ESTIMATING THE HISTORICAL IMPACTS OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON INDUSTRIAL ENERGY DEMAND

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Overview

Information and communication technologies (ICTs) are changing industrial structures and business processes, and have complex implications for energy demand. On one hand, ICT offers many benefits, such as being energy efficient and is an enabler of green growth. On the other hand, digital technologies have a rapidly growing energy footprint, as improvements in energy efficiency are offset by an increase in energy use. Thus, the overall impact is ambiguous and therefore, we address the following question: Are ICTs a net energy saver? More specifically, the aim is to examine the direction of the net impact of ICT on industrial energy use. Using a cross-country and cross-sector panel dataset for 17 countries (EU countries, Australia, Japan and USA) within 28 sectors covering the period 1995-2007, we estimate the effect of ICT capital services on energy cost share. Furthermore, we derive the elasticity of energy consumption with respect to ICT capital services and own price elasticity of demand to measure the magnitude of the effect.

Methods

Economic Model: We employ a short run restricted variable cost function with quasi-fixed ICT capital and non-ICT capital (Brown and Christensen, 1981). Furthermore, it is common to assume separability of materials and services from the remaining inputs. Thus, the restricted variable cost is as follows:

$$VC = f(P_E, P_L, K_{ICT}, K_N, Y, t)$$
$$VC = P_E E + P_L L \tag{1}$$

In the above equation, *VC* is variable cost. P_E represents energy prices and *E* represents energy quantities. Similarly, P_L represents labour prices and *L* represents labour quantities. K_{ICT} and K_N are ICT and non-ICT capital services respectively. *Y* is real output and *t* represents time. Employing the translog function, which is flexible and is consistent with economic theory, it equals to the following equation:

$$\begin{aligned}\ln VC = {} & \beta_0 + \beta_Y \ln Y + \tfrac{1}{2}\beta_{YY}\ln(Y)^2 + \beta_T t + \tfrac{1}{2}\beta_{TT}t^2 + \textstyle\sum_k \beta_k \ln P_k + \sum_m \beta_{K_m} \ln K_m + \tfrac{1}{2}\sum_k\sum_l \beta_{kl}\ln P_k \ln P_l + \\ & \tfrac{1}{2}\textstyle\sum_m\sum_n \beta_{K_mK_n}\ln K_m \ln K_n + \sum_k \beta_{kY}\ln P_k \ln Y + \sum_m \beta_{K_mY}\ln K_m \ln Y + \sum_k\sum_m \beta_{kK_m}\ln P_k \ln K_m + \\ & \textstyle\sum_k \delta_{kT}\ln P_k t + \sum_m \delta_{K_mT}\ln K_m t + \delta_{YT}\end{aligned} \tag{2}$$

In equation 2, $k, l \in (energy, labour)$ and $m, n \in (ICT, non-ICT)$. The share of an input in the total costs (e.g. $S_E = \frac{EP_E}{VC}$) can be obtained from the logarithmic differential of the cost function with respect to the price of that input. Therefore, the energy cost share equation estimated is the following:

$$S_E = \beta_E + \beta_{EE}\ln\left(\frac{P_E}{P_L}\right) + \beta_{EK_{ICT}}\ln\left(\frac{K_{ICT}}{Y}\right) + \beta_{EK_N}\ln\left(\frac{K_N}{Y}\right) + \beta^*_{EY}\ln Y + \delta_{ET}t \tag{3}$$

Equation 3 is the share of energy in the variable costs (S_E), which forms the basis of our econometrics model, where $S_E = \frac{P_E E}{VC}$.

Data Source: The main data source is EU-KLEMS, 2009 release, combined with World Input Output Database, 2013 release, and IEA Energy Prices and Tax Database. Furthermore, we use total Purchasing Power Parity (PPP) taken from the OECD database, as it is necessary to transform the nominal values to real values in a cross-country and cross-sector dataset. Thus, the estimating sample is a cross-country and cross-sector panel dataset for 17 countries (EU countries, Australia, Japan and USA) within 28 sectors, covering the period 1995-2007. Controlling for input prices, non-ICT capital services and output, we estimate the effect of ICT capital services on energy cost share. Furthermore, we derive the elasticity of energy consumption with respect to ICT capital services to measure the magnitude of the effect. This study provides a comprehensive evidence on whether ICT investment is, ceteris paribus, associated with an increase or decrease in energy consumption. Although previous studies have analysed the relationship between ICT and energy demand, such as Bernstein and Madlener (2010) or Schulte et al. (2014), our study benefits from using an extensive dataset that includes more countries and sectors. Furthermore, our study conducts several robustness checks to provide additional confidence in the results.

Results

Using OLS regression techniques, the parsimonious regression includes only the main covariates of interest: relative energy prices (i.e. $\ln\left(\frac{P_E}{P_L}\right)$), ICT capital (i.e. $\ln\left(\frac{K_{ICT}}{Y}\right)$), non-ICT capital (i.e. $\ln\left(\frac{K_N}{Y}\right)$) and output (i.e. $\ln Y$). The coefficient on ICT is negative and significant at 1 percent, whereas the coefficient on non-ICT is positive and highly significant, however both coefficients are close to zero. This indicates that ICT and non-ICT have a very small effect (almost close to zero) on the energy cost share. The coefficient on output is negative and is statistically significant at 1 percent, suggesting non-constant returns to scale; however, the coefficient is close to zero. And the relative price of energy has no effect on energy cost share in the parsimonious regression. Our preferred model includes the main covariates of interest, the country and sector dummy variables, but not year dummy variables. This is because we estimated different specifications using the time trend as well as year dummy variables and found that time is not shown to be significant for most years, especially the earlier years. After including both country and sector dummy variables, the size of the ICT coefficient remains close to zero, but it is positive and statistically significant, suggesting an extremely small effect on energy cost share. Similarly, non-ICT is statistically significant with a small positive coefficient. The relative price coefficient is negative, implying that as relative prices increase, the energy cost share is likely to fall. In order to measure the magnitude of these effects, the total average elasticity and own price elasticity is calculated. For our preferred model, the total average elasticity calculated is -0.08, implying that a 1 percent increase in ICT results in lowering energy use by 0.08 percent. The own price elasticity calculated is -1.2, implying that a 1 percent increase in relative prices reduces the energy use by 1.2 percent.

Thus, the results show that overall ICT does not have a large effect on energy savings across all industries and countries taken together. In order to provide additional confidence in our results, we split the sample into the manufacturing and the services sector, and estimate the effect of the variables of interest on energy cost share. The results show that there is evidence of energy savings in the service sector. Furthermore, we use interaction models by sector, and we find separate effects on different sectors and different countries.

Conclusions

We explore the impacts of ICT on energy demand for 17 countries within 28 sectors from 1995-2007. Using a cross-country and cross-sector panel dataset, we estimate the energy cost share equation derived from the translog cost function to estimate the net effects of ICT on energy use. The results show that ICT capital does not have a large effect on energy savings across all industries and countries taken together. However, there is evidence of energy savings in the services sector. These results are consistent across different samples and are robust to several specifications to provide additional confidence in our research outputs. Furthermore, we use interaction models by sector, and we find separate effects on different sectors and different countries.

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