Electricity consumption and ICT in the French service sector

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Abstract

The paper documents the evolution of electricity use and the development of information and communication (IC) technologies in the French service sector. To that purpose, we put together two data sets documenting electricity consumption and the diffusion of IC capital goods. Using a simple factor demand model, we estimate the structural parameters of the model using both the time series and the cross-sectional dimension of the data, and allow for a specific effect of IC capital goods on the efficiency of electricity in production. We obtain robust results showing that, once controlled for technical progress, prices, and heated areas, electricity intensity of production increases with computers and software, while it decreases with the diffusion of communication device.

JEL classification: Q410; Q430

Keywords: Electricity consumption; Information and communication technologies; Efficiency

1. Introduction

The production of the information and communication (hereafter IC) sector represented 5\% of French GDP in 1997—more than the energy and automobile sectors put together (see Heitzmann and Rouquette, 1999). Beyond, out of the 1.7\% of GDP growth achieved
the same year, 40 basis points can be attributed to the IC sector—more than proportional to the size of this sector. Further, not only the IC sector (computers manufacturing, telecommunication, and electronics) has developed, but the use of IC devices has spread all over the economy. Cellular phones and personal computers are now widely used in most of productive activities. As shown in Mairesse et al. (2000), the investment in IC capital-to-production ratio has doubled within 20 years. It now represents nearly 20% of total investment in equipment. According to the French statistical institute (see INSEE, 2000), computers accounted for 10 basis points out of the 4.5% of average yearly growth in GDP from 1967 to 1977. This contribution rose to 12 out of 2% over the period 1977–1987 and 9 out of 2% over 1987–1997. Although, by itself, this observation may not be very surprising and is consistent with the common wisdom on the diffusion of IC technologies in the last two decades of the 20th century, when juxtaposed with the following observation, it becomes quite intriguing.

Indeed, this recent increase in the diffusion of IC capital goes together with a reduction in energy intensity of production—defined as the consumption of energy-to-output ratio. For instance, Romm (2000) reports that US GDP and energy use grew, respectively, at a yearly average rate of growth of 3.2% and 2.4% in the “pre-Internet era” (1992–1996), and 4% and 1% in the “Internet era” (1996–2000). As noted by Laitner (2000), energy intensity was 4.4% in 1996, while it was only 0.8% for IC sectors.

Put together, these observations raise the question of the existence of a potential causality between those two phenomena, going from the diffusion of IC capital goods to the decrease in energy intensity of production. At first sight, one may be tempted to reject such a causality as computers and telephones are electrical devices. For instance, in 1995, personal computers and terminals were consuming 13% of the electricity used by commercial buildings in the United States—as much as air-conditioning. Forecasts realized by the U.S. EIA for 2001–2010 show a 3.2% annual growth of electricity demand for office equipment, against 1.4% for the U.S. economy as a whole.

But, from a broader point of view, the net effect of ICT diffusion may be more difficult to evaluate given the uncertainty on its consequences on the productive and social structures. Romm (2000) proposes to distinguish two type of energy gains related to the ICT diffusion: (i) efficiency gains and (ii) structural gains. The former corresponds for instance to a better management of an assembly line that would be permitted by ICT, while the latter would show up if, for instance, consumers use less their cars to go to shopping malls and rather rely on the Internet to shop. Although quite appealing, these gains—and especially structural gains—may be extremely difficult to quantify.

Hence, rather than relying on case studies or expert analysis, we aim here at analyzing a relative good set of sectoral data using structural econometrics. This work can therefore be viewed as a complement to the work of experts and to microeconomic studies. We put together two data sets for the service industry: one related to electricity consumption and one to the diffusion of IC capital goods for the sample period 1986–1998. Using a simple factor demand model, we estimate the structural parameters of the model using both the time series and the cross-sectional dimension of the data, and allow for a specific effect of IC capital goods on the efficiency of electricity in production. Our results suggest that—once controlled for technical progress, prices, and heated areas—electricity intensity of production increases with the diffusion of computers and softwares, while it decreases
with the diffusion of communication devices. Interestingly, these results are robust to correction for potential endogeneity of the diffusion of ICT.

The remainder of this paper is organized as follows. Section 2 describes the data and presents some descriptive statistics. In Section 3, we introduce a simple factor demand model and discuss the main empirical results. Section 4 offers some concluding remarks.

2. Energy and IC data

We first describe the data and the required preliminary work we had to carry out before applying any econometric technique. We then present some descriptive statistics and energy consumption and IC capital goods.

2.1. Available information

In this study, we rely on electricity consumption and IC capital goods data for the French service sector. Unfortunately, these data are not available from a single source and we have to gather, and therefore match, two data sets. Each provides a precise evaluation of the electricity consumption and of IC capital goods used in some sectors of the service industry in France.

The first data set is provided by the French National Statistical Institute (INSEE) and documents the IC capital stocks at a relatively disaggregated level. We are more particularly interested in data for the sector services, whose INSEE’s definition is reported in Table 1. At such a level of disaggregation, data availability enables us to use yearly observations over the period 1978–1999 for total capital stock and for the following IC devices: computer and software capital stock and communication capital stock. It is well known that many measurement problems are associated with durable goods and equipment (see for instance Gordon, 1990). In particular, an important aspect of the measurement of IC capital is related to the measurement of its price, which partly accounts for technological progress. This issue is addressed by Mairesse et al. (2000), who describe the way those data were constructed. To sum up, hedonic prices are estimated for computers, while factor cost evaluation is used for softwares. As far as communication devices are concerned, the split between volumes and prices is computed using manufacturing sale prices obtained from surveys. Finally, production prices and the level of production of the sector are also borrowed from INSEE.

Electricity consumption is obtained from the CEREN—a semi-public institution that conducts surveys at a very detailed level. In particular, CEREN reports climate adjusted energy consumption for services (see Chapter 2 of the report of CEREN, 2000). Energy consumption is disaggregated between electricity, oil, gas, and other energies. Each type of energy consumption is also available by use. Data are reported at a yearly frequency for the period running from 1986 to 1998. The sample is therefore much shorter that the IC capital one (13 observations). Nevertheless, since much of the diffusion of IC capital goods took place in the 1990s, it is much likely that not much information on the specific impact of IC would be obtained by extending the sample backward. Eight sectors are documented in this survey. Unfortunately, the classification scheme used by CEREN differs a lot from that used by INSEE. The eight sectors are: (1) bars, hotels, and
restaurants (cafés, hôtels, and restaurants); (2) collective lodging places (habitat communautaire); (3) health and social services (santé and action sociale); (4) education and research (enseignement recherche); (5) sport, culture, and other recreational activities (sport, loisirs, and culture); (6) offices and administration (bureaux and administration); (7) trade (commerce); and (8) transportation (transport).

Working out the definitions of those sectors, it is possible to match the two data sets for some of them. As we do not have more disaggregated data for CEREN, INSEE data are rebuilt in order to match CEREN’s definition of sectors. Table 2 summarizes the adjustment we have made, and lists the six sectors we will use in the remainder of this study. The match is good for bars, hotels, and restaurants; for health and social services; for education and research; and for trade. Since we cannot get any specific IC capital data for collective lodging places, this sector is excluded from the study. The energy consumption related to transportation activity (mainly gas oil for trucks) is excluded from CEREN’s survey, which only reports energy consumption related to the buildings used by this sector. This implies a very high level of disaggregation for the sector that cannot be reached for capital stock data. Therefore, this sector is also excluded from the analysis. Finally, the match is only partial for two sectors. The first one is sport, culture, and other recreational activities, because this sector is very heterogenous in the CEREN classification. For example, ski-lifts are included in this sector, while they are included and aggregated in the transportation sector by INSEE. The last sector is business and public administration. A potential problem arises as CEREN’s definition of this sector stems on buildings rather than on activity. Namely, in CEREN’s survey, this sector gathers

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1 See Collard et al. (2001) for an extensive presentation.
administrative departments and offices of all firms and public services. But, at the same
time, INSEE allocates some offices to industry. While this may not be such an issue for
production activities of the sector of services, this becomes more problematic when we are
interested in agriculture and manufacturing offices. Note that this affects both the sign and
significance of our estimates if those offices behave in the same way that the one of the
service industry as far as IC technologies and electricity consumption are concerned.

CEREN’s survey also reports data for heated areas (in square meters) in each sector.
This series will be prove useful to control for changes in the production process that are a
priori uncorrelated with the diffusion of IC, such as, for example, a change in the average
size of an office. Finally, the electricity price is proxied by a weighted residential
electricity price (average receipts of the French Electricity Provider–EDF–per kilowatt
hour invoiced to low voltage electricity consumers, in French franc/100 kW h).

2.2. Some descriptive statistics

We now compute and comment some descriptive statistics summarizing our data set (see
Table 3). Let us first focus on the last column of Table 3, which reports statistics for the sector
of services as a whole. The results indicate that production in the service sector has grown
at a faster pace (2.40%) than its energy consumption (2.04%), such that energy intensity–
defined as the energy consumption to production ratio–has decreased at an average yearly
rate of 0.36%. Note that this result does not hold for all sectors. In particular, the energy
intensity has grown at a quite fast pace in sectors “bars, hotels, and restaurants,” “sport,
culture, and other recreational activities,” and “offices and administration.”

When only electricity is considered, the results display a fairly different pattern.
Electricity consumption has grown faster than production—4.19% to be compared to the
already reported 2.40%. Therefore, electricity intensity has increased by more than 1.79%
per year. More interesting is the fact that this pattern is shared by all sectors, as electricity
intensity has risen at an average yearly rate of growth ranging from 0.18% in sector “trade”
to 3.29% in sector “bars, hotels, and restaurants.” Electricity represents on average 37% of
energy consumption, “trade” and “offices and administration” being the two sectors in
which electricity amounts to more than 45% of total energy consumption.

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Table 2
Matching INSEE data with the CEREN classification

<table>
<thead>
<tr>
<th>CEREN</th>
<th>INSEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bars, hotels, and restaurants</td>
<td>FP1</td>
</tr>
<tr>
<td>Collective lodging places</td>
<td>–</td>
</tr>
<tr>
<td>Health and social services</td>
<td>FQA+FQB</td>
</tr>
<tr>
<td>Education and research</td>
<td>FQ1+FN4</td>
</tr>
<tr>
<td>Sport, culture, and other recreational activities</td>
<td>FP2</td>
</tr>
<tr>
<td>Offices and administration</td>
<td>FN1+FN2+FN3+EL+EM+ER</td>
</tr>
<tr>
<td>Trade</td>
<td>EJ</td>
</tr>
<tr>
<td>Transportation</td>
<td>–</td>
</tr>
</tbody>
</table>

2 Note that by “sector of services as a whole,” we mean not all the service industry but the sum of the six sectors under study.
Offices and administration is the bigger sector of our aggregate sector of services, as it accounts for about 60% of total services production over the period. Note that “bars, hotels, and restaurants” is the most electricity intensive sector, with about 24 W h per 1995 franc produced in 1998.

Table 3 also indicates that IC capital represents a pretty small fraction of total capital in the sector of services (0.85% for communication and 0.58% for computers and software), even though it has grown exponentially as a share of total capital. The two sectors that have made the most intensive use of IC capital are “sport, culture, and other recreational activities” (almost 5%) and “trade.”

### 3. A structural econometric approach

This section introduces a simple factor demand model and discusses the main empirical findings.

#### 3.1. The model

We propose a simple factor demand model that will provide us with an interpretable relation between electricity consumption and IC capital. We assume that the production...
function of the typical firm in the service sector is a nested CES constant return to scale production function:

\[
y_t = \left[ \omega \left( \Theta_t E_t \right)^{\frac{\sigma - 1}{\sigma \tau}} + (1 - \omega) \left\{ F(X_t K_t, X_t L_t) \right\}^{\frac{\sigma - 1}{\sigma \tau}} \right]^{\frac{\tau}{\sigma - 1}}
\]

with \( \omega \in [0,1] \), \( \sigma > 0 \) denotes the elasticity of substitution between production factors. \( K \) is the stock of capital of the firm, \( E \) is the electricity use, and \( L \) is the level of employment in the firm. \( F(.) \) is any homogenous of degree 1 function, quasi-concave function, and \( X_k \) and \( X_r \) denote, respectively, capital augmenting and labor augmenting technological progress. We assume that \( X_k \) and \( X_r \) are exogenous to the firm.

The electricity augmenting technological progress, \( \Theta_t \), is assumed to evolve as:

\[
\log(\Theta_t) = \theta_0 + \theta_T t + \theta_K \log \left( \frac{K_{C,t}}{K_t} \right) + \theta_C \log \left( \frac{K_{CS,t}}{K_t} \right) + \theta_{HA} \log \left( \frac{H_{At}}{K_t} \right)
\]

Implicit in this specification is that the electricity content of production can be partially controlled by the firm, as it depends on the technology that is chosen to produce output. The endogenous change in the production process is proxied by three variables: the physical size of the firm (heated areas in square meters) normalized by its capital stock (\( HA/K \): heated areas/total capital stock) and the penetration of IC capital goods (\( K_C/K \): communication capital goods/total capital stock and \( K_{CS}/K \): computers and software/total capital stock). The exogenous change in the production process is modelled as a log-linear time trend that is aimed at reproducing the secular trend in energy saving technological progress. \( \theta_0 \) is a parameter that indicates–ceteris paribus–the electricity intensity of production in the firm.

Assuming perfect competition on the services market, the first-order conditions (hereafter FOC) of the profit maximization program of the firm state that inputs are demanded up to the point where their price equals their marginal productivity. Therefore the demand for electricity, expressed in logarithms, is given by:

\[
\log \left( \frac{E_t}{Y_t} \right) = \sigma \log(\omega) - \sigma \left( \frac{P_t}{P_E} \right) + (\sigma - 1) \log(\Theta_t)
\]

where \( P_E \) is the user price of electricity and \( P \) is the production price. The variable \( E_t/Y_t \) represents the electricity content of physical production. It therefore corresponds to the technical coefficient of an input–output matrix, and is often referred to as a Leontiev coefficient. Simple as it is, this theory provides us with a set of explanatory variables for the technical coefficient. Plugging Eq. (2) into Eq. (3) leads to a log-linear equation from which estimates for the vector of structural parameters \( \Phi = (\sigma, \theta_T, \theta_{HA}, \theta_C, \theta_{CS}) \) can be obtained.

### 3.2. Estimation method

As aforementioned, data availability on IC capital stocks and electricity consumption induces a relatively small sample size. Thirteen observations on electricity consumption and IC capital for six subsectors of services sector can be used. One possibility would have
been to estimate the five parameters and a constant term for each sector, or for the aggregate sector. But, this would have yielded poorly estimated coefficients as only seven degrees of freedom would be reached. Therefore, we adopt a dynamic panel approach, which has the advantage to fully combine the cross-section and time series dimensions. This enables us to use information on 6/13=78 observations in order to estimate the five parameters plus six sectoral specific constant terms, accounting for fixed effects. This parsimonious approach assumes that the elasticities ($\sigma$, $\theta_T$, $\theta_C$, $\theta_{HA}$, $\theta_{IC}$) are the same for the six sectors.

The structural parameters are estimated directly using a nonlinear least square (NLS) method. The parameter estimates correspond to the value of the vector $\Phi$ that minimizes the loss function $e_t'W e_t$, where $e_t$ is the stacked vector of residuals for the nonlinear model and $W$ is a consistent estimate of the covariance matrix of residuals.

An important issue is related to the potential endogeneity of the explanatory variables entering the electricity augmenting technical progress ($HA/K$, $KC/K$, and $K_{CS}/K$) (i.e., these variables may be correlated with the residuals). To correct such a possible simultaneity bias, we adopt a two-stage method (TSNLS), wherein we use a set of instrumental variables that consists in the same explanatory variables with one lag. More precisely, we run an OLS estimation—for each sector—of a VAR(1) model for $HA/K$, $KC/K$, and $K_{CS}/K$ taken in logs. One-step-ahead forecasts of these variables are then computed from the VAR. The actual values of $HA/K$, $KC/K$, and $K_{CS}/K$ are then replaced by their predicted values in the structural model.3

3.3. Empirical results

Table 4 reports our main empirical results. Eqs. (2) and (3) are both estimated using disaggregating the IC capital stock between computers and software and communication devices (columns (I) and (II)) or using an aggregate IC capital stock (columns (III) and (IV)). Let us first comment on column (II), which corresponds to our baseline case: the

<table>
<thead>
<tr>
<th>Estimation method</th>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
<th>(IV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.333 (8.33)</td>
<td>0.249 (7.67)</td>
<td>0.148 (2.36)</td>
<td>0.146 (2.56)</td>
</tr>
<tr>
<td>$\theta_T$</td>
<td>0.025 (16.29)</td>
<td>0.022 (22.69)</td>
<td>0.003 (3.31)</td>
<td>0.002 (2.30)</td>
</tr>
<tr>
<td>$\theta_{CS}$</td>
<td>-0.180 (11.76)</td>
<td>-0.026 (4.09)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\theta_C$</td>
<td>0.331 (9.89)</td>
<td>0.045 (13.11)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\theta_{IC}$</td>
<td>-</td>
<td>-</td>
<td>0.068 (3.72)</td>
<td>0.084 (5.25)</td>
</tr>
<tr>
<td>$\theta_{HA}$</td>
<td>-0.144 (2.48)</td>
<td>0.199 (4.09)</td>
<td>-0.356 (6.38)</td>
<td>-0.159 (2.89)</td>
</tr>
</tbody>
</table>

For each column, the estimation is carried out using the dynamic panel of six sectors and allowing for individual fixed effects. NLS=nonlinear least squares; TSNLS=two stages NLS. The estimated constant is not reported. $T$ statistics are reported in parenthesis.

Note that in order to avoid losing any observation, actual data are used for the first observation of the sample.
two IC capital goods are considered separately (communication on one side, computer and software on the other one) and two-stage estimation is performed in order to correct for potential simultaneity bias.

First of all, our results indicate that $\sigma$ is significantly smaller than one (0.249). Energy and the capital–labor aggregate therefore display more complementarity that the Cobb–Douglas case. This result is in line with previous results at the macroeconomic level. Second, there exists empirical evidence for a positive trend in electricity augmenting technological progress, as $\theta_T$ is always positive and significant. Since $\theta_T$ is multiplied by a negative number ($\sigma - 1$) in the electricity intensity equation (see Eq. (2)), ceteris paribus, electricity intensity exhibits a downward trend. Note that part of this result is due to the fact that electricity has been an increasing source of energy for the service sector compared to gas and fuel over the sample period.

Results are more ambiguous as far as the heated areas-to-capital ratio coefficient is concerned. Indeed, this sign of this coefficient is not robust to the specification. Nevertheless, $\theta_{HA}$ is negative for three of the four cases we consider. Our results therefore suggest that producing one French franc is more electricity-intensive when the production process requires more heated areas per unit of capital.

We now turn to the specific contribution of IC capital. We first consider the impact of aggregated IC capital. This effect is accounted for by the parameter $\theta_{IC}$ reported in columns (III) and (IV) of Table 4. As can be seen from column (III) in the table, $\theta_{IC}$ is positive and significant. In other words, as a whole, IC capital has increased the productive efficiency of electricity and therefore contributed to the reduction in electricity intensity in the service sector. For instance, any 1% increase in the IC capita-to-total capital ratio led to a 0.058% decrease in the electricity intensity in the sector. It is worth noting that this result is robust to correcting for potential endogeneity of the diffusion of ICT (column (IV)). This “aggregate” result can actually be decomposed into two significant and opposite effects. Indeed, columns (I) and (II) in Table 4 clearly indicate that the impact of the diffusion of IC capital on electricity intensity differs a great deal depending on the type of ICT. More precisely, computers and software have contributed negatively to the productive efficiency on electricity, while communication device has exerted a positive influence on it. This result is robust to the correction for potential endogeneity, although point estimates change significantly. In other words, ceteris paribus, electricity intensity of production has increased with computers and software, while it has decreased with the diffusion of communication devices. Further, communication devices have, ceteris paribus, exerted a greater effect on electricity intensity than computers and softwares. For instance, a 1% increase in the computers and software capital stock yielded a 0.0195% increase in the electricity intensity, while a 1% increase in communication devices yielded a 0.0338% decrease.

4. Conclusion

We have estimated a factor demand model that allows to evaluate the specific effect of IC capital good on electricity intensity of production in the French service sector. Taking advantage of both the time series and cross-sectional dimension of the panel, we have
shown that electricity intensity of production has increased with computers and software, while it has decreased with the diffusion of communication device over the period 1986–1998. If microstudies and expert analysis lead to conflicting conclusions on the net effect of the IC revolution on energy consumption, our results indicate a robust relation in the French service sector over the sample period. In the next future, those results should be checked using new data points and for other sectors and other countries.

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