ICT in a Model of Technology Embedded in Investment

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Executive Summary

This paper studies the effects of ICT technology upon industry productivity in Europe. The analysis uses a panel of data for 4 EU countries and annual data covering a period between 1980 and 2001. We assess the impact on productivity of technology related to ICT investment assets against measures of technology based on broader investment. The results show the importance of distinguishing type of asset and industry. At the same time, measurements of investment in machinery are better to predict changes in productivity.

Key results are:

- ICT investment does not show a consistent effect raising productivity. The size of the parameter on ICT is small.
- A measurement of investment based on all assets does not show a consistently significant effect on productivity
- Stronger links were found between investments in machinery and productivity in both the entire period 1980-2001 and the late period 1990-2001

1 Methodology and Background

1.1 The contribution of ICT to productivity

ICT and the new economy

The term new economy emerges to label two broad recent economic trends. Firstly, the globalisation of business or the spread of capitalism around the world linked to the collapse of socialism, deregulation of trade and capital flows and the greater role that international trade and investment plays in economic policy. Secondly, the manifest revolution in information and communication technologies (ICT). This paper is concerned with the second aspect. In particular, assessing the ways in which the emergence of this new economy has been facilitated by rapid improvements in computer power and connectivity[1].

The contribution of ICT to productivity

The key issues of the new economy are the effects of investment in physical capital, in particular Information and Communication Technologies (ICT), and the contribution to productivity by the increasing use of ICT. As new technologies, new processes and ways of working are adopted into production the number of units produced increases independently from the increases in other inputs. The theory behind the models that we review in this section incorporates ideas about the impact of technological change on labour demand and productivity. Technological change is broadly defined in this study so that it includes new scientific discoveries, electronic inventions and engineering, advances in general. Ideally, ICT technology change will be best described by all the new inventions in a time period but restricted to such products as telecommunication equipment and office machines. Empirical studies of the new economy make the connection between the role of ICT in the production process and the physical goods used in the same process; this is typically ICT capital stock.

Embodiment of technology in investment

The model we study here requires a specific measure to act as a proxy for technological change. Some direct measures are available, such as expenditure on research and development or number of patents. In this study we adopt an indirect measure following the work of Lee et al (1990) and Barker (1998), building on the earlier work of Kaldor (1957, 1961). According to this model technological progress is embodied in the process of capital accumulation as new equipment and machines embody the most up-to-date technology. In this approach the influence of past investments on the current state of technology declines over time[2].

Technological change and labour skills

The successful incorporation of new technology to production requires that the other inputs to production can adapt to new technology. An important aspect of the new economy is the availability of skills in the labour force needed to match the improvement in technology. This is not a study of labour skills and we assume that the skills required to match the new technology are available or that they will adjust over a reasonably short period of time.

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[1] Other aspects of ICT development are decreasing prices if ICT goods, software capital accumulation and the development of the Internet.

[2] These coefficients are estimated in Lee et al (1990) and in Barker (1998). This rate of decline is rather fast, as only 10% of investment in a particular year will have an effect on technology in the next period.

1.2 The Cambridge Econometrics studies

In a study of productivity in Europe, motivated by the suggestion that there has been a strong ICT effect in the US, but not in Europe despite similar investment levels I have found mixed evidence of the new economy (de-Ramon, 2004). The analysis of German and UK data shows that ICT investment is still a relatively small fraction of total investment in most industries. However, the rate of growth of ICT investment has been higher than investment in other assets. The broad trends from the German data are for strong growth in ICT (computer in particular) investment, particularly in service industries. However, it does not seem that the late 1990s in the data stand out from earlier periods.

Different types of investment show different effects

The study looks in detail over the periods 1975-1990 and 1990-2000 to find evidence of a shift in productivity that can be linked to ICT technology[3]. According to the results, ICT technology has hardly any effect on per-worker productivity. The only exception to this were some effects in services, for the late period, in the UK (manufacturing, services and banking) and in Germany (trade & repair). However, stronger links were found between investments in machinery in general and productivity both in the UK and Germany in the late period. These links are particularly strong in manufacturing (at 5% significance) and some effects in services; again trade and repair in Germany and financial services in the UK. Telecommunications assets are significant in Germany in the early period only, where they seem to raise productivity in the services industry and in the overall economy. The study also compares alternative models, from a more traditional ICT-capital-productivity relationship[4] to an ICT-technology approach like in the present study. The effects of alternative ICT-capital indicator on productivity are not strong in the data and the results are overall similar to the ICT-technology approach.

ICT-investment can be a relatively small component

In a separate study de-Ramon and Lewney (2004) present a quantification of several aspects of the introduction of ICT in Europe over the period up to 2020. The work is based around estimating the effects of ICT technology on the demand for products and employment of the model E3ME (Barker 1998). This empirical analysis covers 19 regions of Europe and 40 industries. Scenario results based on this model show that the introduction of ICT technology in the EU in key sectors could have beneficial consequences for economic growth. However, these benefits will be limited by the relatively small importance of ICT investment in overall investment and because ICT has a strong imported component.

Recent technology can be more relevant

In a study for the European Commission DG Economics and Finance analysing economic trends and forecasts to 2005 (Barker et al 2002) a series of alternative specifications of a technology index, similar to the investment based index used here, were implemented. The results broadly indicate that more recent variations of investment have greater significance when explaining a range of variables including productivity and external trade performance. These results confirm the evidence of Lee et al. (1990) that the influence of past investments on the current state of technology declines fast.

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[3] The breakdown serves also to account for the volatility during the period of German re-unification

[4] In this capital is accumulated as in a perpetual inventory index making allowances for the actual services associated to the capital

1.3 Evidence in the US and Europe

The importance of multifactor productivity studies

Many of the new economy empirical studies are concerned with increases in multifactor productivity (MFP), namely the amount of economic growth that cannot be accounted for by the measured inputs to production (such as labour and capital services). Many of these studies report large rises in MFP in the US since 1995, which is typically attributed to the increased ICT investment over the decade.

The neoclassical methodology treats investment in computers simply as investment in a particular type of capital, which is a substitute in the production process for labour and other capital inputs. As the price of computing drops[5], firms respond by increasing investment in computing assets, substituting them for other inputs. If firms manage to produce the same output with a different mix of inputs, or if they increase output by increasing the scale of productive inputs, there is no effect on MFP.

However, in a market that is not in equilibrium the application of ICT is associated with positive new economy externalities; for example improved access to information and others. There may also be improvements in MFP in the industries that use ICT as well as those that produce it. Alternatively, first-mover advantages may allow firms to earn supernormal returns on ICT investment, if technological change opens up opportunities that were not previously available either on grounds of technical feasibility or cost. Nevertheless, all these externalities support the hypothesis of new technology driving productivity.

Like in this study, ICT technology presents unique features that were not present in past technology. The application of ICT technology introduces new features to the organisation of existing industries.

Jorgenson and Stiroh (2000) study US economic growth in the last decade at the industry level using growth accounting[6]. While a substantial portion of the productivity gains can be attributed to technological change in IT equipment, they conclude that a contribution from software and communication equipment can also be observed. Their results indicate that technology is the driving force in the growth resurgence, but productivity growth in the production of ICT is responsible for a large portion of the total factor productivity (TFP)[7] increase in the US. The scale of this contribution reflects the substantial price declines in semi-conductors and high-tech assets that resulted from technological progress.

The relevance of industry level studies

Greenspan (2000) suggests that the top-down nature of growth accounting miss the actual business practices that are driving the productivity gains. It is likely that there are substantial differences across firms and industries, and that gains in one area of the economy may be larger than appears in the aggregate data. Industry studies attempt to determine the impact of ICT in those individual industries that use it intensively. One problem is that measuring output and productivity in services is hard and these industries

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[5] A trend that has been observed over the past 50 years

[6] Their measure of output is gross output rather than value added, to reflect the fact that industry output may be used as intermediate inputs in other industries or the same industry

[7] TFP – total factor productivity, is the aggregate economy level equivalent of industry level MFP.

(eg financial businesses, business services and retail and wholesale trade). In spite of this, estimates of labour productivity at the detailed industry level suggest an acceleration of productivity[8] after 1995.

Broersma and McGuckin (2000) carry out a micro-economic study of the effect of computers on the Dutch retail and trade sectors. This industry is the non-ICT producing sector broadly acknowledged in the literature as having the most potential for growth as a result of ICT investment. Despite a new data set detailing Dutch trade companies the authors give a word of caution in their conclusions as the data availability is generally poor[9]. Another problem with this study is that it only considers the period 1988-1994, hence missing out on the late 1990s which is generally perceived as the main impact period of ICT investment.

The study is based on a balanced data panel of firms from the trade industry. Their model estimates parameters for the changes in product, employment and productivity depending on different types of investment and skills[10]. In summary they find that computer investment does have a positive impact on output and productivity but their results are sensitive to price indices and to comparisons with other forms of capital.

These results support an approach in which certain industries are studied in more detail. We focus here on those sectors that have the potential for productivity improvements from the use of ICT technology.

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[8] In contrast all-industry aggregated studies, such as Gordon (2000 and 2002), find little evidence of the new economy in Europe.

[9] They also warn that the size of the firms studied, often small, might lower the availability of successful stories of ICT adoption in retail and hence affect their results.

[10] Using wages as a proxy

2 The Model

2.1 Investment and productivity

Technology and new investment assets

In a labour demand study of the UK Lee at al (1990) find strong evidence of a linkage between their measure of technology and by industry employment productivity at a roughly disaggregated industrial level. Their analysis involves estimating separate labour demand equations for 41 industries covering manufacturing and services in the UK. Their technology index embodies investment goods of any type and they generally find evidence that technology raises productivity. The technology index puts a heavy weight on new assets while investment in previous periods is rapidly discounted. A similar model was used by Attanasio et al (2000) to study the causality links between investment and growth of per-capita income[11].

Technology as accumulate investment

We follow here Lee et al (1990) specifying a technological index derived from accumulated investment at a constant rate. The idea of the index is that it smoothes out investment as technology changes through the infusion of new equipment and machines. Today's investment will induce an increase in technology but only part of this will have an effect on prices, productivity, etc., while part of the past technology will have an effect too. Lee et al (1990) propose low rates of accumulation of investment; this implies that the technology index is very close to current investment and is like an investment moving average with fast decay in autocorrelation[12]. Such technology index will be close to a perpetual inventory capital measurement where the depreciation is extremely high. A Cambridge Econometrics project for the Directorate General Economics and Finance (2001) studied the consequences of using higher rates of accumulation. This study applies the technology index in a multi-industry analysis and derives productivity from the demand of products and employment. Higher accumulation of investment generates a much smoother measure of technology[13]. The issue of the speed of adaptation of new technology is relevant to decide the rate of accumulation of investment to generate a proxy of the technology input to production.

In the present approach we apply this technology model to explain the rate of change in labour productivity. As in Lee et al (1990) we maintain a low rate of accumulation of investment to generate the proxy of technology. The specification experiments with a number of models of the following family:

$$yp_{it} = a_i + \sum_{s=1}^{p} a_s yp_{i,t-s} + \sum_{s=0}^{q} b_s k_{i,t-s} + e_{it}$$

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[11] This is macro-economic study using a panel of countries to link long-term economic growth with the rate of investment. They find causal evidence from investment to growth and vice versa. Their study does not make any special allowances for a theory of technology driven by investment; therefore they do not try representing technology in their model.

[12] If investment is not serially correlated the technology index will have little serial correlation.

[13] In this study the technology index is an AR(1) process similar to capital accumulation by perpetual inventory, but rescaled at each accumulation period to the level of current investment.

Here *yp* is productivity change based on annual data for each industry and country (indexed by *i*), *k* represents investment growth in three different types of assets: office machines and telecommunication technology, machinery and total. The parameters a_i represent a specific effect for each group. The model above was fitted to each of four industries and for Germany, France, the Netherlands and the UK.

2.2 Model options

Model comparisons

The purpose of this study is to analyse the different specifications of the technology driven productivity model above. This is not a model comparison exercise and we do not test the present theory against alternatives. Nevertheless, previous studies suggest that the present approach performs better given the data used, countries and industries, and the period considered[14].

Alternative measures of investment

However, several variations of the model have been tested, using different lag lengths, three types of investment, different time periods and groups of countries. These variations seek to test the robustness of the results and to explore different dimension of the technology-productivity link. Given some unavoidable constraints, such as early data not available and the German re-unification in the early 1990s, the model above cannot be estimated in such a general way as described in the formula above. For this reason the different approaches will test a reduced form, where only one type of asset is tested at a time or the number of lags in time-series analysis is limited.

Choice of periods

Empirical studies of the new economy attempt to link the sustained increase in productivity, in the second half of the 1990s, to the huge increase in ICT investment over the period, and the consequent increase of capital per worker (capital deepening). Most empirical studies consider relatively short periods of time, typically comparing 1973-1995 against the economic expansion of the late 1990s. In the present study the time periods available are also relatively short and we also compare the pre and post 1990 periods.

[14] See for example de-Ramon (2004)

3 Results

3.1 Model details and data sources

Data issues

The models described earlier in section 2 were estimated over a panel of annual data covering Germany, France, the Netherlands and the UK. All the models were fitted to the four industry groups: mechanical engineering, automotive industry, retail and wholesale trade and banking. The detailed industry description is shown in Table 3.1 below. The industry groups are defined according to NACE Rev. 3 1990 classification, using also two digits of ISIC classification in some cases (see Table 3.1 below). Such a choice is intended to make it easier comparing these results with other industry studies. Moreover, data measured at a medium level of aggregation, like annual industrial output, GVA or employment, is generally classified following NACE Rev. 3.

TABLE 3.1. DETAILED DESCRIPTION OF INDUSTRIES

Mechanical Engineering	ISIC : 29	NACE DK
Automotive Engineering	ISIC : 34	NACE DM (part)
Trade & Repair	ISIC : 50 to 52	NACE G
Credit Institutions	ISIC : 65	NACE J (part)

Three groups of assets were tested in the econometric estimation below: investment in computers and telecommunication, investment in general machinery and investment in all products. These three groups of assets were also defined in terms of their corresponding NACE classification.

The data was taken from four main sources: E3ME industrial database, Eurostat Breakdowns, OECD Stan industry database and Groningen Growth and Development Centre (GGDC).

Choice of time periods

We use four periods for the analysis in different panels:

- Germany early 1980-1989, West Germany pre-unification;
- Germany late 1994-2001, Germany post-unification
- Other countries early 1980-1989
- Other countries late 1990-2001

These four periods were chosen after consideration of the degrees of freedom and other data constraints. In addition, these time periods allowed us to make comparisons between all the countries, including Germany, with a relatively similar number of observation and in similar cycles.

Econometric methodology

All models were estimated in differences by instrumental variables and generalised method of moments (GMM)[15]. Several different lags of the dependent and explanatory

[15] We used the DPD package of Ox, Doornik et al (2002).

variables were attempted for each equation. On doing this we generally kept variables that were significant at the 10% level. In order to keep valid equation tests, we add the lag of productivity to the models where all investment effects have been dropped.

Choice of instruments

The choice of instruments attempts to get the most efficient estimation given the short-time span of the series. This means that the instruments run from one lag period backwards and as long as it is possible given the starting point of the data. In addition to Sargan tests, for over-identifying restrictions, we run additional regression with shorter-time instruments having similar results.

3.2 Estimation results

Table 3.2 below summarises the results for the GMM regressions on the three assets under study. A number of tests were performed on the adequacy of results. In particular Sargan tests show that no over-identifying restrictions have been detected in the regression. The assumption of no serial correlation of the residuals is essential for the consistency of results; these are in general acceptable and are show in detail in appendix A1.

TABLE 3.2 REGRESSION SUMMARY RESULTS

Period	**Asset**	**Countries**	**0 lags**	**1 lag**	**2 lags**
1980-2000	ICT	All 4	*	*	*
1990-2000	ICT	All 4	–	–	–
1980-2000	ICT	UK-DE	–	*	–
1990-2000	ICT	UK-DE	–	–	–
1980-2000	Machinery	UK-DE	**	**	**
1990-2000	Machinery	UK-DE	**	**	**
1980-2000	All assets	All 4	–	–	–
1990-2000	All assets	All 4	*	*	*

Note(s) : '–' means no effect was detected; '*' means a 5% significant effect was estimated and '**' means a 1% significant effect was detected. See also notes for Table B1.21 in Appendix B.
Each row of the table summarises the results obtained by GMM regressions for the indicated industry period and group of countries, with productivity measured using employment headcount and investment measured using harmonised prices. The full results are in Tables A1.1 to A3… in Appendix A.

3.3 Investment in all assets

The regression in tables 3.3 and 3.4 show the detailed results for a selected model using investment in all assets. In these all the less significant lags of productivity and investment have been dropped to illustrate both the net effect of investment and the group effect for the data.

TABLE 3.3 ALL ASSETS AND FIXED EFFECTS

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	-0.1008	0.0554	-1.82	[0.0720]
dz	0.8147	0.4366	1.87	[0.0650]
G FR ME	0.0293	0.0049	5.94	[0.0000]
G FR AU	-0.0204	0.0068	-3.01	[0.0030]
G FR RE	0.0121	0.0054	2.25	[0.0260]
G FR FI	0.1001	0.0070	14.40	[0.0000]
G NL ME	0.0287	0.0070	4.08	[0.0000]
G NL AU	-0.1495	0.0095	-15.70	[0.0000]
G NL RE	0.0729	0.0152	4.81	[0.0000]
G NL FI	0.0608	0.0083	7.33	[0.0000]
G UK ME	0.0494	0.0087	5.71	[0.0000]
G UK AU	0.0389	0.0015	26.90	[0.0000]
G UK RE	0.0221	0.0059	3.72	[0.0000]
G UK FI	0.0367	0.0010	36.40	[0.0000]
G DE ME	0.0561	0.0028	19.80	[0.0000]
G DE AU	0.0596	0.0043	13.80	[0.0000]
G DE RE	0.0097	0.0044	2.21	[0.0290]
G DE FI	-0.0637	0.0044	-14.40	[0.0000]
Sigma		0.1748		
RSS		3.3612		
TSS		3.9410		
No. of parameters		18		
No. of observations		128		
Wald (joint): Chi^2(2) =		7.369	[0.025]	*
Wald (dummy): Chi^2(16) =		397	[0.000]	**
Sargan test: Chi^2(130) =		107.4	[0.926]	
AR(1) test: N(0,1) =		-0.9512	[0.341]	
AR(2) test: N(0,1) =		-1.432	[0.152]	
AR(3) test: N(0,1) =		-1.513	[0.130]	
AR(4) test: N(0,1) =		-1.383	[0.167]	

Note(s): Within groups transformation used (deviation from individual means). Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3). Other level instruments are Gmm(dz,1,99) and Gmm(dy,1,99). No time dummies. Number of individuals 16 (derived from year). Longest time series 9 observations [1993 - 2001]. Shortest time series 5 observations (unbalanced panel)

Table 3.3 above shows the detailed group effects. We see that some of these dummies are consistently high according to the groups. Only the UK shows consistent growth in productivity independent of the industrial sector and so does the Netherlands with the exception of the automotive industry. On the other hand, Germany and France are not consistently growing in all sectors. From the industry point of view, only mechanical engineering sees consistently rising productivity while retail shows productivity growth to a lower extent and more variable. Financial services are particularly high in France and the Netherlands but not in Germany.

TABLE 3.4 ALL ASSETS AND WITHIN REGRESSION

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	-0.1015	0.0803	-1.260	[0.2090]
Dz	0.8014	0.4285	1.870	[0.0640]
dz(-1)	0.0137	0.4027	0.034	[0.9730]
Sigma		0.1748		
RSS		3.3612		
TSS		3.9410		
No. of parameters		18		
No. of observations		128		
Wald (joint): Chi^2(2) =		7.369	[0.025]	*
Wald (dummy): Chi^2(16) =		397	[0.000]	**
Sargan test: Chi^2(130) =		107.4	[0.926]	
AR(1) test: N(0,1) =		-0.9512	[0.341]	
AR(2) test: N(0,1) =		-1.432	[0.152]	
AR(3) test: N(0,1) =		-1.513	[0.130]	
AR(4) test: N(0,1) =		-1.383	[0.167]	

Note(s): Within groups transformation used (deviation from individual means). Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3). Other level instruments are Gmm(dz,1,99) and Gmm(dy,1,99). No time dummies. Number of individuals 16 (derived from year). Longest time series 9 observations [1993 - 2001]. Shortest time series 5 observations (unbalanced panel)

Table 3.4 show the within regression results with an important effect of investment on productivity. As a general conclusion a 1% increase in technology (investment) leads roughly to a ¾% increase in productivity.

3.4 Results for investment in machinery

The results for machinery investment are presented in Table 3.5. The effects of machinery investment in productivity were consistently significant in all the regression performed. In the results shown here all the non-significant lags of the dependent variable have been deleted from the regression. This has been done to ensure that the dynamics of the process are properly captured in the regression and that the results are reliable. The parameter on investment here implies that a 1% increase in machinery investment will produce an increase of around % in productivity. No additional lags of investment appear to be significant in this regression although the dynamics of the process appear through lag values of the dependent variable.

TABLE 3.5 REGRESSION RESULTS FOR INVESTMENT IN MACHINERY

	Coefficient	Std.Error	t-value	t-prob
dy(-3)	-0.1470	0.0568	-2.590	0.011
dz	0.7582	0.0944	8.03	0.000
Constant	-0.0227	0.0122	-1.860	0.065
Sigma		0.0959		
RSS		1.0755		
TSS		2.1334		
No. of parameters		3		
No. of observations		120		
Wald (joint): Chi^2(2) =		75.680	[0.000]	**
Wald (dummy): Chi^2(16) =		3.470	[0.063]	
Sargan test: Chi^2(130) =		106.0	[0.777]	
AR(1) test: N(0,1) =		0.792	[0.428]	
AR(2) test: N(0,1) =		-0.329	[0.742]	
AR(3) test: N(0,1) =		-1.276	[0.202]	
AR(4) test: N(0,1) =		1.357	[0.175]	

Note(s): Within groups transformation used (deviation from individual means). Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3). Other level instruments are Gmm(dz,1,3) and Gmm(dy,1,3). No time dummies. Number of individuals 8 (derived from year). Longest time series 19 observations [1983 - 2001]. Shortest time series 11 observations (unbalanced panel)

4 Conclusions and Interpretation of Results

[To be added]

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Appendix A.

A.1 Detailed results for ICT investment

The following tables show the results for the model using ICT investment only and without lags of investment. Table 3.3 to 3.5 of section 3 summarises other results.

Table 3.5a: GMM for ICT investment (period 1980-2000)

	Coefficient	**Std.Error**	**t-value**	**t-prob**
dy(-1)	0.0715	0.0653	1.09	0.28
dz	0.7722	0.0807	9.57	0.00
Constant	-0.0270	0.0101	-2.68	0.01

Sigma	0.0977	sigma^2	0.0095
RSS	1.1160	TSS	2.1334
no. of observations	120	no. of parameters	3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,3) Gmm(dy,1,3)

Constant: yes time dummies: 0
Number of individuals 8 (derived from year)
Longest time series 19 [1983 - 2001]
Shortest time series 11 (unbalanced panel)

Wald (joint): Chi^2(2) = 93.15 [0.000] **
Wald (dummy): Chi^2(1) = 7.160 [0.007] **
Sargan test: Chi^2(118) = 106.3 [0.771]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

Table 3.5b: GMM for ICT investment (period 1990-2000)

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	-0.0067	0.0931	-0.07	0.94
Dz	0.7710	0.1172	6.58	0.00
Constant	-0.0164	0.0166	-0.99	0.33

Sigma	0.1091	sigma^2	0.0119
RSS	0.5829	TSS	1.1254
no. of observations	52	no. of parameters	3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,3) Gmm(dy,1,3)

Constant: yes time dummies: 0
number of individuals 8 (derived from year)
longest time series 9 [1993 - 2001]
Shortest time series 4 (unbalanced panel)

Wald (joint): Chi^2(2) = 43.27 [0.000] **
Wald (dummy): Chi^2(1) = 0.9727 [0.324]
Sargan test: Chi^2(58) = 45.00 [0.894]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

Table 2.5a: GMM for ICT investment (period 1980-2000)

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	0.0382	0.1068	0.36	0.72
dz	0.0433	0.0416	1.04	0.30
Constant	0.0149	0.0146	1.02	0.31

sigma 0.1404 sigma^2 0.0197
RSS 1.9112 TSS 1.9480
no. of observations 100 no. of parameters 3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,99) Gmm(dy,1,99)

constant: yes time dummies: 0
number of individuals 8 (derived from year)
longest time series 16 [1985 - 2000]
shortest time series 9 (unbalanced panel)

Wald (joint): Chi^2(2) = 1.865 [0.393]
Wald (dummy): Chi^2(1) = 1.042 [0.307]
Sargan test: Chi^2(340) = 97.00 [1.000]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

Table 2.5b: GMM for ICT investment (period 1990-2000)

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	-0.0631	0.1616	-0.39	0.70
dz	0.0347	0.0550	0.63	0.53
Constant	0.0254	0.0237	1.07	0.29

sigma	0.1570	sigma^2	0.0247
RSS	1.1098	TSS	1.1196
no. of observations	48	no. of parameters	3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,99) Gmm(dy,1,99)

constant: yes time dummies: 0
number of individuals 8 (derived from year)
longest time series 8 [1993 - 2000]
shortest time series 4 (unbalanced panel)

Wald (joint): Chi^2(2) = 0.4008 [0.818]
Wald (dummy): Chi^2(1) = 1.144 [0.285]
Sargan test: Chi^2(108) = 45.00 [1.000]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

Table 2.5c: GMM for ICT investment (period 1980-2000)

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	0.1103	0.0645	1.71	0.09
dz	0.0647	0.0273	2.37	0.02
Constant	0.0214	0.0135	1.58	0.12

sigma 0.1951 sigma^2 0.0381
RSS 8.5629 TSS 8.9298
no. of observations 228 no. of parameters 3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,99) Gmm(dy,1,99)

constant: yes time dummies: 0
number of individuals 16 (derived from year)
longest time series 16 [1985 - 2000]
shortest time series 9 (unbalanced panel)

Wald (joint): Chi^2(2) = 8.931 [0.012] *
Wald (dummy): Chi^2(1) = 2.488 [0.115]
Sargan test: Chi^2(340) = 186.0 [1.000]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

Table 2.5d: GMM for ICT investment (period 1990-2000)

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	-0.0018	0.0900	-0.02	0.98
dz	0.0347	0.0324	1.07	0.29
Constant	0.0146	0.0188	0.78	0.44

sigma	0.1868	sigma^2	0.0349
RSS	3.8042	TSS	3.8712
no. of observations	112	no. of parameters	3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,99) Gmm(dy,1,99)

constant: yes time dummies: 0
number of individuals 16 (derived from year)
longest time series 8 [1993 - 2000]
shortest time series 4 (unbalanced panel)

Wald (joint): Chi^2(2) = 1.149 [0.563]
Wald (dummy): Chi^2(1) = 0.6077 [0.436]
Sargan test: Chi^2(108) = 104.7 [0.572]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

Table 1.5a: GMM for ICT investment (period 1980-2000)

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	0.0752	0.0635	1.18	0.24
dz	-0.2626	0.1873	-1.40	0.16
Constant	0.0283	0.0118	2.39	0.02

sigma 0.1886 sigma^2 0.0356
RSS 9.1412 TSS 9.3225
no. of observations 260 no. of parameters 3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,99) Gmm(dy,1,99)

constant: yes time dummies: 0
number of individuals 16 (derived from year)
longest time series 18 [1984 - 2001]
shortest time series 11 (unbalanced panel)

Wald (joint): Chi^2(2) = 4.669 [0.097]
Wald (dummy): Chi^2(1) = 5.725 [0.017] *
Sargan test: Chi^2(418) = 246.0 [1.000]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

Table 1.5b: GMM for ICT investment (period 1990-2000)

	Coefficient	Std.Error	t-value	t-prob
dy(-1)	-0.0219	0.0825	-0.27	0.79
dz	0.8196	0.3238	2.53	0.01
Constant	0.0215	0.0154	1.39	0.17

sigma	0.1737	sigma^2	0.0302
RSS	3.7693	TSS	3.9410
no. of observations	128	no. of parameters	3

Transformation used: none
Transformed instruments: dz(-1) dz(-2) dz(-3) dy(-1) dy(-2) dy(-3)
Level instruments: Dummies Gmm(dz,1,99) Gmm(dy,1,99)

constant: yes time dummies: 0
number of individuals 16 (derived from year)
longest time series 9 [1993 - 2001]
shortest time series 5 (unbalanced panel)

Wald (joint): Chi^2(2) = 6.408 [0.041] *
Wald (dummy): Chi^2(1) = 1.943 [0.163]
Sargan test: Chi^2(130) = 116.6 [0.794]

Notes: dy is % change in productivity per worker. dz is % change in investment. Model has been estimated by GMM.

A.2 Data issues

[To be completed]