Searching for the determinants of IT investment: Panel data evidence on European countries

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Abstract

The aim of this paper is to identify the stage of IT adoption in individual European economies, and to analyse the determinants of IT investment in a panel of EU countries. We first analyse the dynamics of IT investment expenditure in 15 European countries from 1992 until 2001 and, by means of a cluster analysis, we draw a picture of IT diffusion in Europe. By clustering the European countries according to their shares of IT spending over GDP, we identify three fairly stable groups of fast, medium and slow adopters. We then build an econometric equation of the determinants of IT investment to be estimated with panel data for five European economies over 1980-2001. We consider both aggregate IT investment, and investment in hardware or software taken alone. Financial conditions, income growth and comparative advantage turn out to affect IT investment, but we find that the determinants of hardware investment only partially overlap with those of software.

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(†) Department of Economics - University of Rome “La Sapienza”, e-mail: p.guerrieri@mclink.it;
(**) Department of National Accounts and Economic Analysis - Italian Statistical Institute, e-mail: Cecilia.jona@libero.it;
(***) Department of Economics - University of Perugia, e-mail: steman@unipg.it;
1. Introduction

During the late 1990s, Information Technology (IT) accounted for a large and growing share of investment and contributed significantly to output growth, particularly in the United States. The diffusion of IT throughout the economy has improved economic efficiency and substantially increased productivity growth in the United States as well as in other OECD countries. Due to the impressive productivity performance of the US economy in the late 1990s, most of the recent research has been devoted to analyse the impact of IT (or ICT, including also Communication technologies) production and diffusion on US productivity growth (Oliner and Sichel, 2000; Jorgenson and Stiroh, 2000). The main message from these studies is that the US economy can be viewed in many respects as a technology and productivity “leader”. If a new IT-based source of productivity growth is established in the US economy, this raises the potential for other countries to follow suit.

During the same period, IT investment has considerably increased in European countries as well, but this has not always been followed by an equivalent acceleration in productivity growth. Moreover, the contribution of information technology to growth seems to be quite heterogeneous across European countries (van Ark et al., 2002). Thus, it is crucial to investigate the record of European countries in adopting new technologies and reducing their IT gap vis-à-vis the US.

The aim of this paper is first to identify the stage of IT adoption in individual European economies, and then to analyse the determinants of IT investment in a panel of “representative” EU countries. A brief review of the literature on IT diffusion and investment is presented in Section 2, which is based both on comparative and on country studies. In Section 3, we study the dynamics of IT investment expenditure in 15 European countries from 1992 until 2001 and, by means of a cluster analysis, we draw a picture of IT diffusion in Europe. By clustering the European countries according to their GDP shares of IT spending, we identify three groups fairly stable along the 1990s: fast, medium and slow adopters. In Section 4, we build an econometric equation of IT investment to be estimated with panel data on European economies over 1980-2001, both considering aggregate IT investment and disaggregating between hardware and software. Since most European countries have only recently started to collect data on investment in IT items, and for several countries these data are still unpublished, we choose one or two “representative” countries for each of the three groups mentioned before, and perform the econometric analysis for these countries. Section 5 discusses our econometric findings on the determinants of IT investment in Europe, while final remarks and suggestions for further research are discussed in Section 6.
2. ICT diffusion and investment: a brief review

Since the mid-1990s, that is almost a decade after the start of the “endogenous growth” debate, the so-called “New Economy” and its relations with growth have moved to the centre of the stage. More and more researchers have started to study the conceptual links between the introduction of ICT and economic growth, and evaluate their quantitative effects on national accounts. One reason for this widespread interest has been the mounting attention to the “Computer productivity paradox”, i.e. why productivity growth in the US had not been so strong in the 1980s and early 1990s despite the spread of ICT throughout the economy (Triplett, 1999).

A number of interpretations have been provided for this paradox. First, there was (and possibly is) a measurement problem involved in the definition of the ICT sector itself, and then in the economic evaluation of the ICT goods. The problem is now apparently solved as the OECD provides an official definition of ICT, and ICT goods and services are evaluated taking account of their inner quality (in the US, with the tool of hedonic pricing; see Colecchia and Schreyer, 2001, for an overview of such methodological issues).

Another interpretation draws on the definition of “productivity” and on the productivity dynamics postulated by New-Economy theorists. The distinction between the production and use of ICT is central in this case. According to a simple two-sector neoclassical framework, if we are to measure the growth contribution of technical progress in the sectors producing ICT, we have to compute total factor productivity in the ICT-producing industries, as in this case technical progress is associated with an outward shift of the production function. If alternatively we are to measure the impact of ICT utilization on the productivity of whole economy, we have to calculate the variation in average labour productivity associated with the economy-wide rise in ICT investment (see Stiroh, 2001a). This distinction is fundamental, because the overall impact of ICT on per capita output crucially depends on which is the main channel of productivity improvement, and on the relative weight of the ICT sector vis-à-vis the rest of the economy. On the one hand, the contribution of technical progress is the smaller, the lower the relative weight of the ICT-producing sector. On the other hand, in order for the effects of the ICT investment channel to become visible, more time is required for the new capital goods to fully generate a strong and permanent effect on labour productivity. Both these features may contribute to explain the Computer productivity paradox.

A third interpretation has to do with productivity spillovers associated with ICT adoption. In this case as well, one can distinguish between spillovers due to the diffusion of technical progress from the ICT-producing sectors, and productivity spillovers due to the use of ICT in the rest of the
economy (network externalities; technical complementarities with other innovations generating in other sectors, such as the aircraft industry). Moreover, productivity improvements stemming from the production or the utilization of ICT could reinforce each other, for instance through intense producer-customer relationships prompted by proximity (see Rosenberg, 1982). Here again, measurement issue and the identification of the spillovers may partly explain the paradox mentioned before.

Empirical studies on the contribution of ICT to growth have flourished in the US in recent years, and the debate has eventually moved from a US-centred to an international dimension. In May 1999, the Economics Department of the OECD launched an ambitious two-year research project on “Sustainable growth and the New Economy”, which has so far provided us with a great deal of comparative studies on the nature and dynamics of innovation- and information-based growth. The starting point of comparative studies is twofold. First, there is still evidence of a gap in the relevance of the ICT sector between continental Europe, on the one side, and the US and a few other industrial countries, on the other side (see for instance OECD, 2003). Second, the growth performance of continental Europe and Japan has been worse than those of the US in the second half of the 1990s, although the ICT investment gap has been progressively closed during the decade (Schreyer, 2000).

Even within Europe, laggards (Italy, Spain and to a lesser extent Germany and France) and fast adopters (the UK, Netherlands, Sweden, Finland) can be identified (van Ark et al., 2002). However, once industrial economies are classified according to their ICT endowments, the question becomes: Has the wedge between leaders and slow adopters been partially closed since the mid-1990s? For some ICT components the answer seems to be positive. According to Colecchia and Schreyer (2001) the annual rate of growth of IT investment at constant prices over 1995-2000, based on harmonised indexes, has been 32.4 percent in the US, 31.6 percent in France, 31.2 and 30.9 percent respectively in Italy and Germany. As a matter of fact, ICT expenditure rates are now close to 6 percent of GDP in Western Europe, with a strong catch-up effect vis-à-vis the US (Iammarino et al., 2001).

This brings us to the second topic mentioned in the Introduction. The US experienced a historically unprecedented period of growth during the 1990s, while the pace of economic growth has been (and is) sensibly slower in continental Europe. Of course, many factors contributed to these outcomes, including fiscal consolidation in Euroland, accommodative monetary policy in the US, structural differences in labour, product and financial markets across the Atlantic, the higher weight of R&D in the US economy relative to Europe. However, the estimated growth contribution of information technologies was substantial in the UK and Netherlands, and rapidly increasing in over the 1990s in
Finland, Ireland and Denmark. Conversely, new technologies contributed less to growth in France, Germany, Belgium and Sweden, and only marginally in Spain and Italy (van Ark et al., 2002). Hence, with the notable exception of Sweden, the distinction between fast and slow IT adopters in Europe replicates that between economies with a high or a low contribution of IT to aggregate growth. Therefore, it is crucial to investigate more deeply the dynamics of IT adoption in EU countries, and the determinants of IT investment both at the micro- and at the macro-economic level (for the Italian case, see for instance the essays in Rossi, 2002).

Another intriguing issue is to what extent the US success story is accounted for by the existence of a strong IT-producing sector, which is lacking in several countries in Europe? In other words, is there a key issue of comparative advantage in high-tech industries that is consistent with a windfall of technical progress in the US but not in continental Europe? Roeger (2001) suggests that productivity growth is associated with the comparative advantage the US have in the production of high-tech goods, hence comparative dis-advantage and not only Eurosclerosis must be blamed for the inferior growth performance of the EU. Moreover, comparative advantage in producing IT could also be associated with faster-than-average adoption of IT in the economy, due to manufacturer-customer relations favoured by proximity and a common language.

Country studies of European economies have been mainly devoted to quantify the contribution of new technologies to economic growth by means of a growth-accounting approach. Further, due to the complexity of official estimates of ICT capital formation (Iammarino et al., 2001), and to the paucity of data, country studies have been mainly devoted to the measurement of ICT investment and to the analysis of the impact of new technologies on productivity growth, and less to the determinants of IT investment. Among them, Oulton (2001) develops new estimates of investment in and output of information and communication technologies for the UK and measures the contribution of ICT to the growth of output and productivity for the period 1980-1999. Melka et al. (2003) follow a similar approach to assess the role of ICT in stimulating the French economy: their main purpose is to make a first step towards a thorough identification of the sources of growth across industries, in order to comprehend more properly the contribution of new technologies to overall productivity in ICT-using and ICT-producing industries in France.

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1 See Gordon (2003) among others.
3. IT diffusion among European countries: a cluster analysis

In this section we draw a picture of the diffusion of IT investment expenditure across Europe over the period 1992-2001. We focus on Information Technologies excluding Communication equipment because the latter item includes a large share of rather “traditional” investment goods, whose behaviour in terms of investment functions and contribution to productivity growth is likely to be rather different than for IT. In particular, we track the variability of the expenditure share of IT over GDP across 15 European countries plus the US. To study the variability of the IT/GDP ratio across countries and across time, we employ Ward’s approach to the analysis of variance that allows us to evaluate the distance between clusters of countries (Everitt et al., 2001). This method minimizes the sum of squares of any two (hypothetical) clusters that can be formed at each step of the analysis, and therefore is consistent with a minimum-variance approach. We applied Ward’s methodology both to the data for the whole period 1992-2001, and year-by-year data. Chart 1 displays the results we obtain when implementing Ward’s algorithm on data for the entire period: three groups of countries (slow, medium and fast IT adopters) are identified. Among the fast adopters, Sweden is associated with the highest IT/GDP ratio while among the slow adopters, Greece displays the lowest IT/GDP rate.

[Chart 1 about here]

The three emerging groups are basically consistent with those identified in the literature (see for instance OECD, 2003, Chapter 1): US, UK plus some Scandinavian countries and the Netherlands (fast adopters); continental Europe plus other Scandinavian economies (medium adopters); and Mediterranean countries plus Ireland (Slow adopters). The main difference with other studies concern France, which ranks higher here than in other classifications, and Finland for which the opposite is true: notice however that our clusters are based on IT data which exclude Communication equipment and services, and that this may explain why France (Finland) performs better (worse) in our classification than in others.

Chart 2 shows the results we obtain year by year. It is interesting to note that during the whole period only few countries moved across groups. In particular, with the exception of Ireland that was classified as medium adopter in 1992 and as slow adopter in the following benchmark years, slow adopters and most of medium adopters (Austria, Finland, Belgium, Norway) maintained their

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2 See the Appendix for a definition of the IT and CT sectors, which draws on the economic activity classification (ATECO 91) that follows the NACE rev.1 up to the fourth digit level. The fifth level that is used in the present analysis is a further diggregation of the fourth.
original ranking over time. On the contrary, rankings among fast adopters shifted almost every year, although only Sweden moved from the medium into the fast adopters cluster over time. The next step is to search for common determinants of IT investment across European economies, and to identify key relationships that may account for the persistent differences they display in the rate of IT adoption (as proxied by the ratio of IT investment to GDP).

[Chart 2 about here]

4. The determinants of IT investment in European countries: empirical model and data

In order to move from the description of national patterns of IT accumulation to the analysis of the determinants of IT investment across European countries, we build an econometric model to be estimated with panel data for five representative EU countries over 1980-2001, where “representative” refers to the fact that at least one country for each of the three clusters identified above is included in the sample. The model we adopt is rather eclectic in that it combines features of standard models of aggregate investment with features we believe can usefully be applied to the specific case of IT investment choices.3 According to the Keynesian tradition, aggregate investment is modelled as a function of disposable income and the real interest rate; disposable income is in turn related to gross domestic product (see for instance Pindyck and Rubinfeld, 1981, chapter 14). In our case, we estimate the share of IT investment over GDP and we normalize other variable with gross domestic product, hence we do not include disposable income among the explanatory variables. However, we do include a proxy for the (expectation of) growth of the size of the national market, the lagged rate of growth of GDP. To account for country-specific financial conditions we use long-term real interest rates, lagged one year as their influence on IT investment is likely to occur after a time lag (this variable is common both to the Keynesian and to the Neoclassical approach to aggregate investment: see Blanchard and Fischer, 1989, chapter 2). More recent theoretical and empirical approaches to business investment underline the key role of liquidity constraints in an environment characterized by widespread financial market imperfections. Liquidity-constrained entrepreneurs have to rely on retained profits as well as on credit flows to finance their investment plans (see for instance Fazzari et al., 1988). In this case, higher profit shares in the distribution of GDP should be associated with higher investment rates. Other scholars point out to a different causal link, going from higher wage compensations to a more intense substitution of capital to labour inputs in the production function, hence to higher investment rates (see Daveri and Tabellini, 2000). As the labour and the profit share

3 See Chirinko (1993) for a survey of business investment models.
(where the latter includes the compensation for capital services) are linked through the accounting identity of the distribution of national income, we use either aggregate labour costs (CPE, compensation per employee) or net operating surplus (NOS), both as shares of GDP. As in the case of the real interest rate, we include the lagged value of CPE/GDP or NOS/GDP, as financial conditions (or relative factor prices) are supposed to affect investment rates after a time lag.\(^4\)

So far concerning the variables that belong to standard models of aggregate business investment let us turn to variables that may apply to the specific case of IT investment choices. The literature on the determinants of ICT diffusion among national economies points out to a number of variables, such as the direct costs of ICT, implementation barriers, risk and uncertainty related to the applications of new technologies, the competitive and regulatory environment (see OECD, 2003). Unfortunately, most of these variables are hardly viable in our context, either because they are conceptually flawed when analysing the EU, or because data are difficult to collect and substantially unavailable on a yearly basis. Take for instance the price of IT goods: there should not be significant differences in such prices within the EU Internal Market, as in principle even non-tariff barriers such as technical requirements for IT goods should not be so different across EU economies as to drive a price wedge. Quantifying risk and uncertainty related to the applications of new technologies is very difficult, and it is almost impossible to provide time series data on that. More information has become recently available on the competitive and regulatory environment of OECD countries (see for instance, Nicoletti et al., 2000). Drawing on this source of data, Alesina et al. (2003) estimate a dynamic model of investment in utilities, transport and telecommunication and find that net investment is significantly hampered by tight regulation. We have tried to take advantage of this literature, and have included an economy-wide measure of regulatory strictness in our regressions of IT investment, but no significant effects of this variable has been detected in this context.\(^5\)

Among other factors potentially affecting IT investment across EU economies, we have selected a (rough) measure of national comparative advantage in IT (the share of export over import of IT capital goods, EXP/IMP), and a measure of the intensity of R&D expenditure on a country basis (R&D/GDP). A priori, we expect comparative advantage in the production and trade of IT goods (as measured by a high value of EXP/IMP) to positively affect IT investment, as production and utilization of IT could reinforce each other through intense producer-customer relationships prompted by proximity. National comparative advantage could also be significant as a proxy for direct costs and implementation barriers relative to the IT sectors, if the assumption of price equalization within the borders of the EU Internal Market fails to hold. Furthermore, we expect the

\(^4\) We also tried different lags structures for financial and other variables, but with no appreciable results.
aggregate intensity of R&D expenditure to positively affect IT investment if R&D-intensive sectors or firms tend to command more IT investment (in the Italian case, there is evidence that this holds: see De Arcangelis et al., 2003). Therefore, our baseline empirical relation is shown in Equation 1.

\[ \text{Equation 1} \]

\(^3\) We used the OECD summary indicator of Employment Protection Legislation, (Nicoletti et al., 2000).
Equation 1

\[
\left( \frac{I_{tech}}{GDP} \right)_{i,t} = \alpha_{0,i} + \alpha_{1} r_{i,t-1} + \alpha_{2} (d \ln GDP)_{i,t-1} + \alpha_{3} \left( \frac{R \& D}{GDP} \right)_{i,t} + \alpha_{4} \left( \frac{CPE \ or \ NOS}{GDP} \right)_{i,t-1} + \alpha_{5} \left( \frac{EXP}{IMP} \right)_{i,t(IT)} + \varepsilon_{t}
\]

where:

tech = IT, hardware, software;
i = GE, FR, ITA, NE, UK;
t = [1980;…; 2001]

r = 10-years real interest rate;
GDP = gross domestic product;
R&D = BERD, Business enterprise expenditure on R&D (or other proxies for R&D expenditure as indicated in the Tables);
CPE = aggregate labour compensation in the business sector (compensation per employee);
NOS = net operating surplus in the business sector;
(\frac{EXP}{IMP}) = export over import in the “Office machine and computer industry”.
We use yearly data for five countries (Germany, France, Italy, Netherlands and the United Kingdom) over 1982-2001. Each of the three diffusion clusters relative to EU countries – as identified in Section 3 - is represented in our panel. All variables (except of course the real interest rate, the export-import ratio and the growth rate) have been normalized by GDP in order to avoid dimensional effects, and then log-transformed. Lack of detailed information on IT capital goods, such as prices and depreciation rates, as well as of long enough series on IT stocks for every country, implies that the normalization to GDP is possibly the best available choice. We estimate our equation with a least square dummy variable method (LSDV), which amounts to assuming country fixed effect.

Official data on ICT investment, although often partial and for a few years only, are available for most EU member countries (van Ark et al., 2002). However, for five countries only (Germany, France, Italy, Netherlands and the United Kingdom) available disaggregated data series for the three main ICT investment categories (hardware, software, and communication equipment) cover a long enough time interval. Other countries (Austria, Finland, Ireland, and Sweden) only publish data on software. We have thus assembled sufficiently long time series (covering 1980-2001) for those five EU countries, in order to analyse the determinants of IT expenditure at current prices. Data have been collected both on IT investment and its components in the five EU countries, and on the variables to be tested as exogenous determinants of IT expenditure at the macro level. All data stem from national account sources, except for the UK whose data on IT capital goods are taken from Oulton (2001).

5. Empirical findings

We first discuss the estimates of equation 1 using data for the investment in IT as a whole, and then provide separate estimates for investment in hardware and software. As shown in the first column of Table 1, our empirical equation fits yearly data on IT investment in the five EU countries rather well, although taken individually only some coefficients are statistically significant. The real interest rate has a negative coefficient as expected; the share of labour costs is negatively correlated with IT investment, supporting the financial constraint hypothesis against the labour-capital substitution conjecture. In order to test the financial constraint hypothesis more directly, in column two we re-estimate the equation using NOS instead of the aggregate labour share (CPE), and finding a weaker but still significant positive coefficient as expected. While the lagged growth rate

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6 IT data for UK are available only until 1998. The data for 1999-2001 are estimates by the authors.
7 Italian data are from ISTAT – National Accounts; data for Germany, France and Netherlands come from the European Central Bank; while the source of UK data is Oulton (2001).
of GDP tends to show a positive relation with IT investment, R&D intensity does not display a statistically significant relation with IT/GDP. Our measure of comparative advantage is instead positively and significantly correlated with the endogenous variable. In column three we experiment an alternative measure of R&D, but the results are not consistent with our a-priori.

If IT capital is complementary to skilled labour or to the share of scientists or technicians in the labour force, it might be the case that IT investment raises with the national level of higher education, or with the proportion of the labour force that has scientific or technical skills. We have controlled for a wide range of these variables in the regressions, but obtained no significant result. Once again, this is possibly due to the poorness of our proxies, hence more research deserves to be undertaken in the direction of testing more refined measures of the skills required by IT investment.

[Table 1 about here]

One possible reason why some of the variables included in equation 1 turn out not to be statistically significant is that they affect hardware and software investment in a different way: merging together the data on hardware and software may then be inappropriate. Table 2 on the determinants of investment in hardware supports this conjecture. Column one shows that all the variables included in equation 1 turn out to be significant in explaining hardware investment, and with the expected sign. More precisely, financial tightness has a negative impact, while growing domestic demand, a higher intensity of R&D and comparative advantage in the hardware sector, enhance the accumulation of hardware. In column two, instead of CPE we have used NOS which is associated with a positive but non-significant coefficient, while no remarkable differences arise for the other variables. In column three we test an alternative proxy for R&D, which yields results comparable with those in column one. Finally, in column four we check for complementarity between hardware and software, including lagged investment in software among the determinants of hardware investment. However, the data do not support the hypothesis that more investment in software command more investment in hardware the year after.9

[Table 2 about here]

In the case of software investment, Table 3 shows that while the set of financial proxies behaves consistently with the assumption, this is not true of the other variables (see column one). The proxy

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8 See the Appendix for a detailed definition of IT capital goods.
9 We also have tried different lags structures, but the results were not encouraging. Education and skill variables did not turn out to be significant for hardware investment as well.
for the (expectation of) domestic demand dynamics is not significant, R&D intensity exerts a
*negative* effect on software investment, while our proxy for comparative advantage seems to play
no role in determining EU patterns of software investment. Using NOS instead of CPE makes the
coefficient of EXP/IMP significant, but worsen that of the interest rate (column two), while testing
a different measure of R&D does not alter the picture (column three). Interestingly, lagged
expenditure in hardware has a positive and significant effect on software investment (column
four).\(^\text{10}\)

[Table 3 about here]

Taken together, Tables 1-3 suggest that:

- the real interest rate has a negative coefficient as expected, and also the share of labour costs is
negatively correlated with IT investment, pointing out to a negative effect of financial tightness on
IT investment. This is true also in the case of hardware and software investment taken separately;

- these results are robust once net operating surplus is included instead of labour costs (of course
NOS has a positive coefficient), but only in the case of aggregate IT and software;

- growing domestic demand, a higher intensity of R&D and comparative advantage enhance the
accumulation of hardware;

- in the case of software investment, only the set of financial proxies behaves consistently with the
theoretical assumptions. R&D intensity displays a negative relation, while the coefficients of
domestic demand and comparative advantage tend to be estimated less precisely. Software
investment does respond positively to lagged hardware accumulation.

An explanation for these results for software investment could be that sectors with a low R&D
intensity tend to invest relatively more in software than in hardware (for instance, this could be the
case of some service sectors such as business services, see for instance, Tomlinson 2001). If this is
the case, a rise in software investment need not be positively correlated with an increase in the share
of R&D expenditure. As for comparative advantage, it is likely that producer-customer relationships

\(^{10}\) Even for software, education and skill variables turn out to be not significant.
prompted by proximity are more relevant for investment in hardware than in software, which could explain the poor performance of EXP/IMP as a RHS variable in Table 3.

6. Conclusions and hints for future research

In this paper, we first analyse the dynamics of IT investment expenditure in 15 European countries from 1992 until 2001 and, by means of a cluster analysis, we draw a picture of IT diffusion in Europe. By clustering the European countries according to their GDP shares of IT spending, we identify three fairly stable groups, labelled fast, medium and slow adopters. We then build an econometric equation of the determinants of IT investment to be estimated with panel data for five European economies over 1980-2001, both considering aggregate IT investment and disaggregating between hardware and software.

Financial conditions, income growth and comparative advantage turn out to affect IT investment, but the determinants of hardware and software investments differ considerably. On the one hand, the real interest rate has a negative coefficient as expected, and also the share of labour costs is negatively correlated with IT investment. This is true also in the case of hardware and software investment taken separately. On the other hand, growing domestic demand, a higher intensity of R&D and comparative advantage enhance the accumulation of hardware, but this is not in general true for software. In the case of R&D intensity, software investment displays a negative relation. Moreover, software investment does respond positively to lagged hardware accumulation, while the converse is not true.

A possible explanation for the peculiar results for software investment is that sectors with a low R&D intensity tend to invest relatively more in software than in hardware (for instance, this could be the case of some service sectors such as business services). If this is the case, a rise in software investment need not be positively correlated with an increase in the share of R&D expenditure. As for comparative advantage, it is likely that producer-customer relationships prompted by proximity are more relevant for investment in hardware than in software. In any case, more research deserves to be made to investigate the specific determinants of investment in different categories of IT goods. There are two other dimensions of the determinants of IT investment where more analysis is strongly require: first, in the direction of obtaining more refined measures of regulatory and competition intensity that can be usefully applied to the case of IT investment; and second, in the direction of testing more refined measures of the education attainments and labour skills required by IT diffusion.
References


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International Monetary Fund, World Economic Outlook October 2001, Washington, DC.


Appendix

The ICT industry (excluding goods-related services)

Manufacturing

30010 Manufacture of office and accounting machinery
30020 Manufacture of computing machinery
31300 Manufacture of insulated wires and cable
32100 Manufacture of electronic valves and tubes and other electronic components
32201 Manufacture of television and radio transmitters
32202 Manufacture of apparatus for line telephony and line telegraphy
32203 Repairing of television and radio transmitters and apparatus for line telephony and line telegraphy
32300 Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods
33201 Manufacture of instruments and appliances for measuring
33202 Manufacture of gas water and other liquids meters for measuring, checking, testing
33203 Manufacture of navigational aids, hydrological, geophysical and meteorology instruments
33204 Manufacture of instruments and appliances for other purposes, except industrial process control equipment
33205 Repairing of scientific and precision instruments (optical ones excluded)
33300 Manufacture of industrial process control equipment

Intangible services

64200 Telecommunications
72100 Hardware consultancy
72200 Software consultancy and supply
72300 Data processing
72400 Data base activities
72500 Maintenance and repair of office, accounting and computing machinery
72601 Services of telematics, robotics, computer graphics
72602 Other computer related activities
ICT capital goods

**Hardware**: (30010) manufacture of office and accounting machinery and (30020) manufacture of computing machinery.

**Software**: (72200) Software consultancy and supply; (72300) data processing; (72400) data base activities; (72500) maintenance and repair of office, accounting and computing machinery; (72601) services of telematics, robotics, computer graphics; (72602) other computer related activities.

**Communication equipment**: (32100) manufacture of electronic valves and tubes and other electronic components; (32201) manufacture of television and radio transmitters; (32202) manufacture of apparatus for line telephony and line telegraphy; (32203) repairing of television and radio transmitters and apparatus for line telephony and line telegraphy; (32300) manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods; (33201) manufacture of instruments and appliances for measuring.

**IT sector**: hardware and software sectors

**CT sector**: communication equipment sectors
Chart 1 – Clustering of the countries based on IT/GDP: 1992-2001
Table 1 – Estimation results: IT

<table>
<thead>
<tr>
<th>Variable</th>
<th>LSDV</th>
<th></th>
<th></th>
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<tr>
<td></td>
<td>1°</td>
<td>2°</td>
<td>3°</td>
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<tr>
<td>(Int. Rate)</td>
<td>-0.046</td>
<td><strong>-0.036</strong></td>
<td>-0.043</td>
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<tr>
<td></td>
<td>(0.013)</td>
<td>(0.014)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>(CPE)/(GDP)</td>
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<td>-1.292</td>
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</tr>
<tr>
<td></td>
<td>(0.363)</td>
<td>(0.401)</td>
<td></td>
</tr>
<tr>
<td>(NOS/GDP)</td>
<td><strong>0.496</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.249)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(dlnGDP)</td>
<td>0.006</td>
<td>0.005</td>
<td><strong>0.008</strong></td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>(R&amp;D)/(GDP)</td>
<td>-0.115</td>
<td>0.022</td>
<td><strong>-0.025</strong></td>
</tr>
<tr>
<td></td>
<td>(0.156)</td>
<td>(0.181)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>(EXP)/(IMP)</td>
<td>0.393</td>
<td>0.772</td>
<td>0.478</td>
</tr>
<tr>
<td></td>
<td>(0.147)</td>
<td>(0.174)</td>
<td>(0.150)</td>
</tr>
<tr>
<td>Adj. R sq.</td>
<td>0.882</td>
<td>0.848</td>
<td>0.876</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SSE</td>
<td>0.119</td>
<td>0.134</td>
<td>0.120</td>
</tr>
<tr>
<td>n. obs</td>
<td>74</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>d. of freedom</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

Note: LSDV=Least Squares Dummy Variable; standard errors in parentheses; underlined means significative at 1%; boldface means significative at 5%, italics at 10%.

* In this case, the R&D indicator is the percentage of BERD conducted by the Business Enterprise Sector, and implemented in the “Office machine and computer industry” only. The normalization by GDP does not of course apply in this case.
Table 2 – Estimation results: Hardware

<table>
<thead>
<tr>
<th>Variable</th>
<th>1°</th>
<th>2°</th>
<th>3°</th>
<th>4°</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Int. Rate)</td>
<td>-0.044</td>
<td>-0.040</td>
<td>-0.041</td>
<td>-0.041</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>(CPE)/(GDP)</td>
<td>-0.855</td>
<td>-0.736</td>
<td>-0.631</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.357)</td>
<td>(0.368)</td>
<td>(0.390)</td>
<td></td>
</tr>
<tr>
<td>(NOS/GDP)</td>
<td></td>
<td>0.247</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.224)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(dlnGDP)</td>
<td>0.013</td>
<td>0.012</td>
<td>0.013</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.003)</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>(R&amp;D)/(GDP)</td>
<td>0.339</td>
<td>0.407</td>
<td>0.012*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.153)</td>
<td>(0.163)</td>
<td>(0.006)</td>
<td>0.414</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.162)</td>
<td></td>
</tr>
<tr>
<td>(EXP)/(IMP)</td>
<td>0.426</td>
<td>0.613</td>
<td>0.423</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.144)</td>
<td>(0.157)</td>
<td>(0.145)</td>
<td>0.391</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.146)</td>
<td></td>
</tr>
<tr>
<td>SW_{(T-1)}</td>
<td></td>
<td></td>
<td></td>
<td>0.095</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.069)</td>
</tr>
<tr>
<td>Adj. R sq.</td>
<td>0.902</td>
<td>0.895</td>
<td>0.901</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.903</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSE</td>
<td>0.117</td>
<td>0.121</td>
<td>0.118</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.116</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n. obs</td>
<td>74</td>
<td>74</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. of freedom</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: LSDV=Least Squares Dummy Variable; all IV’s are lagged variables; standard errors in parentheses; underlined means significative at 1%; boldface means significative at 5%, italics at 10%.

* In this case, the R&D indicator is the percentage of GERD (General Expenditure on R&D) conducted by the Business Enterprise Sector. The normalization by GDP does not of course apply in this case.
Table 3 – Estimation results: Software

<table>
<thead>
<tr>
<th>Variable</th>
<th>1°</th>
<th>2°</th>
<th>3°</th>
<th>4°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSDV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Int. Rate)</td>
<td>-0.049 (0.020)</td>
<td>-0.036 (0.022)</td>
<td>-0.034 (0.020)</td>
<td>-0.032 (0.021)</td>
</tr>
<tr>
<td>(CPE)/(GDP)</td>
<td>-2.109 (0.598)</td>
<td></td>
<td></td>
<td>-1.930 (0.583)</td>
</tr>
<tr>
<td>(NOS)/(GDP)</td>
<td></td>
<td>0.963 (0.378)</td>
<td></td>
<td>0.941 (0.337)</td>
</tr>
<tr>
<td>(dlnGDP)</td>
<td>-0.002 (0.006)</td>
<td>-0.005 (0.006)</td>
<td>0.003 (0.006)</td>
<td>-0.006 (0.005)</td>
</tr>
<tr>
<td>(R&amp;D)/(GDP)</td>
<td>-0.725 (0.257)</td>
<td>-0.497 (0.274)</td>
<td>-0.071* (0.016)</td>
<td>-0.923 (0.262)</td>
</tr>
<tr>
<td>(EXP)/(IMP)</td>
<td>0.338 (0.242)</td>
<td>0.907 (0.264)</td>
<td>0.944 (0.238)</td>
<td>0.140 (0.248)</td>
</tr>
<tr>
<td>HW(T-1)</td>
<td></td>
<td></td>
<td>0.413 (0.176)</td>
<td></td>
</tr>
<tr>
<td>Adj. R sq.</td>
<td>0.923</td>
<td>0.917</td>
<td>0.931</td>
<td>0.928</td>
</tr>
<tr>
<td>SSE</td>
<td>0.196</td>
<td>0.204</td>
<td>0.185</td>
<td>0.190</td>
</tr>
<tr>
<td>n. obs</td>
<td>74</td>
<td>74</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>d. of freedom</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

Note: LSDV=Least Squares Dummy Variable; standard errors in parentheses; underlined means significative at 1%; boldface means significative at 5%, italics at 10%.

* In this case, the R&D indicator is the percentage of BERD conducted by the Business Enterprise Sector, and implemented in the “Office machine and computer industry” only. The normalization by GDP does not of course apply in this case.