ICT and productivity in OECD energy and water supply industries - A dynamic panel estimation

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Abstract

In the recent years, the so-called 'energy triangle' of market liberalization, supply security and environmental protection have been at the forefront of regulatory policy discussions concerning energy and water utilities. This new direction highlights the role of market-based tools and ICT to achieve security of supply through: increased cross national interconnectivity, increased share of distributed generation (mostly renewable sources), decoupling the rate of energy consumption from the GDP growth, and demand-side participation among others. Adoption of ICT however involves significant costs that go beyond the price of ICT hardware and soft ware. Ultimately, the paradigm shift brought about by the ICT revolution entails change in the relationship of traditional factor inputs vis a vis ICT capital. Presently, there is a scarcity of econometric studies on the impact of ICT capital investment – relative to labor and non-ICT capital -- on energy and water utilities. This paper aims to take a step towards filling this research gap by using General Method of Moment (GMM) estimation to estimate this impact on the Average Labor Productivity (ALP) growth of water and energy supply industries in 22 OECD countries. The results indicate that this impact is different for Europe and the Anglo-Saxon economies and that the difference reflects broader structural differences that exist between the two groups of countries.

1. Introduction

Network utilities appear to be inching closer to the promise of the coming ‘intelligent utility’. By merging Information and Communication Technology (ICT) networks with utility networks, it is hoped that intelligence can be injected into the energy grids and water mains that have been inherited from the 19th and 20th century. This promise however comes with a price. Adoption of ICT involves significant costs that go beyond the price of ICT hardware and soft ware. These can include, among others, the cost of developing complementary organizational capital and extensive skill upgrading required for ICT adoption. In absence of supporting organizational, human and infrastructural adaptations, investing in ICT may be no different than pouring water into sand.

There have been a number of valuable studies on the Impact of ICT investment on growth at the macro level and industrial level (e.g. Colecchia and Schreyer, 2001; Van Ark, et al., 2003; Jorgenson, 2003; Schreyer, et al. 2003) but only a few that study the ICT-growth link in the utilities sector. Most studies on the utility industries use the descriptive growth accounting models and there is an acute shortage of studies that use tools from econometrics to explain the causal impact of ICT investment in the utility sector. The paper address this research gap through the use of generalized method of moments (GMM) panel regression estimators applied to a dynamic panel data of 22 OECD countries to determine the relative impact of capital (ICT, non-ICT) and labor intensity growth on average labor productivity growth of electricity, gas and water supply industries. The results of the estimation indicate that utilities in continental European economies follow a markedly different growth trajectory compared to the rest of the OECD economies. Furthermore, differences in the relative importance of different factor intensities in the two groups of countries reflect broader market structure differences that exist between continental Europe and the Anglo-Saxon economies.

The rest of the paper is organized as follows. Section 2 describes the key characteristics of network utilities and the sector dynamics brought about by technological innovation in the last 15 years. Section 3 provides a review of relevant literature. Section 4 describes the theoretical framework and model specification for the dynamic panel data analysis. Section 5 contains the description of the data, section 4 presents the results of the dynamic panel estimation and section 5 presents the overall conclusions.

2. Network utilities

Network utilities like electricity, natural gas and water supply industries are characterized by the requirement of large fixed networks, potential for substantial economies of scale and high capital intensity in the production process. According to OECD studies, continental Europe has built up a significant advantage over the North American economies with regards to network utilities, notably energy and water supply (Morrow et. al. 2009). At the same time, network utilities are sectors that command significant economic value. In 2006, the approximately 22.2 thousand energy sector enterprises[1] in EU-27 employed just 3% of the total industrial workforce (1.2 million persons) but generated a value added of 9% of total

[1] Electricity, gas and hot water supply industry (NACE 40)

industry that amounted to 180 billion Euros[2] out of which 177 bn was attributed to electricity and gas industries (Eurostat, 2009). In terms of value added, the electricity and gas sector is nearly six times as large as the water sector which employed 0.92% of total industrial workforce (0.37 million persons) and generated total value added of 1.16% of total industry (23.3 billion Euros) in the same period. Growth of value added, however, is much higher for water (2.0% annually) while electricity and gas grew only 0.3% per year over the period 1995-2006. (Eurostat, 2009)

Aside from their significant value added contribution to the economy, these industries are also key drivers of competitiveness in the overall industrial sectors. Energy utilities in particular have significant impact on input prices for other industries and, therefore, on the competitive situation of economy as a whole. Subsequently, utilities are the target of numerous economic and social regulatory actions aimed improving productivity, efficiency and competitiveness.

2.1 Sector dynamics and the role of ICT

Since 2000, the so-called 'energy triangle' of market liberalization, supply security and environmental protection have been at the forefront of regulatory policy discussions concerning energy and water utilities. This new direction highlights the role of market-based tools and ICT to achieve security of supply through increased trans-European interconnectivity, increased share of distributed generation (mostly renewable sources), decoupling the rate of energy consumption from the GDP growth, efficiency gains by means of demand-side participation among others. In broad terms, the growth of energy and water supply sectors is no longer contingent on growth of output (eg building new power plants) but on restructuring the production and distribution process to achieve improved security of supply. A large part of this improvement envisioned by the EU is expected to emerge out of the diffusion of Information and Communication Technologies (ICT) [3] based innovations (complemented by labor skill upgrading). This is because supply of energy in a liberalized market requires complex interactions of generation, transmission and distribution facilities that have to be constantly in-sync information-wise. These processes can be greatly facilitated through ICT systems like Smart metering, smart grids, demand management, intelligent power plants. ICT systems such as these can help manage and integrate distributed generation from renewable energy sources, enable better informed load control in the grid and improve the range of offered products and intensify competition in the retail sector (Wissner, 2009). Table 1 below provides a synopsis of main ICT solutions in energy supply companies.

Heavy investments in increasing efficiency of existing technologies and in ICT have increased the capital intensity of electricity, gas and water supply industries up to twice the manufacturing industry average (European Commission, 2009). According to the industrial taxonomy described by O'Mahony & van Ark (2003), the electricity, gas and water supply industries are categorized as Non-ICT industries or industries that do not make intensive use of ICT capital alongside construction, mining and quarrying sectors (O'Mahony & van Ark 2003, p. 69). In terms of occupational taxonomy however, O'Mahony & van Ark (2003) classify electricity, gas and water industries as 'dynamic IT user with a high and growing IT-labor intensity'.

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[2] The data are for electricity, gas and hot water supply comprising the NACIS 40 industrial category.

[3] Information and communication technology (ICT) is an umbrella term that encompasses a wide array of hardware, software and services used for data processing, the information part of ICT, as well as telecommunications which is the communication part of ICT (IDC EMEA, 2009)

TABLE 1 SUMMARY OF MAIN ICT SOLUTIONS IN ELECTRICITY AND WATER SUPPLY INDUSTRIES

<table>
<tr><th></th><th>Generation</th><th>Transmission & Distribution</th><th>Metering</th><th>Retail</th></tr>
<tr><td rowspan="2">Specific systems for energy supply</td><td>• Plant asset management
• Work management
• Load forecasting
• Generation plan & scheduling
• Carbon management system
• Energy Trading & Risk management</td><td>• Grid Asset Management
• Work management
• GIS
• Energy Management System
• Distribution Management System
• SCADA
• Outage Management System</td><td>• Meter Asset Management
• Meter Data Management</td><td>• Billing
• Customer Relationship Management (CRM)
• Call Centre Management</td></tr>
<tr><td colspan="4">ICT for monitoring distributed energy units (DER), forecast production from DER, ICT for dispatch energy from DER, ICT for linking DE,</td></tr>
<tr><td>General Enterprise ICT system</td><td colspan="4">Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Document Management System (DMS), Computer-Aided Design (CAD), Product Lifecycle Management (PLM), Environment, Health & Safety (EH&S)</td></tr>
</table>

Source: (Bigaliani, Gaboardi, Gallotti, & Cattaneo, 2009)

2.2 The opportunity cost of substitution towards ICT capital

Successful implementation of ICT projects requires costly reorganization in the form of fees paid to consultants, management time, or expenditure on the retraining of workers. Based on econometric evidence of the effect on stock prices of ICT investment, Brynjolffson, Hitt, and Yang (2002) suggest that as much as 9 dollars of total investment is associated with 1 dollar of ICT investment. During the 10 years between 1997 and 2007, supply output of electricity, gas, steam and hot water in the EU-27 increased more or less in line with that for total industry, but employment fell faster and output prices grew much faster in the electricity, gas and steam supply industry, reflecting increasing substitution away from labor to capital deepening. The decrease in employment averaged 3.0 % per annum in the ten years while the increase in price averaged roughly 5.5% per annum. At the same time, because of the complementarities that exist between ICT capital and skilled workers, the increase in capital intensity in the utility sector also means increasing demand for skilled workers, rising cost of training and retraining workers and creation and decreasing employment opportunities for low skilled workers.

3. Literature review

Some of the earliest studies that analyzed the impact of ICT on economic growth were aimed at resolving the Solow Paradox: in words of the Nobel Laureate Robert Solow 'computers were visible everywhere except in the productivity statistics' (Solow 1985). While the first major studies at the macro level were unable to find significant link between ICT and growth, the outlook became more positive in the early 21st century compared to the findings of studies done in the 1980s, most likely due to the availability of larger electronic datasets in the recent decades.

A number of authors (for example Jorgenson, 2001; Van Ark, et al. 2002a), have employed the growth accounting methodology pioneered by Robert Solow in 1957 to estimate the contribution of different factor inputs to labor productivity growth. Growth accounting (over a period) divides output growth into the contribution of the (share weighted) growth of inputs (labor, ICT and non-ICT capital) and the contribution of the residual (Total Factor Productivity). Van Reenen et. al. (2006) summarize the macro growth accounting literature as follows:

1. The Solow Paradox arose because ICT was a small part of the capital stock;

2. Productivity growth has accelerated in the US since 1995;

3. This acceleration appears to be linked to ICT[4]

4. There has been no acceleration of productivity growth in the EU, mainly due to the performance of the ICT using sectors.

Growth and productivity studies of electricity, gas and water industries are few and far in between, in most cases relegated to the appendix or footnotes. Moreover, studies on productivity in the network utilities are almost exclusively reported by researchers from the GGDC using growth accounting methodology. The results suggest that electricity, gas and water industries were one of the small numbers of industries that contributed positively to narrowing the productivity growth rate gap between Europe and the US.[5] As of yet, the only studies that estimate the impact of ICT and other inputs to the utility (electricity, natural gas and water supply) industries have employed growth accounting methodologies. For example Van Aark et. al. (2003) used EU KLEMS dataset to decomposed the ALP growth in the network utilities of US and four major EU economies into share weighted contributions of capital (ICT and non-ICT), labor quality improvement and TFP for the period 1979-2000. The results indicate that non-ICT capital deepening contributed a lion's share to the sector's ALP growth rate (2.47 % points of 3.49%) in 1990- 1995. After 1995 ALP growth rate almost doubled to 6.63 percent. This growth corresponded to a rise in the contribution of TFP and ICT capital deepening while contribution of non-ICT capital intensity stayed put at around 2.5%. All through the 1990s, the four European countries (Germany, France, UK and Netherlands) seem to outperform the US in terms of the growth rate of both ALP as well as the contribution of TFP to the ALP. Using similar methodology, Wissner (2008) suggests that in the case of Germany, contribution of ICT capital investment to ALP growth increased between 1995-2000 and then decreased between 2001-2005 when Germany witnessed strong emergence of energy market liberalization indicating reluctance to adopt ICT due to regulatory uncertainty.

Despite the clarity and ease that growth accounting methodology offers, no causal relationship between changes in inputs and productivity growth can be inferred. At the same time, the strength of relationship between, say ICT capital and growth is also not measured during the calculations. This paper uses General Method of Moment (GMM) estimation of dynamic panel data of 22 countries for 10 years (1995-2005) to examine the impact of ICT capital intensity growth in Average Labor Productivity (ALP) growth

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[4] Very sharp decline in quality adjusted prices for IT goods due to rapid progress in semiconductor technology during the mid-1990s made ICT investment very attractive relative to non-ICT capital. Growing ICT investment was reflected in TFP growth in the IT producing sectors and IT capital deepening in other sectors, two avenues by which ICT contributed to macro productivity growth

[5] Studies by van Ark *et al*. (2002a) indicate that the value added ALP growth in the EU was roughly twice that of US and Canada at 4.9% during 1995-2000.

in water and energy supply industries.

4. Methodology

In order to highlight the main drivers of productivity growth in the energy and water supply industries, I fit a dynamic panel regression model on to a dataset of input and output services per hour worked in the electricity, gas and water supply sectors of OECD economies. The regression equation can be specified as follows:

$$\boldsymbol{ALP_{i,t} = \beta_0 + \beta_1 K_{i,t} + \beta_2 L_{i,t} + \beta_3 TFP + \beta_4 X_{i,t}} + \varepsilon \qquad (1)$$

where ALP annual volume index of gross value added Average Labor Productivity (ALP)[6] for country i in time t, K and L are capital and labor services per hours worked (capital and labor intensities respectively), TFP is the index of Total Factor Productivity (TFP) and X represents control variables: share of large and small scale firms; share of hours worked by high, medium and low skilled workers. Capital services per hour worked are further divided into ICT and non-ICT capital services. The model excludes intermediate inputs including energy prices and the focus is solely on the value added by each primary input per hour worked. All variables are initially in their level form with 1995 as the reference year. Prior to running the regression estimations, the variables are first differenced to control for autocorrelation and unobserved country specific fixed-effects (for example the initial level of efficiency). Hence our predictor variables are: 1) ΔICT capital services per hours worked (ICT capital deepening) 2) ΔNon-ICT capital services per hours worked (Non-ICT capital deepening) 3) ΔLabor services per hours worked (labor quantity plus labor composition/quality) 4) Total factor Productivity growth. A brief description of these input service indices and their derivation is given below.

The input factor services (labor and capital) are derived by multiplying the stock of input by its income share which allows stocks of factor inputs to be converted to their respective service flows7. The index of labor services input (Lab) for country i in period t is given by:

$$Lab_{t,i} = \Sigma v_{l,t} H_{l,t} \qquad (2)$$

where $H_{l,t}$ is the log of hours worked by labor type l and the weight $v_{l,t}$ is the share of each type of labor in the total labor compensation. Thus in theory, the labor services index should be proportional to the hours worked and the workers' marginal productivities as reflected in their incomes. Typically, a shift in the share of hours worked by low-skilled workers to high-skilled workers will lead to a growth of labor services. Likewise, the index for capital services input is expressed as:

[6] Labor productivity in this sense reflect a host of other effects: changes in capital intensity, technology, organization, efficiency changes within and between firms, influence of economies of scale and measurement errors (OECD 2001, p 14)

[7] For a detailed description on the growth accounting methodology, refer to Timmer, O'Mahony, and B. van Ark (2007).

$$K_t = \Sigma v_{l,t} S_{k,t} \qquad (3)$$

where $S_{k,t}$ is the of stock of asset type k. Capital services are further sub-divided into two categories, ICT capital services (Kit) and non-ICT capital services (Knit). Because they incorporate both the quantity and the quality of the factor inputs, service flows have an advantage over stock values when it comes to reflecting the heterogeneity of the inputs.

Finally the TFP index reflects technological changes (embodied, disembodied) as well as non-technical factors like scale and cyclical effect and measurement errors.
Additionally, shares hours worked by high skilled, medium skilled and low skilled employees in the total hours worked are controlled for.

4.1 Model specification

To analyze the impact of the growth rates of various input factor intensity on ALP growth rates, the paper employs two General Method of Moment (GMM) dynamic panel estimators: Arellano-Bond difference GMM estimator and Blundell-Bond system GMM estimator. The main advantage of dynamic panel estimators is that they allow for empirical modeling of dynamics (where past behavior directly affects current behavior) and also make sure that our estimates will not be biased by omitted country-specific variables that are constant over time (unobserved heterogeneity). Difference and system GMM estimators are popular dynamic panel estimators that are designed for data with 1) few time periods and many individuals; 2) individual variables that are not strictly exogenous[8] (for eg TFP, capital deepening can be assumed to be endogenous as regards the dependent variable ALP); 3) presence of heteroskedasticity and autocorrelation within the countries but not across (Roodman, 2006, p. 1).

The difference GMM estimator by Arellano and Bond (1991) use moment conditions in which lags of the dependent variable and first differences of the independent variables are instruments for the first difference equation. Blundell and Bond (1998) augments the Arellano-bond estimator by using first-differenced instruments for the equation in levels in addition to using instruments in levels for the first difference equation. Hence the key difference between the two is that the Blundell-Bond estimator includes lagged difference of the dependent variables as instruments for the level equation while Arellano-Bond estimator does not. Moreover, the system estimator uses more instruments than the difference estimator. Hence in a situation where there are fewer observations and cross-sectional groups, the difference GMM estimator is preferred over the system GMM estimator since ideally, the number of instruments should be as close to the number of groups. Therefore, for models 3 and 4 where only a subset of the 22 countries is used, I use the difference GMM estimator instead of the system estimator.

To save space, I describe the estimation process using only the Blundell-Bond system GMM estimator. With the system GMM as our model specification, a dynamic model of productivity is fitted to an unbalanced panel of countries in the OECD. In order to control for the fixed-effects, we take the first difference of all variables on both sides. This has the effect of removing the individual level fixed effects from the equation since the fixed effect does not vary with time:

[8] Correlated with past and possibly current realization of the error

$$\Delta LP_{H_{i,t}} = \beta_0 + \beta_1 \Delta LP_{H_{i,t-1}} + \beta_2 \Delta CAPIT_{i,t} + \beta_{3\Delta} CAPNIT_{i,t} + \beta_4 \Delta LAB_{i,t} + \Delta e_{i,t} \quad (4)$$

In equation (4), $LP_{H_{i,t-1}}$ is the lagged value of the dependent variable, Gross value added per hour worked (ALP), KIT is index of ICT Capital deepening, KNIT is index of of Non ICT capital deepening, LAB is index of labor services per hour worked (LAB). All the variables are indices of input and productivity services with 1995 as the base year. Additionally, i denotes the individual countries and t denotes the year. Finally, the residual term $u_{i,t}$ is the sum of two orthogonal components: time-invariant country specific fixed effects μ_i and observation specific error γ_{it}.

Even after first differencing the left and right hand side variables, the dependent variable $\Delta LP_{H_{i,t}}$ is still correlated with the observation specific error terms $\Delta e_{i,t}$. To deal with problem, Arellano and Bond (1991) have shown lagged levels of the regressors (input services indices) as well as the first-differenced lagged dependent variables can be used as instruments for the first difference equation. Because the lagged levels of the covariates are pre-determined, they are not correlated with the error term. Up to this point, both estimators are similar. However, system GMM estimator augments difference GMM by estimating simultaneously in differences as well as levels. These two equations are distinctly instrumented with lagged differences of the dependent variables used as instruments for the level equation.

5. Data

This paper focuses on three network utility industries, electricity, natural gas and water supply that comprise section E of the NACE classification. Class E covers a) production, transmission, distribution and wholesale market trade of electricity (NACE Group 40.11 – 40.13) b) manufacture and distribution of gas via mains including wholesale trade over distribution networks owned by others (NACE Group 40.21 – 40.22) c) steam and hot water supply (NACE 40.30) and collection, purification and distribution of water (NACE 41). The EU-KLEMS database published by the Groningen Growth and Development Centre (GGDC) in March 2008 contains industry level data on three sets of variables: (1) basic variables; (2) growth accounting variables and (3) additional variables. This paper makes use of the third group of variables: capital services per hour worked (ICT and Non-ICT), labor services per hour worked, Value Added Total factor Productivity and Gross Value Added per hours worked. These additional series are used in generating the growth accounts but are not growth accounting variables themselves. Likewise, the data on the share of high, medium and low skilled workers in the NACE E industries are also available in the EU KLEMS database while data on number of enterprises by size class were obtained from OECD business demographics dataset. A total of 22 OECD countries have been included in the panel dataset. The EU member countries that are included in the panel data are: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Spain, Sweden, UK, Ireland, Portugal and Luxemburg. Likewise, the non-EU countries include Japan, Korea, US, Canada, Australia. For the estimation process, this paper classifies the 22 countries into three groups: 12 continental European economies (Eur-12); 3 New Member States (NMS) and finally a third category comprising of 5 Anglo-Saxon economies plus Japan and Korea.

6. Descriptive statistics

Recall that our variables are first differences of volume indices with 1995 as the reference year. Hence the numbers can be interpreted as annual growth indicators for the respective inputs. Table 1 reports means and standard deviations of the differenced indices for the cross-sectional time-series data. We observe that for the period between 1995 and 2005, the value added average labour productivity for the electricity, natural gas and water supply industries grew twice as fast when compared to the total industries. The period average for the network utilities was 5.08 index points while it was 1.98 points for the total industry.

TABLE 2 MEAN AND STANDARD DEVIATION OF INPUT AND PRODUCTIVITY VARIABLES

Variable	Utilities All countries	Total industry All countries	West Europe (Utilities)	Anglo Saxon, Jpn, Kor. (Utilities)
ΔALP (lph)	5.08 (10.34)	1.98 (2.65)	5.95 (6.94)	4.97 (13.77)
ΔICT Capital deepening (Capit)	8.68 (32.61)	3.83 (10.30)	1.29 (4.03)	27.12 (57.71)
ΔNon-ICT capital deepening (Capnit)	47.37893 (236.43)	7.00 (26.87)	4.98 (16.16)	156.0489 (430.56)
ΔTFP	1.52 (6.28)	.49 (1.67)	2.32 (5.38)	.95 (3.78)
ΔLabor services per hour worked (lab)	3.5994 (23.78)	4.24 (16.81)	0.22 (.79)	11.41 (44.03)

The same was true for the ICT and Non-ICT capital deepening. Only labor services per hours worked grew faster for the total industry than for the electricity, natural gas and water supply industries. Finally, the average total factor productivity growth for the utilities was 1.52 index points while it was 0.49 index points for the total industries.

When comparing the variables between Western Europe and the Anglo Saxon plus Japan and Korea, we observe that ALP and TFP grew faster for continental Europe. Meanwhile, ICT and Non-ICT capital deepening growth was much higher for the non-European countries, a large part of which was the result of inclusion of Japan and Korea. The labor services per hour worked also grew much faster for the Anglo Saxon, countries, Japan and Korea (11% annually) compared to the older European economies (0.22%).

Similarly, table 2 and 3 displays the correlation or covariance matrix for the productivity variables in the network utilities and the total industries. For both sets of tables, the highest correlation coefficient between the predictors is just over 0.7 hence there is no collinearity between the predictors. We notice that average labor productivity growth is most strongly correlated with the TFP growth followed by ICT capital deepening for the utility industries. For the total industries meanwhile, the ALP growth is also most strongly correlated with the TFP growth followed by non-ICT capital deepening. Finally, we observe that for the network utilities, growth of non ICT capital deepening is strongly correlated with growth of ICT capital deepening (0.61) while for total industries, non ICT capital deepening is strongly correlated with labor services per hour worked (0.73). This gives us a rough idea of what we can expect from our regression analysis that is to follow. Finally, TFP growth seems to be much more strongly correlated with ALP growth for the energy and water industry (0.73) than for the total industries (0.42).

TABELLE 3 CORRELATION MATRIX (ELECTRICITY, GAS AND WATER SUPPLY INDUSTRIES)

	Δlph_u	**Δkit_u**	**Δknit_u**	**Δtfp_u**	**Δlab_u**
Δlph_u	1				
Δkit_u	0.4120	1			
Δknit_u	0.0918	0.6133	1		
Δtfp_u	0.7381	0.0654	0.0133	1	
Δlab_u	0.1424	0.1955	0.0254	-0.0039	1

TABELLE 4 CORRELATION MATRIX (TOTAL INDUSTRY)

	Δlph_t	**Δkit_t**	**Δknit_t**	**Δtfp_t**	**Δlab_t**
Δlph_t	1				
Δkit_t	0.0689	1			
Δknit_t	0.2446	0.4291	1		
Δtfp_t	0.4262	0.0532	0.0994	1	
Δlab_t	0.1240	0.2786	0.7371	-0.0029	1

7. GMM estimation results

For the econometric estimations we used the /Blundell-Bond linear system General Method of Moment (GMM) estimator in Stata. The estimations were obtained from a dynamic panel regression of average labor productivity on ICT and Non-ICT capital services per hour worked (ie capital deepening), Labor services per hour worked and an index for TFP growth.

We studied four different model specifications in our analysis. The first model includes all 22 countries while in the second model adds control variables for the share of large and small sized utility enterprises in the total number of utilities to the initial model. Meanwhile, models 3 and 4 compare continental EU countries (excluding new member states) and the Anglo Saxon countries (including Korea and Japan) respectively. In model 3 we include the 12 continental western European countries. In model 4 we only use the five available Anglo-Saxon countries (US, UK, Canada, Australia and Ireland) plus Japan, Korea.

In model 1 and 2 we employed system GMM estimator. Meanwhile for models 3 and 4 where we use only a subset of the 22 countries, we will use the difference GMM estimator instead of the system estimator in order to reduce the number of instruments.

We calculated 2 two-step GMM estimator instead of the default one-step for models 1 and 2 to ensure that the group of instruments are valid and exogenous. 2-step estimation implies that the standard covariance matrix is robust to panel-specific autocorrelation and heteroskedasticity but this comes at the cost of downward biased standard errors. Likewise, we used WC-robust standard errors which are consistent with panel-specific autocorrelation and heteroskedasticity in two-step estimation in the first two models. Robust standard errors were use in the last two models. All the variables (excluding the control variables for year and skill levels) are indices (1995 = 100), the regression coefficients estimate the change in ALP growth rate per unit change in the factor intensity growth rate.

As regards Sargan test for overidentification of restrictions, the p values are non-significant for all 4 models hence we do not reject the null hypothesis that overidentifying restrictions are valid (see table 4). Non-rejection of null implies that we can have some amount of confidence in our set of instruments because the test did not detect endogenity in the instruments (the set of instruments are thus exogenous). Due to the small number of countries and large number of instruments, model 4 yields relatively weaker Sargan test results.

The system GMM as well as the difference GMM estimators have default test for autocorrelation with the null hypothesis of no autocorrelation. This test is applied to the differenced residuals. The test for AR (1) process is not very important. Of greater concern is the AR (2) test because it will detect autocorrelation in levels. For all four of our models, we accept the null hypothesis of no serial autocorrelations in the residuals.

In model 1 which includes all 22 countries, the dependent variable ALP growth is significantly predicted by ICT capital deepening growth and to a lesser extent by the labor services per hours worked. Meanwhile, non-ICT capital deepening is not a significant predictor of value added ALP growth. Interestingly, when the respective share of large and small utility enterprises[9] for each country is controlled for in model 2, the relationship between ICT capital intensity growth and labor productivity growth is no longer significant. Equally interesting are the findings that emerge when we compare the old European economies and the Anglo Saxon countries plus Japan and Korea. When only the old European economies are included in our model, we see that TFP growth and non-ICT capital deepening are significant predictors of ALP growth while the impact of ICT capital deepening is no longer significant. The coefficient on labor services per hour worked large and positive but is significant only at the 90% level, indicating strong variance in the role played by labor quality improvements across Europe.

Meanwhile, for the Anglo Saxon countries, Japan and Korea we observe that coefficients on ICT capital deepening and labor services and TFP growth are positive and significant were able to significantly predict ALP growth. A 1 percent point increase in the growth rate of ICT capital intensity causes roughly 0.2 percentage point increase in the ALP growth rate. However, similar to Model 1, the impact of ICT capital deepening on productivity is no longer significant when the size of the utility firms is controlled for. Additionally, TFP growth is by far the strongest predictor of average labor productivity growth in the utility sector in all four models, more so for the Anglo-Saxon and Asian OECD countries than for the EU-12 countries. High coefficient on TFP is most likely a reflection of the economies of scale enjoyed by network utilities like electricity, gas and water supply sectors. Overall, we can conclude that TFP growth aside, utility sector productivity growth in the Anglo-Saxon countries plus Japan and Korea are driven by the knowledge economy (ICT capital intensity and labor quality improvement). Meanwhile for continental Europe, the productivity growth in the utility sector is largely driven by non-ICT capital intensity growth.

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[9] OECD structural business statistics categorizes utility enterprises into 5 national size classes based on the number of people employed. In the paper, enterprises employing less than 20 people (size class 1 and 2) is categorized as 'small' and those employing more than 20 people (size class 3, 4 and 5) are categorized as 'large'.

TABLE 5 PARAMETER ESTIMATES FOR DYNAMIC PANEL REGRESSION

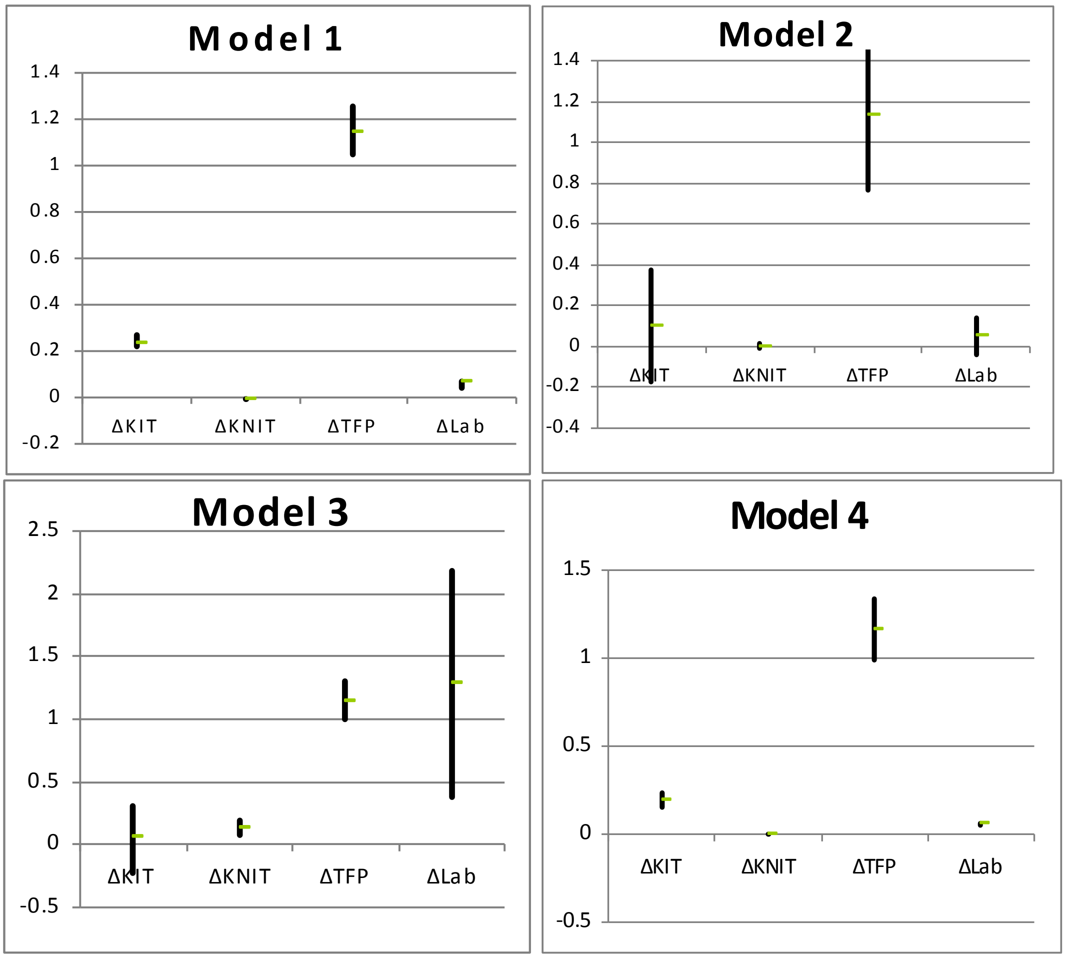
Dep var: Δlph	(Model 1)	(Model 2)	(Model 3)	(Model 4)
Countries **Estimator**	**All countries** **2-step xtdpdsys**	**All countries, controlling for firm size** **2-step xtdpdsys**	**West Europe** **1-step xtabond**	**Anglo-Saxon/Jpn/ Kor** **1-step xtabond**
ΔALP Lagged	-.0399286	-.0915418	-.0077986	-.1238276
ΔICT intensity	.2443452***	.1003188	.0407382	.1980977***
ΔNon-ICT intensity	-.0027621	.0016952	.136939***	-.00068
ΔTFP	1.151187***	1.130094***	1.149108***	1.166542***
Δlabour services/hour	.054853***	.0526136	1.281522	.0575532***
% total hours worked (High skilled)	-3.739932	-2.349973	-.0840794	1.60777
% total hours (Medium skilled)	-3.721685	-2.167163	-.1870172	-.1695777
%total hours (Low skilled)	-3.807594	-2.006331	-.4064564	1.151894
% small enterprise		8.823086		
% large enterprises		8.678667		
Cons	375.2187	-659.5998	-11.49456	-44.41047
AR test				
order 1(p> z)	0.0499	0.0543	0.0277	0.1026
Order2(p> z)	0.8264	0.7363	0.1562	0.9726
Sargan test(GMM error)				
chi2	13.34614	12.51705	6.103411	17.93325
Prob> chi2	0.5756	0.6395	0.5277	0.0123
Obs:	194	174	97	53
Groups:	22	20	13	7
Instruments:	24	26	16	16

*** significant at 99% level

** significant at the 95% level

Figure 1 and 2 illustrate the different variability of the single parameter estimates for models 3 and 4. In the following paragraphs,

FIGURE 1: CONFIDENCE INTERVALS FOR PARAMETER ESTIMATES OF MODEL 1,2, 3 AND 4



8. Conclusion

Using dynamic panel regression analysis, this paper has tried to estimate the impact of different factor input intensities on the productivity growth of energy and water supply industries in 22 OECD countries. The results indicate an apparent distinction in the productivity trajectory taken by Euro Zone countries and non European economies (Anglo Saxon, Japan, Korea). During the period between 1995 and 2005, the utility sector's labor productivity maintained strong growth for the Euro zone countries but this growth came at the expense of declining rate of employment, and stagnant labor quality improvements with ICT capital intensity playing an insignificant role. This is in contrast with the experience of the Anglo-Saxon countries, Japan and Korea where productivity growth and was driven jointly by labor service intensity and ICT capital intensity. In part this was because growth rate of ICT capital deepening in western European utilities was very small compared to the other countries (see Table 2). Secondly, ICT investment was not complemented with corresponding skill upgrading of the labor force in continental Europe. On average, the share of total hours worked by high skilled workers in Anglo-Saxon countries, Japan and Korea was larger and grew faster than in the older European countries (see figures 3 and 4, appendix). Ultimately, while the Euro Zone was characterized by high labor productivity and low employment rate (due to substitution away from labor to non-ICT capital), the Anglo-Saxon countries were characterized by high productivity and high employment rate. This finding for the network utilities reflects a broader trend that has garnered a great deal of attention: European productivity advantage in traditional sectors (non-ICT using sectors) -- the core of the European economy -- has been obtained by substantial reduction of employment in traditional sectors (Encaoua, 2007, Morrow et. al. 2009).

At the same time, it appears that size of the utility enterprises plays a role in mediating the relationship between ICT capital intensity and the utility's labor productivity growth. Figure 3 (appendix) which was constructed using OECD's STAN database on structural business statistics shows that on average, the share of large sized electricity, gas and water enterprises (employing 20 people or more) in the total number of enterprises is larger for the non-Euro Zone economies (Anglo-Saxon countries, Japan and the New Member States). Countries with large markets and relatively high level of interconnection between cross border markets (for example the US and Canada) are able to reach an efficient scale, an advantage that is not available to smaller countries with only internal market where small firms occupy the main part of total employment. In the latter case, enterprises cannot rely on economies of scale to raise capital for ICT investment. Even if small and medium firms do manage to invest in ICT, such small enterprises cannot play a significant role in the dynamics of the overall industry.

Finally, a number of structural differences exist between the two sets of countries that could help explain the different productivity trends. A broad distinction between the two groups of countries (in model 3 and 4) can be made with regards the ownership structure of network utilities. Because there are no clear cut data on the ownership structure (composition of private and public firms) of utilities as a whole, we use ownership structures of electricity supply sector as rough approximate for water and natural gas supply sectors as well for the OECD countries. During the 1995-2000 period, major central European economies like France and Italy included in model 3 consolidated and nationalised their electricity supply industries into state owned, legal monopolies. A variant of this form of organizations which occurred in Germany was regional, legal monopolies, where public enterprise and monopoly occur at the regional level. At the same time, all the countries in Model 3 (with the exception of Spain and Belgium) were mostly public enterprises while only Germany had a mix of private and public ownership. Meanwhile, group 4 countries like the United States and Japan provide examples of investor-owned but regulated regional monopolies that employed rate of return regulation. Moreover, most of the countries in Model 4 were either privately owned or a mixture of private and public enterprises in 1998 (see table 3, appendix). While the differences in relative importance of ICT capital intensity to labor productivity growth cannot be directly linked to ownership structure, the latter does provide a broad framework to compare the ways in which network utilities are operated in the two groups of countries.

Of course, there are a number of caveats to the results. In particular, there are significant cross-country differences in ICT adoption trends within the country groups discussed, particularly the 12 EU countries. Our calculation ignores these differences. Moreover, it is likely that inclusion of more recent data could have yielded a different set of results. At any rate, this paper should be considered a first step in the changing drivers of productivity in the energy and water supply industries.

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Appendix

Figure 3: Natural logarithm of average ICT capital deepening growth in energy and water supply industry (1995-2005)

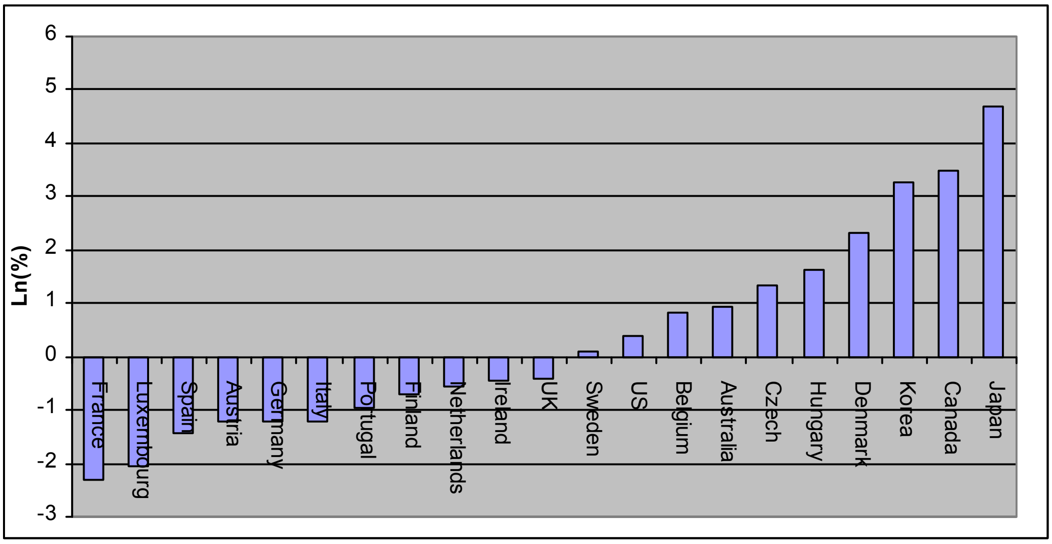
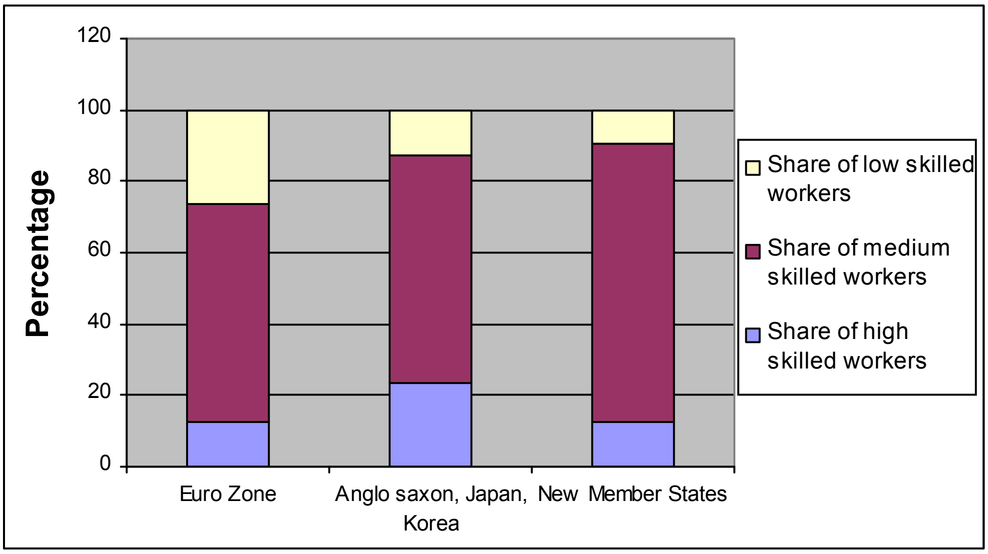


Table 3. Ownership in the electricity supply industry, 1998

	Ownership
Australia	Mixed
Belgium	Mostly private
Canada	Mixed
Denmark	Mostly public
Finland	Mostly public
France	Public
Germany	Mixed
Greece	Public
Ireland	Public
Italy	Public
Japan	Private
Netherlands	Public
New Zealand	Public
Norway	Mostly public
Portugal	Mostly public
Spain	Mostly private
Sweden	Mixed
United Kingdom	Private
United States	Mostly private

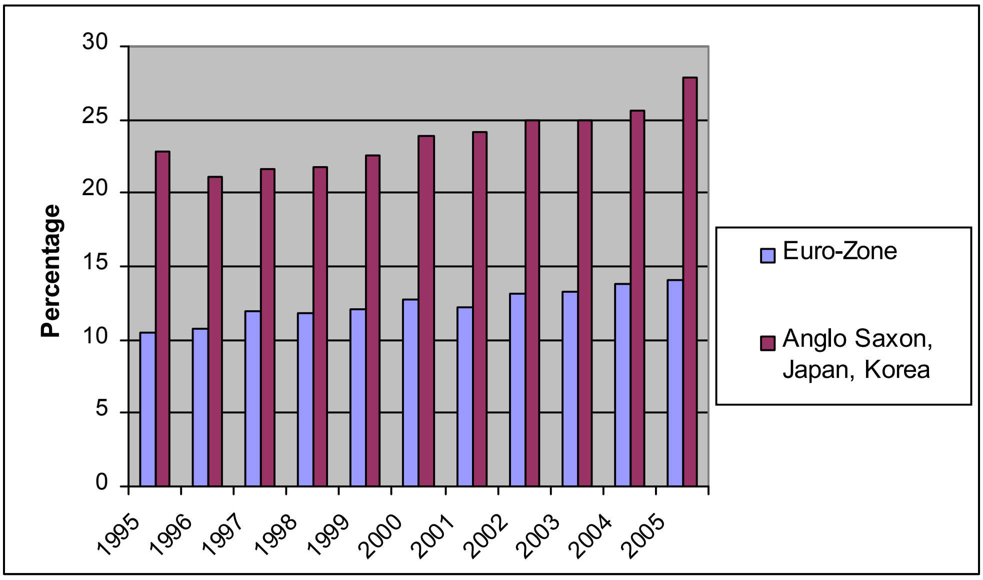
Source: (OECD 2001, p 156)

FIGURE 4: SHARE OF HOURS WORKED BY HIGH, MEDIUM, LOW SKILLED WORKERS 1995-2005 AVERAGE



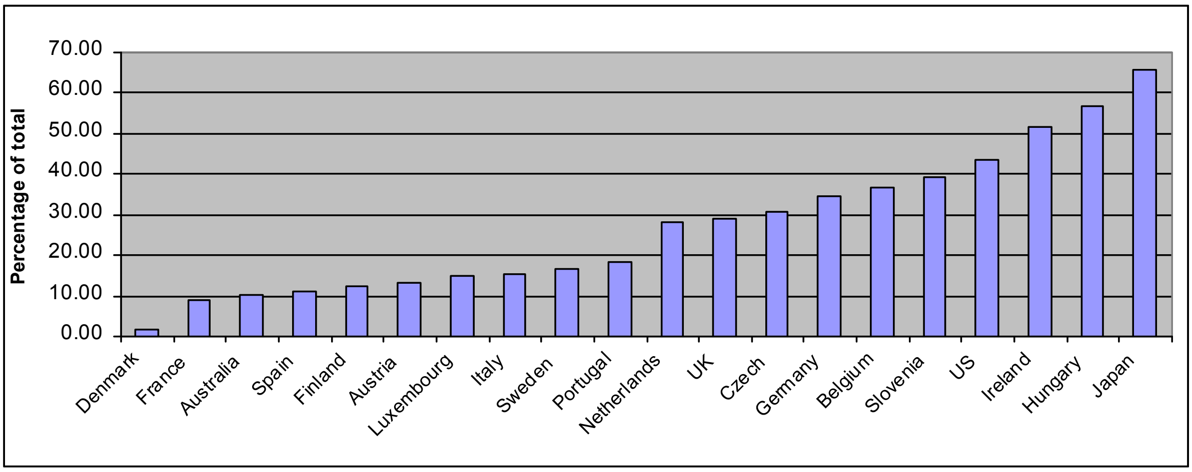
(Source: Own calculations, EU KLEMS database, 2008 release)

FIGURE 5 SHARE OF TOTAL HOURS WORKED BY HIGH SKILLED WORKERS (UTILITIY INDUSTRY 1995-2005)



(Source: Own calculations, EU KLEMS database, 2008 release)

FIGURE 6: SHARE OF ELELCTRICITY, GAS AND WATER ENTERPRISES EMPLOYING MORE THAN 20 PEOPLE (1995-2005 COUNTRY AVERAGE)



(Source: Own calculations based on OECD structural and business demography database)