NOTES D'ÉTUDES

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INVESTMENT IN INFORMATION AND COMMUNICATION TECHNOLOGIES: AN EMPIRICAL ANALYSIS

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Résumé

Des écarts considérables s'observent entre les pays industrialisés en ce qui concerne la diffusion des technologies de l'information et de la communication (TIC) dans l'activité productive. Les Etats-Unis apparaissent comme le pays bénéficiant de la plus forte diffusion. La présente étude se propose d'analyser une piste particulière d'explication du retard européen : celle d'une plus faible (en valeur absolue) élasticité-prix de leur demande. Elle vise aussi à caractériser cette élasticité-prix pour voir si la baisse du prix relatif des TIC peut contribuer à expliquer leur part croissante dans l'investissement et dans le PIB. L'analyse porte conjointement sur cinq pays : la France, l'Allemagne, les Pays-Bas, le Royaume-Uni et les Etats-Unis. Les données mobilisées sont macro-économiques, annuelles, et couvrent la période 1975-2001.

Les résultats obtenus indiquent que le retard européen ne paraît pas pouvoir trouver des éléments d'explication dans des écarts entre pays des élasticité-prix de la demande des différents produits TIC. En effet, les valeurs estimées de ces élasticités sont proches et non significativement différentes entre pays. Une part au moins des écarts de diffusion des TIC trouverait son origine dans des différences plus structurelles entre pays. Enfin, la valeur estimée de l'élasticité-prix des matériels informatiques et des logiciels est généralement inférieure à –1, ce qui explique, compte tenu de la baisse du prix relatif de ces produits, la croissance de leur part dans l'ensemble des dépenses d'investissement ou dans le PIB. Une telle situation, caractéristique d'une étape de diffusion de ces produits, ne peut être que transitoire.

Mots-clés : TIC, investissement, demandes de facteurs.

Classification JEL : E22, O47, O57, R34.

Abstract

Recent economic literature has identified sizeable differences across industrialised countries in the diffusion of Information and Communication Technologies (ICTs) throughout the production structure. This paper addresses the question of whether differences in the price elasticity of demand for ICTs could explain why Europe lags behind the United States in terms of ICT diffusion. We use annual macroeconomic data covering the period 1975-2001 and consider five countries: France, Germany, the Netherlands, the United Kingdom and the United States.

Europe's lag in ICT diffusion does not appear to be linked to cross-country differences in the price elasticity of demand for ICT products. Our results suggest that at least part of the gap in ICT diffusion should be ascribed to more structural cross-country differences. The estimated value of the price-elasticity of computer hardware and software is generally lower than –1 which, given the decline in the relative price of these products, explains the increase in their share of investment expenditure and GDP. This situation is characteristic of a diffusion stage and is necessarily temporary.

Keywords: ICT, investment, factor demand.

JEL Classification: E22, O47, O57, R34.

I. Introduction

In recent years, a large body of literature has been devoted to ICTs and to the impact of ICT production and use on productivity (see for example the OECD's report (2003), Jorgenson (2003) or Oliner and Sichel (2002)). Most of these analyses estimate the impact to be considerable. They also highlight sizeable differences across industrialised countries in the diffusion of ICT. The United States stands out as the country where the diffusion of ICT is the broadest.

Various suggestions have been put forward to explain the European lag. The diffusion lag probably stems partly from the fact that the ICT-producing sector is relatively larger in the United States and that these technologies can therefore begin to spread earlier. Gust and Marquez (2002) put forward three explanations for the European ICT diffusion lag: complementarity of ICT use with skills; burdensome or unstable regulations on goods and labour markets, preventing companies from restructuring work practices; oligopolistic settings raising access cost and lowering Internet use. These explanations are still awaiting robust statistical confirmation.

This paper examines another possible explanation, that of lower price elasticity of demand for ICT (in absolute terms). If the price elasticity were lower, then the continuous steep decline in the relative price of ICTs over the last few decades would have resulted in a smaller increase in the diffusion of these technologies. We build on the analysis of Cette and Noual (2003). We use annual macroeconomic data covering the period 1975-2001 and consider five countries: France, Germany, the Netherlands, the United Kingdom and the United States. National accounting data rely on conventions that differ across countries (cf. Cette, Mairesse and Kocoglu (2000)) and so cannot be used directly for our comparative study. The sources and construction of the data are the same as in Cette and Noual (2003), using the van Ark et alii (2002a) database which greatly reduces methodological differences[1]. We calculate the price series assuming that in each country, the price of each input relative to the GDP deflator is the same as in the United States.
After comparing ICT diffusion throughout the production systems of the different countries (II), we propose a factor demand model (III) and analyse the results of its estimation (IV).

I. ICT diffusion across countries

Earlier studies, including OECD (2002, 2003) or van Ark et alii (2002a and b), show a stable ranking in terms of nominal ICT investment rates and that the United States have a clear lead. ICT investment rates rose at least twofold in all of the countries between 1980 and 2000. The country rankings obtained for the nominal ICT capital output ratio is similar to that found for the investment rate (see Chart).
These findings strengthen the case for modelling ICT capital demand in a bid to explain the diffusion differentials.

II. The model

The estimated model is static and corresponds to a long-term relationship[2]. We identify seven inputs: labour plus six components of capital, namely computer hardware, software, communication equipment, transport equipment, other equipment and structures.
The full model justifying the following regression equation is available from the authors upon request: starting from a constant returns to scale production function, we obtain the predicted factor demand for each input, and augment this equation to take various measurement problems into account. In the end, we obtain:

$$f_{j,k} - q_k = -a1_{j,k} \cdot (c_{j,k} - p_{q,k}) + a2_{T,k} + a3_{j,k} \cdot AGE_{j,k} + a4_{j,k} \cdot chg_k + a5_j \cdot p_{hw,k} + a6_{j,k} + a7_k + u_{j,k}$$

In this relation, for each country k, the logarithm of the capital output ratio of input j, $f_{j,k}$–q_k, depends on: (i) the log of the relative price of input j as compared to all inputs, $c_{j,k}$–$p_{q,k}$; (ii) Total Factor Productivity effects denoted by annual constants $a2_{T,k}$; (iii) mismeasurement correction variables, i.e. average age of equipment for input j, $AGE_{j,k}$, the log of the exchange rate chg_k, the log of the computer hardware price $p_{hw,k}$, country/product dummies $a6_{j,k}$; (iv) country dummies $a7_k$. For software and communication equipment, $AGE_{j,k}$ is used to adjust for cumulated measurement errors in the price of investment in each country. The price of hardware also serves to adjust for a potentially insufficient incorporation of quality improvements in the price series for those two factors. Finally, the exchange rate captures idiosyncrasies in the relative price of each country, as well as direct terms of trade effects for ICT importers.

We also use various simplifying hypotheses to estimate simplified forms of this relation:
H1 – The exchange rate, equipment age and computer hardware prices are removed from the list of independent variables: $a3_{j,k} = a4_{j,k} = a5_{j,k} = 0$;

H2 – The effects of autonomous technical progress follow purely trend-based country-specific movements: $\gamma_{T,k} = \gamma_k \,.\, T.\; a2_{T,k} = a2_k \,.\, T$;

H3 – The product/country constants are removed from the list of independent variables, except in the case of the labour input: $a6_{j,k} = 0 \;\forall j,k \text{ if } j \neq tr$;

H4 – The cost elasticity of factor demand is identical in all countries: $a1_{j,k} = a1_j \;\forall k$.

The equation is estimated for each country over the period 1975-2001 using pooled data for all seven inputs, i.e. 189 observations in all (27 years x 7 products). Under hypothesis H4, the relation is also estimated simultaneously for the five countries, i.e. 945 observations (27 years x 7 products x 5 countries).

III. The results

The OLS estimations are performed by stacking the data on the time/product dimensions or, under hypothesis H4, on the time/product/country dimensions. Concerning the tests under hypotheses H1 to H4, it appears that (Table 1):

- Hypothesis H1 is rejected for all countries except the United States. This supports the inclusion of various variables to adjust for measurement problems;
- Hypothesis H2 is rejected for France and the United Kingdom, but accepted for the other three countries;
- Hypothesis H3 is rejected for all countries;
- Hypothesis H4 is validated for all three ICT products.

In view of these results, we focus our comments on the estimates obtained under hypotheses H2 and H4 simultaneously. The coefficients for the exchange rate, age and the country/product constants combine multiple effects and their sign is indeterminate; their estimated values are neither shown nor commented here. The main lessons that can be drawn from the estimations are that (Table 2):

- Estimated cost elasticities are generally significant and have the expected negative sign;

- Demand for computer hardware and software is highly sensitive to price. There estimated price elasticity are even generally lower than –1;
- These results appear to be robust to hypothesis H2.

To assess robustness, we estimated the model over different periods and without the labour input; estimated elasticities were very similar. The measurement errors problem prompted us to carry out estimations using the instrumental variables (IV) method, but we failed to find acceptable instruments. This does not mean that no list of instruments can be found, but if the measurement errors are certainly sizeable for some variables, the white noise component of these errors is doubtless fairly small.

IV. Conclusion

The European lag in ICT diffusion does not appear to result from cross-country disparities in the price elasticity of demand for different ICT products. Our analysis suggests that, because of the rejection of hypothesis H3, the differential in ICT diffusion is partly rooted in more structural cross-country differences. The estimated value for the price elasticity of computer hardware and software is generally lower than –1, which, given the decline in the relative price of these products, explains the increase in their share of overall capital expenditure and GDP. This situation is characteristic of a diffusion stage and is necessarily temporary.

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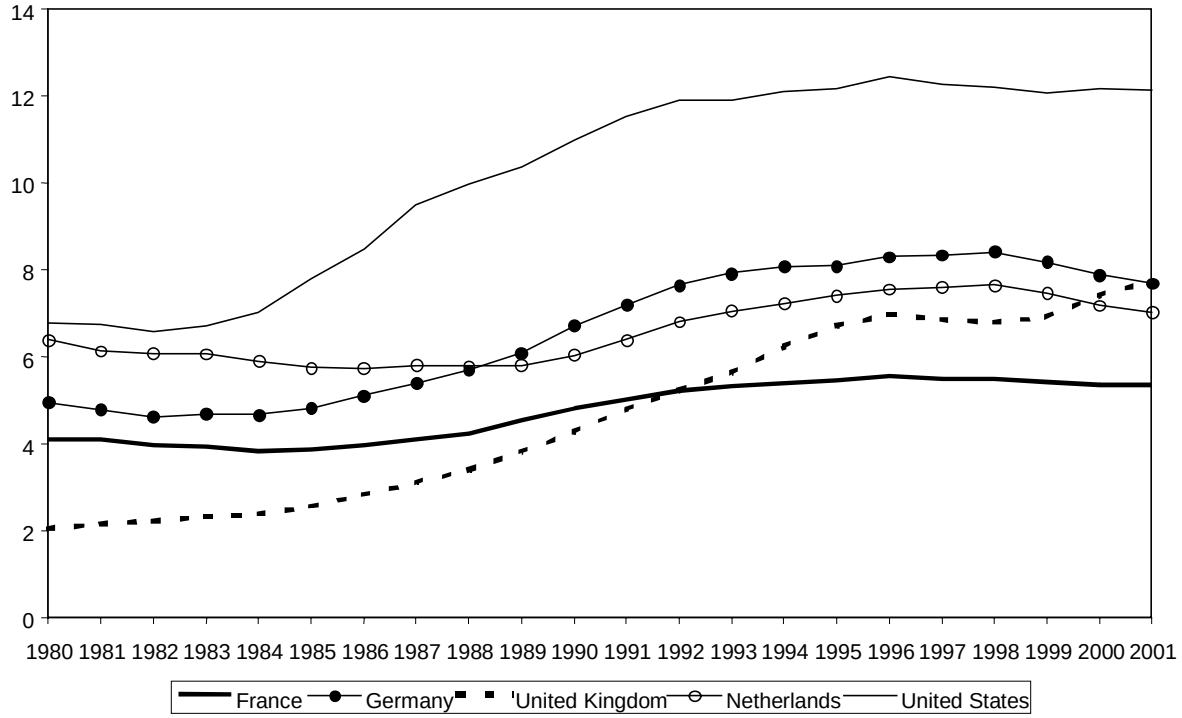
Chart
ICT capital output ratio – ICT capital stock over GDP
In nominal terms and %



Source : Authors' calculations from basic data supplied by van Ark et al. (2002a)

Table 1 : **Tests of hypotheses H1 to H4**
Fisher Tests - Probability of wrongly rejecting the tested hypothesis

A – Tests of hypotheses H1, H2 and H3

		H1 tests	H2 tests	H3 tests	
					Under hypothesis H2
For each country individually	France	0	0.009	0	0
	Germany	0	0.179	0	0.079
	Netherlands	0	0.288	0.030	0.428
	United Kingdom	0	0.037	0	0
	United States	0.445	0.556	0	0
Under hypothesis H4		0	0.049	0	0

The probability of wrongly rejecting hypothesis H1 is 0.445 for the United States and 0 for all other countries. Accordingly, hypothesis H1 appears to be acceptable for the United States.

B – Tests of hypothesis H4

Input	Excluding other hypothesis	Under hypothesis H2	Under hypotheses H2 et H3
Computer hardware	0.235	0.275	0.055
Software	0.533	0.096	0.093
Communications equipment	0.499	0.748	0.960
Other equipment	0	0.209	0.007
Transport equipment	0.038	0.327	0.059
Structures	0.236	0.773	0
Labour	0.044	0.505	0.987

Table 2 : Estimates of the price elasticity of factor demand
Results for coefficient $-a1_{j,k}$. of the estimated relation

Input	Under hypothesis H4	Under hypotheses H2 and H4
Computer hardware	-1.25	-1.27
	(-63.6)	(-62.9)
Software	-1.98	-1.74
	(-15.4)	(-14.1)
Communications equipment	-0.38	-0.07
	(-3.0)	(-0.6)
Other equipment	-0.46	-0.14
	(-6.4)	(-2.1)
Transport equipment	-0.60	-0.12
	(-4.8)	(-1.1)
Structures	-0.12	0.06
	(-3.2)	(1.6)
Labour	-2.03	-1.74
	(-10.2)	(-9.5)
R^2	0.998	0.997

Estimation period : 1975-2001 – Annual data – OLS method.
Estimations are carried out for all countries by stacking the data for different products-countries.
The numbers in brackets correspond to the values for Student's t-statistic. For the sake of place and clarity, the above table shows the estimates for price elasticities only. Contact authors for the full set of results.

[1] For more information, see Appendix 1 of Cette and Noual (2003) or the longer paper available from the authors.

[2] Cette and Noual (2003) propose a number of short-term estimation adjustments corresponding to an error correction model. These yield weak results because of the short time dimension of the data.

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