0.16	0.15	0.20	0.49	118146	17.4	0.18	405.4	1296.2	0.44
Japan	0.17	0.29	0.07	0.47	527805	26.2	0.07	729.3	1162.5	0.08
Korea	0.15	0.15	0.29	0.40	89309	6.4	0.16	277.5	1077.9	0.92
Luxembourg	0.21	0.21	0.02	0.56	1482	29.3	0.11	360.6	1709.5	0.06
Netherlands	0.14	0.18	0.22	0.47	52757	26.1	0.11	333.8	1281.0	0.57
Portugal	0.14	0.13	0.28	0.45	8168	6.0	0.16	308.8	1134.9	0.81
Spain	0.19	0.16	0.25	0.40	59174	16.3	0.13	318.6	1226.9	0.63
Sweden	0.19	0.27	0.19	0.35	17789	22.1	0.15	327.7	947.8	0.48
United Kingdom	0.24	0.16	0.16	0.44	110267	18.3	0.13	296.8	1036.1	0.48
United States	0.23	0.20	0.23	0.33	650382	24.3	0.11	262.8	1313.4	0.72

Table 3b. Descriptive Statistics (1995)

Electrical and Optical Equipment

Country	S_L	S_K	S_E	S_M	Y	w_L	w_K	w_E	w_M	INT
Australia	0.32	0.10	0.02	0.56	7667	15.0	0.13	332.7	842.1	0.06
Austria	0.38	0.11	0.01	0.50	12074	23.7	0.11	406.7	1153.1	0.03
Belgium	0.34	0.12	0.01	0.54	10979	32.7	0.11	327.5	1221.2	0.02
Denmark	0.32	0.12	0.01	0.55	6490	26.4	0.12	354.5	1048.7	0.02
Finland	0.21	0.15	0.01	0.64	11699	25.2	0.13	411.4	1064.0	0.01
France	0.28	0.10	0.02	0.60	83511	26.5	0.12	314.2	1219.7	0.04
Germany	0.43	0.05	0.02	0.50	171027	32.1	0.10	432.9	1394.4	0.03
Greece	0.23	0.14	0.03	0.61	1276	7.6	0.21	354.2	1182.9	0.07
Ireland	0.13	0.20	0.00	0.67	12896	14.8	0.12	372.6	1709.9	0.01
Italy	0.29	0.09	0.02	0.59	61458	17.4	0.18	405.4	1296.2	0.05
Japan	0.27	0.18	0.02	0.54	559964	26.2	0.07	729.3	1162.5	0.02
Korea	0.19	0.13	0.02	0.66	85829	6.4	0.16	277.5	1077.9	0.06
Luxembourg	0.36	0.12	0.01	0.51	200	29.3	0.11	360.6	1709.5	0.03
Netherlands	0.33	0.07	0.01	0.59	20742	26.1	0.11	333.8	1281.0	0.02
Portugal	0.17	0.10	0.01	0.72	4934	6.0	0.16	308.8	1134.9	0.02
Spain	0.28	0.14	0.02	0.56	23726	16.3	0.13	318.6	1226.9	0.05
Sweden	0.27	0.12	0.01	0.60	18037	22.1	0.15	327.7	947.8	0.01
United Kingdom	0.27	0.14	0.01	0.58	74476	18.3	0.13	296.8	1036.1	0.04
United States	0.36	0.18	0.01	0.45	542450	24.3	0.11	262.8	1313.4	0.04

Table 3c. Descriptive Statistics (1995)
Food Products, Beverages, and Tobacco

Country	S_L	S_K	S_E	S_M	Y	w_L	w_K	w_E	w_M	INT
Australia	0.18	0.13	0.02	0.66	34496	15.0	0.13	332.7	842.1	0.06
Austria	0.24	0.13	0.02	0.61	16313	23.7	0.11	406.7	1153.1	0.05
Belgium	0.17	0.10	0.02	0.71	31772	32.7	0.11	327.5	1221.2	0.06
Denmark	0.17	0.08	0.02	0.73	20852	26.4	0.12	354.5	1048.7	0.05
Finland	0.18	0.12	0.02	0.68	11059	25.2	0.13	411.4	1064.0	0.04
France	0.17	0.09	0.02	0.71	137949	26.5	0.12	314.2	1219.7	0.07
Germany	0.23	0.11	0.03	0.63	170822	32.1	0.10	432.9	1394.4	0.07
Greece	0.16	0.08	0.02	0.74	13943	7.6	0.21	354.2	1182.9	0.05
Ireland	0.14	0.17	0.02	0.67	15120	14.8	0.12	372.6	1709.9	0.04
Italy	0.19	0.06	0.02	0.73	96923	17.4	0.18	405.4	1296.2	0.05
Japan	0.22	0.25	0.02	0.52	376455	26.2	0.07	729.3	1162.5	0.02
Korea	0.14	0.08	0.02	0.77	49716	6.4	0.16	277.5	1077.9	0.06
Luxembourg	0.24	0.16	0.02	0.58	639	29.3	0.11	360.6	1709.5	0.05
Netherlands	0.13	0.11	0.01	0.74	55076	26.1	0.11	333.8	1281.0	0.04
Portugal	0.11	0.09	0.01	0.79	13024	6.0	0.16	308.8	1134.9	0.04
Spain	0.16	0.11	0.01	0.72	76792	16.3	0.13	318.6	1226.9	0.04
Sweden	0.18	0.11	0.02	0.70	16001	22.1	0.15	327.7	947.8	0.04
United Kingdom	0.21	0.12	0.02	0.65	96897	18.3	0.13	296.8	1036.1	0.07
United States	0.19	0.18	0.02	0.61	457682	24.3	0.11	262.8	1313.4	0.05

Table 3d. Descriptive Statistics (1995)
Basic Metals and Fabricated Metal Products

Country	S_L	S_K	S_E	S_M	Y	w_L	w_K	w_E	w_M	INT
Australia	0.19	0.16	0.05	0.59	30715	15.0	0.13	332.7	842.1	0.15
Austria	0.31	0.13	0.05	0.51	16236	23.7	0.11	406.7	1153.1	0.11
Belgium	0.24	0.09	0.06	0.60	26954	32.7	0.11	327.5	1221.2	0.17
Denmark	0.35	0.10	0.02	0.52	6980	26.4	0.12	354.5	1048.7	0.06
Finland	0.18	0.14	0.04	0.64	11477	25.2	0.13	411.4	1064.0	0.10
France	0.30	0.12	0.04	0.54	95603	26.5	0.12	314.2	1219.7	0.11
Germany	0.38	0.05	0.06	0.51	181713	32.1	0.10	432.9	1394.4	0.11
Greece	0.25	0.06	0.11	0.58	4340	7.6	0.21	354.2	1182.9	0.28
Ireland	0.33	0.13	0.05	0.49	1576	14.8	0.12	372.6	1709.9	0.11
Italy	0.24	0.13	0.04	0.59	108906	17.4	0.18	405.4	1296.2	0.10
Japan	0.23	0.16	0.04	0.57	466726	26.2	0.07	729.3	1162.5	0.05
Korea	0.15	0.11	0.06	0.68	77413	6.4	0.16	277.5	1077.9	0.20
Luxembourg	0.23	0.02	0.08	0.66	3088	29.3	0.11	360.6	1709.5	0.21
Netherlands	0.30	0.14	0.03	0.53	21877	26.1	0.11	333.8	1281.0	0.07
Portugal	0.28	0.09	0.04	0.60	5336	6.0	0.16	308.8	1134.9	0.13
Spain	0.26	0.17	0.05	0.52	45777	16.3	0.13	318.6	1226.9	0.12
Sweden	0.22	0.18	0.04	0.55	20544	22.1	0.15	327.7	947.8	0.10
United Kingdom	0.32	0.09	0.05	0.54	67240	18.3	0.13	296.8	1036.1	0.14
United States	0.31	0.14	0.04	0.52	366766	24.3	0.11	262.8	1313.4	0.12

Table 3e. Descriptive Statistics (1995)
Pulp, Paper, Paper Products, Printing and Publishing

Country	S_L	S_K	S_E	S_M	**Y**	w_L	w_K	w_E	w_M	**INT**
Australia	0.35	0.16	0.03	0.46	15502	15.0	0.13	332.7	842.1	0.06
Austria	0.28	0.15	0.03	0.54	10422	23.7	0.11	406.7	1153.1	0.07
Belgium	0.27	0.14	0.03	0.56	11929	32.7	0.11	327.5	1221.2	0.08
Denmark	0.38	0.11	0.01	0.49	6767	26.4	0.12	354.5	1048.7	0.03
Finland	0.18	0.22	0.08	0.52	22378	25.2	0.13	411.4	1064.0	0.17
France	0.31	0.10	0.03	0.56	60939	26.5	0.12	314.2	1219.7	0.07
Germany	0.38	0.12	0.04	0.46	97837	32.1	0.10	432.9	1394.4	0.08
Greece	0.35	0.05	0.07	0.52	2511	7.6	0.21	354.2	1182.9	0.17
Ireland	0.19	0.25	0.01	0.55	5482	14.8	0.12	372.6	1709.9	0.03
Italy	0.29	0.12	0.03	0.57	42764	17.4	0.18	405.4	1296.2	0.07
Japan	0.33	0.17	0.03	0.47	231808	26.2	0.07	729.3	1162.5	0.03
Korea	0.28	0.10	0.04	0.57	22281	6.4	0.16	277.5	1077.9	0.12
Luxembourg	0.32	0.15	0.01	0.52	371	29.3	0.11	360.6	1709.5	0.03
Netherlands	0.33	0.15	0.02	0.50	20733	26.1	0.11	333.8	1281.0	0.05
Portugal	0.19	0.24	0.05	0.52	5241	6.0	0.16	308.8	1134.9	0.15
Spain	0.26	0.16	0.03	0.56	26319	16.3	0.13	318.6	1226.9	0.08
Sweden	0.23	0.24	0.04	0.48	22928	22.1	0.15	327.7	947.8	0.11
United Kingdom	0.36	0.14	0.02	0.49	62542	18.3	0.13	296.8	1036.1	0.04
United States	0.39	0.16	0.03	0.43	359368	24.3	0.11	262.8	1313.4	0.08

Table 4a. Parameter Estimates of Total Cost Function[17]
Chemical, Rubber, Plastics and Fuel Products

	Vintage Capital Model		Translog Model	
	est. coefficient	standard error	est. coefficient	standard error
Labor Share Equation: constant	0.454***	0.077	0.576***	0.088
Labor Share Equation: Output	-0.053***	0.005	-0.048***	0.007
Labor Share Equation: Wage	0.058***	0.010	-0.001	0.008
Labor Share Equation: Return on Capital	-0.015***	0.006	0.012**	0.005
Labor Share Equation: Energy Price	0.026***	0.009	0.030***	0.009
Labor Share Equation: Materials Price	0.020***	0.007	0.023***	0.009
Capital Share Equation: constant	-1.320***	0.134	-1.566***	0.131
Capital Share Equation: Output	0.128***	0.009	0.163***	0.011
Capital Share Equation: Wage	-0.143***	0.017	-0.111***	0.012
Capital Share Equation: Return on Capital	0.017*	0.010	0.008	0.008
Capital Share Equation: Energy Price	-0.009	0.015	-0.020	0.013
Capital Share Equation: Materials Price	0.048***	0.012	0.013	0.013
Energy Share Equation: constant	0.906***	0.192	0.762***	0.196
Energy Share Equation: Output	0.008	0.013	0.013	0.016
Energy Share Equation: Wage	-0.013	0.024	0.026	0.018
Energy Share Equation: Return on Capital	0.033**	0.014	0.005	0.012
Energy Share Equation: Energy Price	0.043**	0.021	0.024	0.019
Energy Share Equation: Materials Price	-0.130***	0.017	-0.128***	0.019
Materials Share Equation: constant	0.960***	0.138	1.228***	0.132
Materials Share Equation: Output	-0.082***	0.010	-0.128***	0.011
Materials Share Equation: Wage	0.097***	0.017	0.086***	0.012
Materials Share Equation: Return on Capital	-0.035***	0.010	-0.025***	0.008
Materials Share Equation: Energy Price	-0.060***	0.015	-0.033**	0.013
Materials Share Equation: Materials Price	0.061***	0.012	0.091***	0.013
Labor Efficiency of Capital Stock (ϕ_L)	0.71	n.a.		
Energy Efficiency of Capital Stock (ϕ_E)	0.89	n.a.		
Materials Efficiency of Capital Stock (ϕ_M)	0.01	n.a.		
Exogenous Technological Change (ζ)	0.032	n.a.		
Number of observations	285		285	
Labor Share Equation: R^2	0.93		0.91	
Capital Share Equation: R^2	0.94		0.95	
Energy Share Equation: R^2	0.89		0.88	
Materials Share Equation: R^2	0.89		0.90	
LR Test: $\gamma_L=\gamma_E=\gamma_M=\eta=0$, χ^2 (pval)		71.88 (0.00)		
note: *** p<0.01, ** p<0.05, * p<0.1				

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[17] Estimates for country-specific fixed effects are not reported in Tables 4a-4e, and are available upon request.

Table 4b. Parameter Estimates of Total Cost Function
Electrical and Optical Equipment

	Vintage Capital Model		**Translog Model**	
	est. coefficient	**standard error**	**est. coefficient**	**standard error**
Labor Share Equation: constant	0.952***	0.091	1.211***	0.095
Labor Share Equation: Output	-0.079***	0.005	-0.089***	0.006
Labor Share Equation: Wage	0.057***	0.010	0.033***	0.009
Labor Share Equation: Return on Capital	-0.001	0.008	0.017**	0.007
Labor Share Equation: Energy Price	0.061***	0.012	0.050***	0.012
Labor Share Equation: Materials Price	-0.009	0.012	-0.0003	0.013
Capital Share Equation: constant	-0.604***	0.113	-0.748***	0.120
Capital Share Equation: Output	0.060***	0.006	0.065***	0.008
Capital Share Equation: Wage	-0.103***	0.013	-0.060***	0.011
Capital Share Equation: Return on Capital	0.008	0.010	-0.006	0.009
Capital Share Equation: Energy Price	0.005	0.015	-0.001	0.016
Capital Share Equation: Materials Price	0.047***	0.015	0.037**	0.016
Energy Share Equation: constant	0.029**	0.012	0.046***	0.012
Energy Share Equation: Output	-0.002**	0.001	-0.004***	0.001
Energy Share Equation: Wage	-0.001	0.001	0.003***	0.001
Energy Share Equation: Return on Capital	-0.002**	0.001	-0.004***	0.001
Energy Share Equation: Energy Price	0.008***	0.002	0.005***	0.002
Energy Share Equation: Materials Price	-0.006***	0.002	-0.005***	0.002
Materials Share Equation: constant	0.623***	0.124	0.490***	0.128
Materials Share Equation: Output	0.021***	0.007	0.028***	0.008
Materials Share Equation: Wage	0.046***	0.014	0.024**	0.012
Materials Share Equation: Return on Capital	-0.005	0.011	-0.008	0.010
Materials Share Equation: Energy Price	-0.074***	0.016	-0.054***	0.017
Materials Share Equation: Materials Price	-0.032**	0.016	-0.032*	0.017
Labor Efficiency of Capital Stock (ϕ_L)	0.88	n.a.		
Energy Efficiency of Capital Stock (ϕ_E)	0.045	n.a.		
Materials Efficiency of Capital Stock (ϕ_M)	0.035	n.a.		
Exogenous Technological Change (ζ)	0.027	n.a.		
Number of observations			285	
Labor Share Equation: R^2	0.92		0.92	
Capital Share Equation: R^2	0.74		0.71	
Energy Share Equation: R^2	0.75		0.76	
Materials Share Equation: R^2	0.85		0.84	
LR Test: $\gamma_L=\gamma_E=\gamma_M=\eta=0$, χ^2 (pval)		41.98 (0.00)		
note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$				

Table 4c. Parameter Estimates of Total Cost Function
Food Products, Beverages, and Tobacco

	Vintage Capital Model		**Translog Model**	
	est. coefficient	**standard error**	**est. coefficient**	**standard error**
Labor Share Equation: constant	0.733***	0.084	0.660***	0.081
Labor Share Equation: Output	-0.062***	0.008	-0.061***	0.008
Labor Share Equation: Wage	0.047***	0.007	0.044***	0.006
Labor Share Equation: Return on Capital	-0.008***	0.003	-0.018***	0.003
Labor Share Equation: Energy Price	-0.001	0.006	0.003	0.005
Labor Share Equation: Materials Price	0.017***	0.007	0.019***	0.007
Capital Share Equation: constant	0.047	0.118	0.039	0.113
Capital Share Equation: Output	0.011	0.011	0.016	0.011
Capital Share Equation: Wage	0.019**	0.009	0.016**	0.008
Capital Share Equation: Return on Capital	-0.023***	0.004	-0.023***	0.003
Capital Share Equation: Energy Price	0.009	0.008	0.008	0.007
Capital Share Equation: Materials Price	-0.026***	0.009	-0.032***	0.009
Energy Share Equation: constant	0.140***	0.030	0.129***	0.030
Energy Share Equation: Output	-0.015***	0.003	-0.012***	0.003
Energy Share Equation: Wage	0.007***	0.002	0.006***	0.002
Energy Share Equation: Return on Capital	0.003***	0.001	0.0003	0.001
Energy Share Equation: Energy Price	0.012***	0.002	0.012***	0.002
Energy Share Equation: Materials Price	-0.003	0.002	-0.005*	0.002
Materials Share Equation: constant	0.080	0.118	0.172	0.116
Materials Share Equation: Output	0.065***	0.011	0.057***	0.011
Materials Share Equation: Wage	-0.072***	0.009	-0.066***	0.008
Materials Share Equation: Return on Capital	0.028***	0.004	0.041***	0.004
Materials Share Equation: Energy Price	-0.019**	0.008	-0.023***	0.007
Materials Share Equation: Materials Price	0.012	0.009	0.018*	0.009
Labor Efficiency of Capital Stock (ϕ_L)	0.30	n.a.		
Energy Efficiency of Capital Stock (ϕ_E)	0.72	n.a.		
Materials Efficiency of Capital Stock (ϕ_M)	0.03	n.a.		
Exogenous Technological Change (ζ)	-0.017	n.a.		
Number of observations	285		285	
Labor Share Equation: R^2	0.94		0.94	
Capital Share Equation: R^2	0.92		0.92	
Energy Share Equation: R^2	0.73		0.72	
Materials Share Equation: R^2	0.96		0.96	
LR Test: $\gamma_L=\gamma_E=\gamma_M=\eta=0$, χ^2 (pval)		19.19 (0.08)		
note: *** p<0.01, ** p<0.05, * p<0.1				

Table 4d. Parameter Estimates of Total Cost Function
Basic Metals and Fabricated Metal Products

	Vintage Capital Model		**Translog Model**	
	est. coefficient	**standard error**	**est. coefficient**	**standard error**
Labor Share Equation: constant	1.557***	0.107	1.651***	0.129
Labor Share Equation: Output	-0.122***	0.013	-0.119***	0.013
Labor Share Equation: Wage	0.107***	0.011	0.080***	0.011
Labor Share Equation: Return on Capital	0.014***	0.005	0.028***	0.007
Labor Share Equation: Energy Price	0.026**	0.010	0.028***	0.010
Labor Share Equation: Materials Price	-0.017	0.013	-0.024**	0.012
Capital Share Equation: constant	-0.661***	0.095	-0.760***	0.113
Capital Share Equation: Output	0.087***	0.012	0.096***	0.011
Capital Share Equation: Wage	-0.095***	0.009	-0.078***	0.009
Capital Share Equation: Return on Capital	0.010**	0.004	0.004	0.006
Capital Share Equation: Energy Price	-0.014	0.009	-0.019**	0.009
Capital Share Equation: Materials Price	0.014	0.011	0.009	0.011
Energy Share Equation: constant	0.109**	0.049	0.109**	0.055
Energy Share Equation: Output	-0.011*	0.006	-0.006	0.005
Energy Share Equation: Wage	0.015***	0.005	0.009**	0.005
Energy Share Equation: Return on Capital	-0.006***	0.002	-0.003	0.003
Energy Share Equation: Energy Price	-0.002	0.005	0.001	0.004
Energy Share Equation: Materials Price	0.002	0.006	-0.005	0.005
Materials Share Equation: constant	-0.005	0.134	-0.00005	0.146
Materials Share Equation: Output	0.046***	0.016	0.029	0.014
Materials Share Equation: Wage	-0.027**	0.013	-0.011	0.012
Materials Share Equation: Return on Capital	-0.019***	0.006	-0.028	0.008
Materials Share Equation: Energy Price	-0.009	0.013	-0.010	0.012
Materials Share Equation: Materials Price	0.0003	0.016	0.020	0.014
Labor Efficiency of Capital Stock (ϕ_L)	0.77	n.a.		
Energy Efficiency of Capital Stock (ϕ_E)	0.30	n.a.		
Materials Efficiency of Capital Stock (ϕ_M)	0.90	n.a.		
Exogenous Technological Change (ζ)	-0.002	n.a.		
Number of observations	285		285	
Labor Share Equation: R^2	0.93		0.92	
Capital Share Equation: R^2	0.85		0.82	
Energy Share Equation: R^2	0.75		0.73	
Materials Share Equation: R^2	0.88		0.88	
LR Test: $\gamma_L=\gamma_E=\gamma_M=\eta=0$, χ^2 (pval)	83.31 (0.00)			
note: *** p<0.01, ** p<0.05, * p<0.1				

Table 4e. Parameter Estimates of Total Cost Function
Pulp, Paper, Paper Products, Printing and Publishing

	Vintage Capital Model		**Translog Model**	
	est. coefficient	**standard error**	**est. coefficient**	**standard error**
Labor Share Equation: constant	0.784***	0.110	0.955***	0.110
Labor Share Equation: Output	-0.049***	0.007	-0.055***	0.008
Labor Share Equation: Wage	0.090***	0.013	0.074***	0.012
Labor Share Equation: Return on Capital	-0.022***	0.007	0.012**	0.006
Labor Share Equation: Energy Price	0.009	0.011	-0.000	0.010
Labor Share Equation: Materials Price	-0.014	0.012	-0.006	0.013
Capital Share Equation: constant	-0.906***	0.163	-1.287***	0.176
Capital Share Equation: Output	0.162***	0.010	0.173***	0.013
Capital Share Equation: Wage	-0.154***	0.020	-0.105***	0.020
Capital Share Equation: Return on Capital	0.060***	0.010	-0.015	0.009
Capital Share Equation: Energy Price	-0.005	0.016	0.003	0.017
Capital Share Equation: Materials Price	-0.054***	0.018	-0.062***	0.020
Energy Share Equation: constant	0.124***	0.042	0.137***	0.040
Energy Share Equation: Output	-0.008***	0.003	-0.010***	0.003
Energy Share Equation: Wage	0.009*	0.005	0.006	0.004
Energy Share Equation: Return on Capital	-0.003	0.003	0.001	0.002
Energy Share Equation: Energy Price	0.014***	0.004	0.015***	0.004
Energy Share Equation: Materials Price	-0.015***	0.005	-0.012***	0.005
Materials Share Equation: constant	0.997***	0.184	1.196***	0.183
Materials Share Equation: Output	-0.104***	0.012	-0.108***	0.013
Materials Share Equation: Wage	0.055**	0.022	0.024	0.020
Materials Share Equation: Return on Capital	-0.035***	0.012	0.002	0.010
Materials Share Equation: Energy Price	-0.019	0.018	-0.017	0.017
Materials Share Equation: Materials Price	0.083***	0.020	0.080***	0.021
Labor Efficiency of Capital Stock (ϕ_L)	0.41	n.a.		
Energy Efficiency of Capital Stock (ϕ_E)	0.03	n.a.		
Materials Efficiency of Capital Stock (ϕ_M)	0.42	n.a.		
Exogenous Technological Change (ζ)	0.045	n.a.		
Number of observations	285		285	
Labor Share Equation: R^2	0.92		0.91	
Capital Share Equation: R^2	0.88		0.85	
Energy Share Equation: R^2	0.85		0.85	
Materials Share Equation: R^2	0.78		0.77	
LR Test: $\gamma_L=\gamma_E=\gamma_M=\eta=0$, χ^2 (pval)	86.67 (0.00)			
note: *** p<0.01, ** p<0.05, * p<0.1				

Table 5a. Estimated Energy Demand Elasticities by Country
Chemical, Rubber, Plastics and Fuel Products

Country	Model I (Vintage Capital)								Model II (Translog)							
	η_{EE}		η_{LE}		η_{KE}		η_{ME}		η_{EE}		η_{LE}		η_{KE}		η_{ME}	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Australia	-0.56	0.02	0.43	0.06	0.21	0.05	0.13	0.04	-0.63	0.04	0.45	0.06	0.13	0.05	0.20	0.05
Austria	-0.39	0.15	0.21	0.04	0.04	0.03	-0.02	0.04	-0.62	0.06	0.23	0.03	-0.03	0.02	0.04	0.04
Belgium	-0.57	0.03	0.37	0.11	0.16	0.07	0.09	0.07	-0.66	0.05	0.39	0.11	0.08	0.06	0.15	0.07
Denmark	-0.58	0.01	0.31	0.04	0.15	0.03	0.05	0.03	-0.68	0.01	0.33	0.04	0.08	0.03	0.12	0.03
Finland	-0.55	0.02	0.47	0.06	0.26	0.04	0.15	0.03	-0.61	0.03	0.50	0.06	0.19	0.03	0.22	0.04
France	-0.58	0.01	0.38	0.05	0.16	0.03	0.10	0.03	-0.66	0.02	0.41	0.05	0.07	0.03	0.16	0.03
Germany	-0.58	0.01	0.28	0.05	0.13	0.04	0.04	0.03	-0.68	0.02	0.30	0.05	0.04	0.05	0.11	0.04
Greece	-0.47	0.03	0.58	0.05	0.34	0.03	0.22	0.02	-0.51	0.03	0.60	0.05	0.23	0.04	0.32	0.03
Ireland	0.98	1.08	0.28	0.04	0.01	0.01	-0.17	0.07	0.12	0.60	0.32	0.05	-0.01	0.01	-0.08	0.05
Italy	-0.58	0.01	0.38	0.04	0.15	0.02	0.10	0.03	-0.67	0.02	0.40	0.04	0.06	0.02	0.15	0.03
Japan	-0.38	0.05	0.25	0.02	0.05	0.01	-0.04	0.01	-0.62	0.03	0.28	0.03	0.01	0.01	0.01	0.01
Korea	-0.54	0.03	0.53	0.08	0.26	0.05	0.17	0.04	-0.60	0.04	0.56	0.09	0.18	0.05	0.24	0.05
Luxembourg	1.02	0.31	0.14	0.02	-0.03	0.01	-0.08	0.01	0.14	0.17	0.16	0.02	-0.09	0.02	-0.04	0.01
Netherlands	-0.57	0.01	0.47	0.07	0.20	0.03	0.13	0.03	-0.65	0.02	0.50	0.07	0.13	0.03	0.19	0.03
Portugal	-0.52	0.03	0.56	0.07	0.26	0.04	0.21	0.05	-0.58	0.04	0.59	0.07	0.15	0.03	0.27	0.05
Spain	-0.56	0.03	0.43	0.07	0.23	0.05	0.13	0.04	-0.63	0.04	0.45	0.07	0.15	0.04	0.20	0.05
Sweden	-0.57	0.02	0.39	0.06	0.21	0.05	0.05	0.03	-0.65	0.03	0.41	0.06	0.17	0.04	0.14	0.04
United Kingdom	-0.58	0.01	0.30	0.04	0.13	0.03	0.05	0.03	-0.68	0.02	0.31	0.04	0.04	0.03	0.12	0.03
United States	-0.58	0.01	0.37	0.04	0.21	0.03	0.05	0.03	-0.65	0.02	0.38	0.04	0.16	0.03	0.14	0.03

Table 5b. Estimated Energy Demand Elasticities by Country
Electrical and Optical Equipment

Country	Model I (Vintage Capital)								Model II (Translog)							
	η_{EE}		η_{LE}		η_{KE}		η_{ME}		η_{EE}		η_{LE}		η_{KE}		η_{ME}	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Australia	-0.50	0.06	0.21	0.02	0.11	0.02	-0.14	0.013	-0.51	0.06	0.21	0.02	0.05	0.01	-0.12	0.012
Austria	-0.27	0.08	0.19	0.03	0.12	0.02	-0.14	0.010	-0.27	0.08	0.19	0.03	0.05	0.01	-0.13	0.009
Belgium	-0.24	0.20	0.19	0.02	0.13	0.02	-0.14	0.010	-0.24	0.20	0.19	0.02	0.06	0.01	-0.13	0.010
Denmark	-0.19	0.12	0.20	0.03	0.13	0.05	-0.13	0.009	-0.19	0.12	0.21	0.03	0.05	0.02	-0.12	0.008
Finland	0.57	0.62	0.30	0.07	0.07	0.02	-0.14	0.015	0.56	0.62	0.30	0.07	0.03	0.01	-0.13	0.014
France	-0.44	0.07	0.23	0.02	0.15	0.01	-0.12	0.004	-0.44	0.07	0.23	0.02	0.06	0.01	-0.11	0.004
Germany	-0.44	0.07	0.17	0.01	0.18	0.05	-0.14	0.009	-0.45	0.07	0.17	0.01	0.07	0.02	-0.13	0.008
Greece	-0.67	0.01	0.26	0.02	0.13	0.02	-0.11	0.004	-0.67	0.01	0.27	0.02	0.06	0.01	-0.10	0.004
Ireland	0.56	0.52	0.48	0.14	0.08	0.01	-0.11	0.005	0.55	0.52	0.48	0.14	0.03	0.01	-0.10	0.004
Italy	-0.58	0.12	0.22	0.02	0.14	0.01	-0.12	0.011	-0.58	0.12	0.23	0.02	0.07	0.01	-0.11	0.010
Japan	-0.51	0.05	0.24	0.01	0.10	0.01	-0.13	0.004	-0.51	0.05	0.24	0.01	0.05	0.01	-0.12	0.004
Korea	-0.59	0.12	0.39	0.05	0.13	0.02	-0.09	0.005	-0.59	0.12	0.39	0.05	0.06	0.01	-0.09	0.005
Luxembourg	-0.33	0.06	0.18	0.01	0.11	0.01	-0.15	0.009	-0.34	0.06	0.18	0.01	0.05	0.01	-0.14	0.009
Netherlands	-0.30	0.13	0.18	0.01	0.09	0.26	-0.13	0.007	-0.31	0.13	0.18	0.01	0.04	0.09	-0.11	0.007
Portugal	-0.20	0.29	0.32	0.03	0.21	0.07	-0.10	0.009	-0.20	0.29	0.33	0.03	0.08	0.03	-0.09	0.008
Spain	-0.56	0.05	0.25	0.02	0.14	0.03	-0.11	0.010	-0.56	0.05	0.25	0.02	0.06	0.01	-0.10	0.009
Sweden	0.38	0.23	0.22	0.03	0.10	0.18	-0.13	0.014	0.37	0.23	0.22	0.03	0.04	0.06	-0.12	0.013
United Kingdom	-0.36	0.08	0.21	0.02	0.14	0.04	-0.13	0.009	-0.37	0.08	0.22	0.02	0.06	0.01	-0.12	0.009
United States	-0.38	0.06	0.17	0.01	0.09	0.01	-0.18	0.010	-0.38	0.06	0.17	0.01	0.04	0.00	-0.16	0.009

Table 5c. Estimated Energy Demand Elasticities by Country

Food Products, Beverages, and Tobacco

Country	Model I (Vintage Capital)								Model II (Translog)							
	η_{EE}		η_{LE}		η_{KE}		η_{ME}		η_{EE}		η_{LE}		η_{KE}		η_{ME}	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Australia	-0.44	0.08	0.02	0.003	0.09	0.004	-0.006	0.003	-0.46	0.07	0.04	0.003	0.08	0.004	-0.012	0.003
Austria	-0.51	0.08	0.02	0.006	0.11	0.011	-0.004	0.004	-0.52	0.08	0.04	0.005	0.10	0.010	-0.010	0.004
Belgium	-0.46	0.07	0.02	0.003	0.11	0.008	-0.004	0.003	-0.48	0.06	0.04	0.003	0.10	0.007	-0.009	0.003
Denmark	-0.40	0.05	0.02	0.002	0.14	0.014	-0.006	0.002	-0.42	0.05	0.04	0.001	0.12	0.012	-0.011	0.001
Finland	-0.36	0.13	0.01	0.004	0.11	0.015	-0.007	0.003	-0.39	0.12	0.04	0.003	0.10	0.013	-0.013	0.003
France	-0.52	0.03	0.02	0.002	0.12	0.007	-0.001	0.002	-0.54	0.03	0.04	0.001	0.11	0.006	-0.006	0.002
Germany	-0.62	0.04	0.03	0.005	0.12	0.010	0.005	0.005	-0.63	0.04	0.05	0.005	0.11	0.010	-0.001	0.005
Greece	-0.42	0.04	0.02	0.002	0.13	0.007	-0.005	0.001	-0.45	0.04	0.04	0.001	0.11	0.006	-0.010	0.001
Ireland	-0.30	0.13	0.01	0.003	0.07	0.010	-0.011	0.004	-0.33	0.12	0.04	0.003	0.06	0.009	-0.016	0.004
Italy	-0.52	0.11	0.02	0.007	0.15	0.012	0.001	0.007	-0.54	0.11	0.04	0.008	0.13	0.011	-0.004	0.007
Japan	-0.08	0.06	0.01	0.001	0.05	0.004	-0.024	0.002	-0.12	0.06	0.03	0.001	0.04	0.003	-0.031	0.002
Korea	-0.39	0.08	0.01	0.003	0.12	0.020	-0.004	0.002	-0.41	0.07	0.05	0.004	0.11	0.017	-0.009	0.002
Luxembourg	-0.53	0.07	0.02	0.004	0.09	0.009	-0.005	0.004	-0.55	0.06	0.04	0.003	0.08	0.008	-0.011	0.004
Netherlands	-0.22	0.10	0.01	0.002	0.10	0.010	-0.010	0.002	-0.25	0.10	0.04	0.002	0.09	0.009	-0.015	0.002
Portugal	-0.25	0.27	0.01	0.009	0.11	0.031	-0.005	0.010	-0.28	0.26	0.05	0.012	0.10	0.028	-0.010	0.010
Spain	-0.14	0.11	0.01	0.003	0.10	0.008	-0.012	0.002	-0.18	0.11	0.03	0.002	0.09	0.008	-0.016	0.002
Sweden	-0.29	0.07	0.01	0.002	0.09	0.013	-0.011	0.002	-0.32	0.07	0.03	0.002	0.08	0.011	-0.017	0.002
United Kingdom	-0.44	0.08	0.02	0.004	0.09	0.008	-0.009	0.004	-0.46	0.08	0.04	0.004	0.08	0.007	-0.015	0.004
United States	-0.24	0.04	0.01	0.001	0.07	0.004	-0.015	0.001	-0.28	0.04	0.03	0.001	0.06	0.003	-0.021	0.001

Table 5d. Estimated Energy Demand Elasticities by Country

Basic Metals and Fabricated Metal Products

Country	Model I (Vintage Capital)								Model II (Translog)							
	η_{EE}		η_{LE}		η_{KE}		η_{ME}		η_{EE}		η_{LE}		η_{KE}		η_{ME}	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Australia	-0.98	0.01	0.19	0.012	-0.04	0.010	0.04	0.006	-0.92	0.00	0.19	0.012	-0.07	0.014	0.04	0.006
Austria	-0.99	0.01	0.14	0.012	-0.05	0.024	0.03	0.005	-0.93	0.00	0.15	0.012	-0.09	0.033	0.03	0.005
Belgium	-0.97	0.02	0.17	0.011	-0.10	0.025	0.05	0.011	-0.92	0.01	0.18	0.011	-0.16	0.032	0.05	0.011
Denmark	-1.05	0.01	0.10	0.003	-0.12	0.023	0.01	0.003	-0.93	0.00	0.10	0.004	-0.17	0.031	0.01	0.003
Finland	-0.99	0.01	0.17	0.011	-0.08	0.017	0.04	0.006	-0.93	0.00	0.18	0.012	-0.12	0.022	0.04	0.006
France	-1.02	0.01	0.12	0.004	-0.09	0.015	0.02	0.004	-0.93	0.00	0.13	0.005	-0.14	0.019	0.02	0.004
Germany	-0.97	0.01	0.13	0.011	-0.15	0.072	0.04	0.007	-0.92	0.01	0.14	0.011	-0.22	0.096	0.04	0.007
Greece	-0.92	0.01	0.20	0.013	-0.18	0.063	0.09	0.007	-0.89	0.01	0.20	0.013	-0.28	0.083	0.08	0.007
Ireland	-0.98	0.02	0.14	0.016	-0.03	0.026	0.04	0.013	-0.92	0.01	0.14	0.016	-0.06	0.030	0.03	0.013
Italy	-1.00	0.01	0.14	0.006	-0.09	0.019	0.03	0.005	-0.93	0.00	0.15	0.006	-0.13	0.027	0.03	0.005
Japan	-1.00	0.01	0.16	0.010	-0.05	0.005	0.03	0.003	-0.93	0.00	0.17	0.011	-0.08	0.007	0.03	0.003
Korea	-0.97	0.02	0.26	0.025	-0.05	0.017	0.05	0.015	-0.92	0.01	0.28	0.026	-0.09	0.018	0.05	0.015
Luxembourg	-0.97	0.02	0.18	0.013	-0.26	0.147	0.05	0.015	-0.92	0.01	0.19	0.013	-0.37	0.200	0.05	0.015
Netherlands	-1.03	0.01	0.12	0.005	-0.09	0.021	0.01	0.003	-0.93	0.00	0.12	0.006	-0.13	0.028	0.01	0.003
Portugal	-1.02	0.03	0.14	0.007	-0.10	0.023	0.02	0.009	-0.93	0.00	0.14	0.008	-0.15	0.028	0.02	0.009
Spain	-1.00	0.01	0.15	0.015	-0.05	0.016	0.03	0.005	-0.93	0.00	0.15	0.016	-0.09	0.021	0.03	0.005
Sweden	-1.00	0.01	0.15	0.010	-0.05	0.007	0.03	0.006	-0.93	0.00	0.15	0.010	-0.09	0.011	0.03	0.006
United Kingdom	-0.99	0.01	0.12	0.009	-0.40	0.729	0.03	0.009	-0.93	0.01	0.13	0.009	-0.55	0.980	0.03	0.009
United States	-1.01	0.01	0.12	0.006	-0.05	0.010	0.02	0.005	-0.93	0.00	0.13	0.007	-0.09	0.015	0.02	0.005

Table 5e. Estimated Energy Demand Elasticities by Country

Pulp, Paper, Paper Products, Printing and Publishing

Country	**Model I (Vintage Capital)**								**Model II (Translog)**							
	η_{EE}		η_{LE}		η_{KE}		η_{ME}		η_{EE}		η_{LE}		η_{KE}		η_{ME}	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**
Australia	-0.45	0.04	0.05	0.003	-0.0010	0.006	-0.016	0.003	-0.43	0.04	0.03	0.002	0.04	0.003	-0.01	0.003
Austria	-0.57	0.04	0.07	0.006	0.0012	0.013	0.001	0.004	-0.56	0.05	0.04	0.005	0.06	0.009	0.00	0.004
Belgium	-0.53	0.05	0.06	0.004	0.0002	0.007	-0.003	0.003	-0.51	0.05	0.03	0.004	0.05	0.004	0.00	0.003
Denmark	-0.21	0.15	0.04	0.005	-0.0284	0.009	-0.020	0.004	-0.18	0.15	0.02	0.004	0.04	0.006	-0.02	0.004
Finland	-0.74	0.01	0.12	0.018	0.0523	0.022	0.045	0.014	-0.74	0.01	0.08	0.014	0.10	0.013	0.05	0.014
France	-0.46	0.04	0.06	0.002	-0.0211	0.003	-0.008	0.002	-0.43	0.04	0.03	0.002	0.05	0.004	0.00	0.002
Germany	-0.65	0.04	0.07	0.010	0.0165	0.010	0.005	0.009	-0.64	0.05	0.05	0.009	0.07	0.010	0.01	0.009
Greece	-0.71	0.02	0.09	0.008	-0.0387	0.049	0.024	0.008	-0.70	0.02	0.06	0.007	0.12	0.027	0.03	0.008
Ireland	0.59	0.71	0.06	0.008	-0.0024	0.005	-0.042	0.026	0.66	0.74	0.01	0.007	0.02	0.010	-0.04	0.025
Italy	-0.59	0.07	0.07	0.010	-0.0043	0.011	0.004	0.009	-0.57	0.08	0.04	0.008	0.06	0.007	0.01	0.009
Japan	-0.51	0.06	0.06	0.004	0.0038	0.006	-0.010	0.003	-0.49	0.06	0.03	0.004	0.05	0.004	-0.01	0.003
Korea	-0.65	0.06	0.08	0.012	-0.0159	0.023	0.017	0.011	-0.64	0.06	0.05	0.010	0.08	0.021	0.02	0.011
Luxembourg	-0.33	0.14	0.05	0.005	-0.0143	0.006	-0.014	0.005	-0.31	0.15	0.02	0.004	0.04	0.006	-0.01	0.005
Netherlands	-0.27	0.08	0.05	0.003	-0.0106	0.004	-0.019	0.002	-0.24	0.08	0.02	0.003	0.04	0.002	-0.02	0.002
Portugal	-0.59	0.17	0.09	0.021	0.0237	0.020	0.011	0.019	-0.57	0.17	0.05	0.020	0.06	0.020	0.01	0.019
Spain	-0.52	0.04	0.06	0.004	-0.0004	0.007	-0.005	0.003	-0.51	0.04	0.03	0.003	0.05	0.003	0.00	0.003
Sweden	-0.68	0.02	0.09	0.006	0.0264	0.004	0.015	0.008	-0.67	0.03	0.05	0.007	0.07	0.009	0.02	0.008
United Kingdom	-0.12	0.11	0.04	0.003	-0.0215	0.005	-0.025	0.003	-0.08	0.11	0.02	0.003	0.04	0.005	-0.02	0.003
United States	-0.43	0.04	0.05	0.003	-0.0020	0.004	-0.027	0.007	-0.40	0.04	0.03	0.002	0.04	0.003	-0.02	0.007

Table 6a. Estimated Cross-Price Elasticities of Labor Demand in OECD Manufacturing Sectors

Sector	η_{KL}		η_{EL}		η_{ML}	
	VCM	**TL**	**VCM**	**TL**	**VCM**	**TL**
Chemical, Rubber, Plastics and Fuel Products	-0.75***	-0.54***	0.07	0.42***	0.42***	0.40***
	(0.14)	(0.10)	(0.12)	(0.09)	(0.04)	(0.03)
Electrical and Optical Equipment	-0.39***	-0.58***	0.29***	0.23***	0.40***	0.37***
	(0.12)	(0.10)	(0.05)	(0.05)	(0.03)	(0.02)
Food Products, Beverages, and Tobacco	0.36***	0.33***	0.54***	0.47***	0.08***	0.08***
	(0.07)	(0.06)	(0.12)	(0.12)	(0.01)	(0.01)
Basic Metals and Fabricated Metal Products	-0.75***	-0.56***	0.61***	0.48***	0.23***	0.25***
	(0.05)	(0.05)	(0.10)	(0.10)	(0.02)	(0.02)
Pulp, Paper, Paper Products, Printing and Publishing	-0.79***	-0.44**	0.65***	0.55***	0.42***	0.36***
	(0.16)	(0.15)	(0.19)	(0.15)	(0.05)	(0.05)

Note. VCM - Vintage Capital Model, TL - Translog Model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6b. Estimated Cross-Price Elasticities of Capital Demand in OECD Manufacturing Sectors

Sector	η_{LK}		η_{EK}		η_{MK}	
	VCM	**TL**	**VCM**	**TL**	**VCM**	**TL**
Chemical, Rubber, Plastics and Fuel Products	0.09**	0.25***	0.46***	0.23***	0.09***	0.12***
	(0.03)	(0.03)	(0.07)	(0.06)	(0.02)	(0.02)
Electrical and Optical Equipment	0.10***	0.12***	-0.15***	-0.07	0.08***	0.12***
	(0.02)	(0.02)	(0.05)	(0.05)	(0.02)	(0.02)
Food Products, Beverages, and Tobacco	0.08***	0.02	0.28***	0.14**	0.17***	0.19***
	(0.01)	(0.02)	(0.06)	(0.06)	(0.01)	(0.01)
Basic Metals and Fabricated Metal Products	0.17***	0.23***	-0.02	0.05	0.08***	0.07***
	(0.02)	(0.03)	(0.04)	(0.06)	(0.01)	(0.01)
Pulp, Paper, Paper Products, Printing and Publishing	0.09***	0.47***	0.05	0.05	0.09***	0.04
	(0.02)	(0.02)	(0.11)	(0.08)	(0.03)	(0.02)

Note. VCM - Vintage Capital Model, TL - Translog Model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6c. Estimated Cross-Price Elasticities of Materials Demand in OECD Manufacturing Sectors

Sector	η_{LM}		η_{KM}		η_{EM}	
	VCM	**TL**	**VCM**	**TL**	**VCM**	**TL**
Chemical, Rubber, Plastics and Fuel Products	0.54***	0.55***	0.73***	0.50***	-0.68***	-0.73***
	(0.10)	(0.11)	(0.09)	(0.10)	(0.09)	(0.10)
Electrical and Optical Equipment	0.63***	0.54***	0.57***	0.97***	0.12	0.04
	(0.03)	(0.03)	(0.13)	(0.14)	(0.09)	(0.09)
Food Products, Beverages, and Tobacco	0.77***	0.78***	0.44***	0.38***	0.52***	0.44***
	(0.08)	(0.09)	(0.07)	(0.07)	(0.12)	(0.12)
Basic Metals and Fabricated Metal Products	0.49***	0.47***	0.71***	0.65***	0.60***	0.45***
	(0.08)	(0.11)	(0.06)	(0.06)	(0.12)	(0.10)
Pulp, Paper, Paper Products, Printing and Publishing	0.44***	0.47***	0.11	0.05	-0.08	0.04
	(0.04)	(0.02)	(0.14)	(0.15)	(0.19)	(0.19)

Note. VCM - Vintage Capital Model, TL - Translog Model. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7. Greenhouse Gas Emissions in UK Petrochemical Sector in 2005[18]

Fuel Type	**Fuel Consumption (ktoe)****	**Fuel Share (%)**	**CO2 Emission per toe**	**CO2 emission per Share**
Gasoil / Diesel	1078	0.10	2.90	0.28
Residual Fuel Oil	1970	0.18	3.13	0.56
Liquefied Petroleum Gases	45	0.00	2.50	0.01
Coal	207	0.02	3.70	0.07
Natural gas	4583	0.41	2.17	0.90
Electricity	3188	0.29	2.17*	0.63
Total	11071	1.00		2.44

* Assuming Natural Gas as a Base Load Factor in Electricity Generation

** Excluding SIC 2310 (Manufacture of Coke Oven Products)

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[18] About one third of UK generated electricity is based on coal-fired generators. We assume a single baseload factor in electricity generation to avoid the complications from interfuel substitution in electricity generation with respect to an increase in a greenhouse gas tax.

Appendix II - Charts

Figure 1a. Capital Stock Efficiency Indexes
Chemical, Rubber, Plastics and Fuel Products, United States, 1991-2005

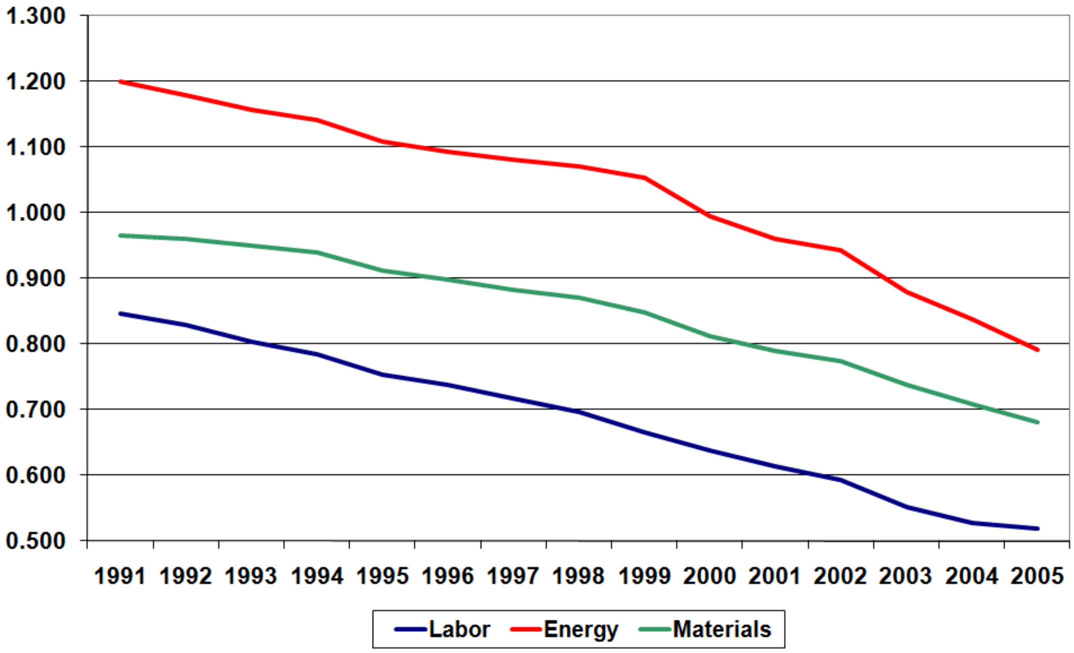

Figure 1b. Capital Stock Efficiency Indexes
Electrical and Optical Equipment, United States, 1991-2005

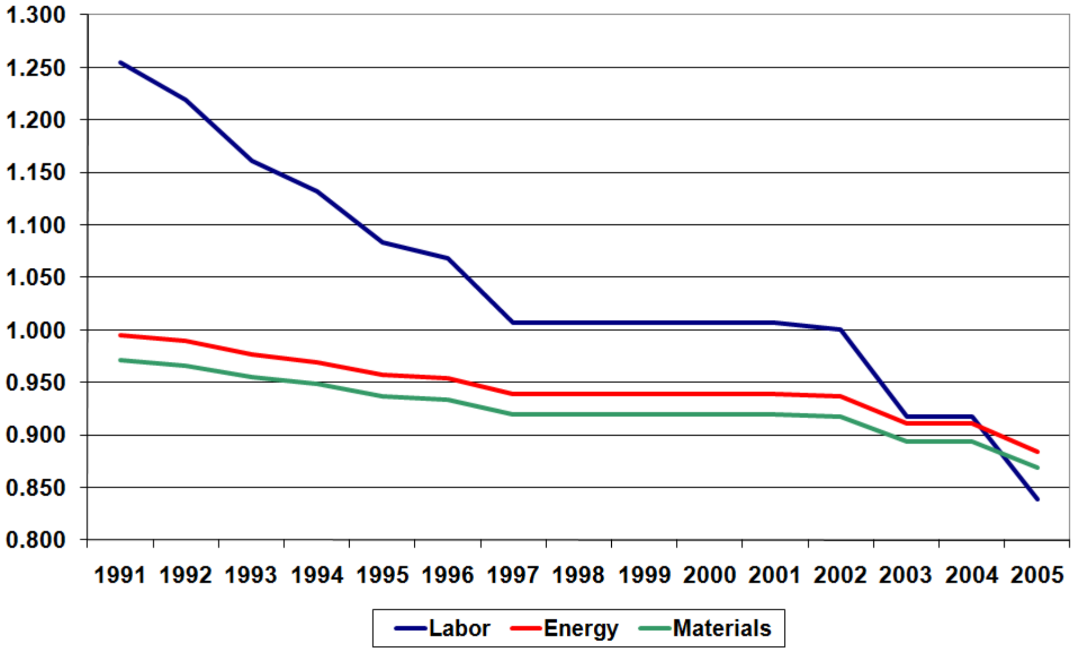

Figure 1c. Capital Stock Efficiency Indexes
Food Products, Beverages, and Tobacco, United States, 1991-2005

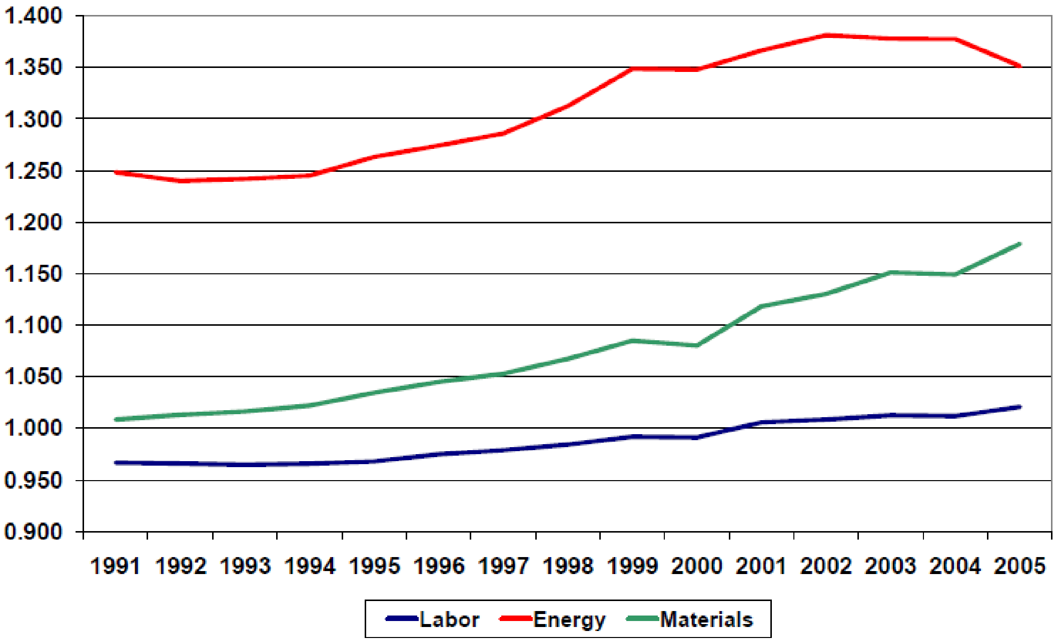

Figure 1d. Capital Stock Efficiency Indexes
Basic Metals and Fabricated Metal Products, United States, 1991-2005

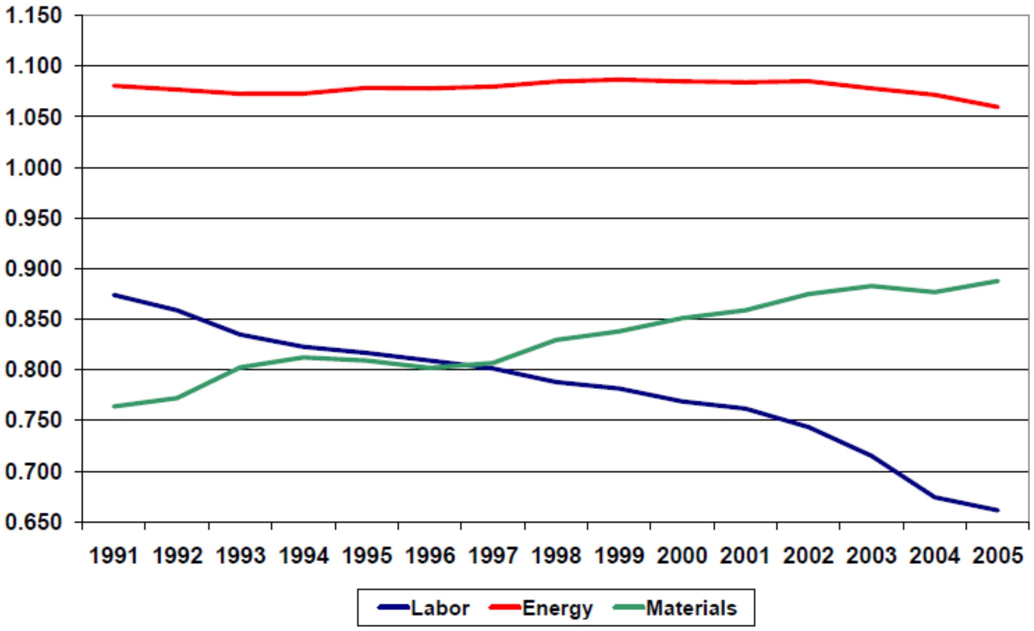

Figure 1e. Capital Stock Efficiency Indexes
Pulp, Paper, Paper Products, Printing and Publishing, United States, 1991-2005