SUSTAINABLE DEVELOPMENT AND INVESTMENT IN INFORMATION TECHNOLOGIES
A Socio-Economic Analysis

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Abstract: The output of investments in Information Systems and Technologies (IST) has been a topic of debate among the IST research community. The “Productivity Paradox of IST Investments” sustains that the investment in IST does not increase productivity. Some researchers showed that developed countries have been having a rather stable and sometimes declining economic growth despite their efforts in Research and Development (R&D). Other researchers argue that there is sound evidence that investments in IST are having impacts on the productivity and competitiveness of countries. This paper analyses the relationship between IST and R&D investments and the global development of countries (not only productivity of countries) using economic, demographic and literacy independent variables that explain global development. The objective is to research whether R&D and IST investments are critical to the productivity and to global development of the countries. Working at a country level, the research used sixteen socio-economic variables during a period of five years (1995-1999). The research methodology included causal forecast, cluster analysis, factor analysis, discriminant analysis and regression analysis. The conclusion confirms the correlation between the Gross National Product (GNP) and R&D and IST investments. The variables illiteracy rate, life expectancy at birth, Software investment as percentage of GNP and number of patents per 1000 inhabitants can explain the development of a country.

1 INTRODUCTION

Research on the relationship between technology and economic growth started long ago and has been studied by several authors. Arrow (1962), on the other hand, suggested that endogenizing the change in technology, the long-term economic growth depends of population growth. Uzawa (1965), Phelps (1966), Ackoff (1967), Conlisk (1967,1969) and Shell (1967) developed studies in the area of technological growth and development of new technologies. Castells (1997) showed that there is a relationship between the demographic position and the development of the country/area. More recently, Romer (1990), Grossmann (1991), Allen (1997), Pereira (2004) and Tavares (2002), all share the idea that persistent investment in new information technologies conducts to continuous economic growth.

The debate on the productivity paradox of IST investments has several justifications. Jones (1995) showed that the number of researchers working in R&D (generally accepted as an indicator of the state of technology) in developed countries has increased substantially over the post-war period, while the economic growth has hardly changed. He tried to explain the contrast between the state of technology and the economic growth, holding that the movement of other variables, different from the state

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of technology, affected the economic growth permanently and suggested that continuous policy measures that probably should have permanent effects on economic growth do not have.

Another well-known author of the productivity paradox of IST investments, Paul Strassmann (1997), indicates that productivity of a country or a company, must be the result of a good economic and financial strategy because economic figures are more important then the technical decisions when it comes to invest in IST. Only this way, this investment can be profitable and therefore contribute to productivity growth. The market pressure for higher productivity drives decision makers to big investments in IST, sometimes without an objective, quantitative knowledge of the markets and strategic positioning. Other authors used a micro-economic approach to study this question (Alpar and Kim,1997).

Several authors and researchers indicate explanations to these findings:

a) R&D statistics do not show all efforts attributed to the technological progress (mainly the efforts from SME´s), Kraemer and Deadrick (1996);
b) In order to achieve full use of technologies there has to be both a change in the organisational structure and the development of complementary technologies (David, 1990);
c) Investments in IST have been directed to product differentiation and less to effective innovation, increasing costumers welfare but not economic growth (Soete, 1996;Young, 1998);
d) Changes in the economy induces changes in the investment of companies and in consumer preferences (Kurdas,1994): when the economy grows both companies and consumers spend a lot on a wide variety of products and services. In the opposite scenario, real interest rates rises, consumers tend to spend on essential products while companies discard their risky efforts in R&D and IST and invest in the existing products. During this period, companies tend to choose the self-financing option instead of looking up for funding in the financial market (Kurdas, 1994).

The new technologies are used to create more flexibility in the internal processes and empower the workers (Alpar and Kim, 1991; Baily and Gordon,1998; Laudon, 1974, 1986; Barua et al 1995). The so-called Information and Communication Technologies cannot be analysed separately but integrated with the surrounding environment, including the impact in the business areas and the relations between those areas (Young, 1998). There are activities within the organisation that do not create value directly (administration, HR management, R&D, for instance) but are essential to the well functioning of the organisation since they support, complement and empower primary activities (Porter, 1985).

Technology is traditionally used to transform existing activities improving the efficiency of the processes and the time of diffusion is probably not enough to get the real output generated by IST investments (David, 1990; Dewan, et al, 1992; Devarej, and Mohli, 2003; Wilcocks and Lester, 1999).

The type of methodology used to understand the impact of IST investments on organisations is sometimes not adequate (Allen, 1997; Brynjolfsson and Hitt, 1999; Barua et al, 1991; Mckeen et all, 1997; Nissen et al, 1998; Orlikowski, 1996) this discussion is still an up-to-date research topic (Bauker and Kauffman, 2004).

The main motivation of this research is to help to determine an answer to the following question: is the investment in IST and in R&D a relevant factor for the sustainable development of the countries? The next chapter will present the hypotheses and the methodology to understand this relationship.

2 HYPOTHESIS

The previous debate contributed to the generation of the following hypothesis of this research:

H1: The investments in R&D and in IST are correlated with the global level of development of the countries. The confirmation of this hypothesis implies that higher investments in R&D and IST lead to a higher global development of a country.

These hypotheses can help to find the answer to the following two objectives:

- Understand the relationship between technology, sustainable development and productivity of the countries.
- Study the impact of R&D effort on the global development and productivity of the countries.

3 METHODOLOGY

The methodology used in this research includes causal forecast, cluster analysis, factor analysis, discriminate analysis, regression analysis and descriptive statistics. The main steps of the methodology are:

a) data gathering about socio-economic and technology variables of countries (OECD, 2002). The following countries are included in this analysis: Portugal, Greece, Spain, Italy, Korea, Ireland, Australia, Finland, Denmark, Holland, France, Belgium, Austria, Canada, Norway, Germany, Switzerland, Sweden, United Kingdom, Japan and USA. The period of analysis is five years (1995-1999).
b) identification of basic relationship between R&D investment and GDP of countries during a longer period of analysis (1981-1999). Correlation between both variables and identification of the time gap between R&D investment and GDP impact for a set of countries using causal forecast analysis.
c) cluster analysis of global development of the countries. The following variables are included in the analysis for each country (OECD, 2002) and this choice was based in previous studies (Alpar and Kim, 1991; Baily and Gordon,1998; Brynjolfsson and Hitt, 1996; Pereira, 2004): GDP per hour worked (United States = 100); Life expectancy (years); GDP per capita (United States = 100); Personal computers per 1,000 inhabitants; Gross domestic expenditure in R&D; Software investment as percentage of GDP; Number of patents per 1000 inhabitants; Share of high-technology investment as percentage of total venture capital of the communications sector; Electric power consumption (kwh per capita); Share of high-technology investment as percentage of total venture capital of information technology sector; Information exportation technology (percentage of manufactured exportation); Illiteracy rate; Share of high-technology investment as percentage of total venture capital of health/biotechnology sector; Internet hosts per 1000 inhabitants; Internet users per 1000 inhabitants; Telecommunications channels per 1000 inhabitants.

The analysis will identify clusters of countries with different levels of development based on the average values in a period of time of all variables in each cluster. The time frame of analysis is five years, although for some variables, due to the lack of data, the period is three years.
d) Discriminant analysis to determine which are the characteristics that distinguish the members of one group from the members of the other group. Knowing the data of a country, we can predict to which cluster it belongs.

The factorial analysis allows to transform a set of original correlated variables in a smaller number of hypothetical variables (Principal Components), not correlated between each other, without loosing significant information from the original variables. Each principal component derives from a linear combination of all original variables.
e) Using variables that reflect the effort in IST and R&D, a regression analysis is designed to correlate them with the GNP. A basic analysis of these three variables is also performed keeping each cluster together, in order to determine if there is, in fact, a relevant difference of investment in IST, in R&D and of GDP between clusters of countries with different global development.

4 ANALYSIS

The following subchapters describe the application of the methodology presented in chapter 3.

4.1 R&D and GDP: Causal Forecast

The first step is to understand the relationship between R&D and GDP across different countries.

Correlation between investment in R&D and GDP in the same year for US, Japan, EU and OECD countries is strong and positive (0,97 for US, 0.99 for Japan, 0.95 for the EU and 0.98 for the OECD countries as we can see in tables 1, 2, 3 and 4, leading us to believe that the investment in R&D depends on the immediate resources generated by the economy.

The causal forecast analysis of GDP using investment in R&D as dependable variable, allowed us to understand that not only R&D is highly influenced by the GDP of each year, but GDP itself is influenced by the investment in R&D in previous years, with different time gaps depending on the research efficiency and capacity of the economy to absorb innovation.

In Japan the effects of R&D in the GDP appear 7 years after the investments. In US, the return of the R&D investment happens after 13 years, in UE after 10 years and in OECD after 11 years. In summary, Japan has a faster return on R&D then the EU, the OECD countries and US, in this order.

4.2 Cluster Analysis

The cluster analysis is the second step. A five-year average of the following statistics are used for this analyses: Electric power consumption, kwh per capita (A), GDP per capita, United States = 100 (B), Information exportation technology (percentage of manufactured exportation) (C), Illiteracy rate (D), Internet users per 1000 inhabitants (E), Life expectancy (F), Personal computers (per 1,000 inhabitants) (G), Share of high-technology

Table 1: Casual Forecast – R&D; GDP – US

	R&D Billions Dollars	GDP	Provisional GDP		Correlation
1981	116	4902		0	0,9748
1982	121	4796		1	0,9677
1983	130	4993		2	0,9448
1984	142	5358		3	0,9094
1985	154	5557		4	0,8751
1986	159	5745		5	0,8493
1987	162	5948		6	0,8631
1988	166	6185		7	0,8880
1989	169	6412		8	0,9059
1990	173	6518		9	0,9294
1991	177	6494		10	0,9519
1992	177	6679		11	0,9627
1993	173	6865		12	0,9777
1994	173	7147	7161	13	0,9948
1995	184	7348	7323	14	0,9901
1996	193	7608	7590	15	0,9779
1997	204	7946	7973		
1998	215	8282	8365		
1999	226	8577	8494		Intercept
2000			8594		3510,12
2001			8719		Slop
2002			8830		31,43
2003			8939		
2004			9062		
2005			9072		
2006			8947		
2007			8946		
2008			9283		
2009			9583		
2010			9928		
2011			10278		
2012			10626		

Data Source: OECD, Analysis by the authors

Table 2: Casual Forecast – R&D; RDP - Japan

	R&D Billions Dollars	GDP	Provisional GDP		Correlation
1981	33	1537		0	0,9933
1982	35	1584		1	0,9527
1983	38	1619		2	0,8934
1984	41	1682		3	0,8569
1985	45	1758		4	0,8669
1986	46	1809		5	0,8971
1987	49	1882		6	0,9397
1988	53	1996	1962	7	0,9462
1989	58	2095	2039	8	0,9129
1990	63	2206	2131	9	0,8673
1991	64	2286	2222	10	0,8365
1992	64	2309	2366	11	0,8840
1993	62	2316	2391	12	0,8783
1994	61	2335	2493	13	0,7977
1995	65	2362	2614	14	0,5949
1996	85	2986	2772		
1997	88	3038	2927		
1998	90	2961	2978		
1999	90	2961	2955		Intercept
2000			2901		912,42
2001			2881		Slop
2002			3009		32,05
2003			3621		
2004			3735		
2005			3797		
2006			3797		

Table 3: Casual Forecast, R&D, GDP – EU

	R&D Billions dollars	GDP	Provisional GDP		Correlation
1983	97	5558		0	0,9539
1984	101	5693		1	0,9301
1985	109	5851		2	0,8967
1986	114	5991		3	0,8604
1987	119	6184		4	0,8250
1988	124	6433		5	0,8032
1989	129	6675		6	0,8117
1990	133	6788		7	0,8598
1991	130	6839		8	0,9170
1992	130	6885		9	0,9788
1993	129	6888	6875	10	0,9903
1994	130	7084	7021	11	0,9827
1995	131	7242	7278	12	0,9853
1996	133	7362	7418	13	0,9924
1997	136	7534	7593	14	0,9898
1998	140	7754	7746		
1999	148	7984	7915		
2000			8028		Intercept
2001			7929		3806,43
2002			7935		Slop
2003			7915		31,73
2004			7920		
2005			7966		
2006			8034		
2007			8109		
2008			8259		
2009			8493		

Table 4: Casual Forecast, R&D, GDP - OCDE

	R&D Billions Dollars	GDP	Provisional GDP		Correlation
1981	261	13236		0	0,9825
1982	273	13239		1	0,9806
1983	287	13621		2	0,9751
1984	309	14240		3	0,9697
1985	336	14751		4	0,9670
1986	347	15223		5	0,9672
1987	360	15785		6	0,9801
1988	374	16468		7	0,9879
1989	390	17087		8	0,9859
1990	403	17531		9	0,9842
1991	417	18623		10	0,9915
1992	419	19042	18900	11	0,9959
1993	415	19291	19376	12	0,9910
1994	418	19900	19960	13	0,9782
1995	442	20947	20819	14	0,9783
1996	462	21593	21905		
1997	482	22332	22333		
1998	500	22921	22843		Intercept
1999	519	23506	23397		8530,64
2000			24023		Slop
2001			24565		39,77
2002			25120		
2003			25190		
2004			25025		
2005			25150		
2006			26107		
2007			26907		
2008			27713		
2009			28401		
2010			29189		

Data Source: OECD, Analysis by the authors

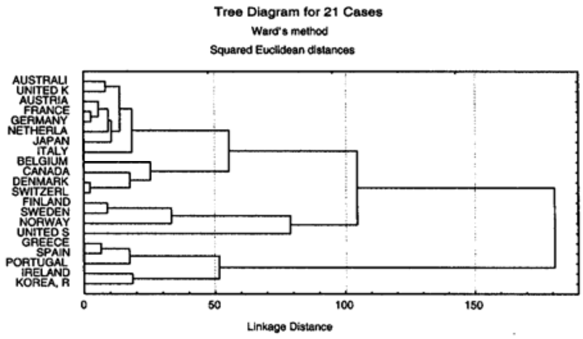


Figure 1: Cluster analysis – Tree Diagram
Data Source: OECD, Analysis by the authors

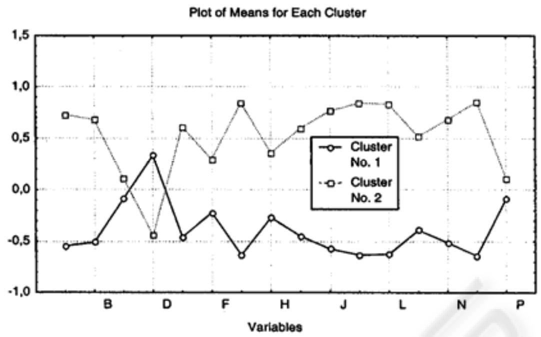


Figure 2: Cluster analysis – Plot of Means

investment as percentage of total venture capital of the communications sector (H), Share of high-technology investment as percentage of total venture capital of information technology sector (I), Share of high-technology investment as percentage of total venture capital for health/biotechnology sector(J), Internet hosts per 1000 inhabitants (K), Telecommunication channels per 1000 inhabitants (L), GDP per hour worked, United States = 100 (M), Number of patents per 1000 inhabitants (N), Software investment as percentage of GDP (O), Gross domestic expenditure in R&D (P).

According to the cluster analysis using the countries mentioned in chapter 3, two clusters of countries emerged. Cluster 1 formed by Greece, Ireland, Korea, Portugal, Spain, with lower average levels on all indicators. Cluster 2 formed by Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan Netherlands, Norway, Sweden, Switzerland, United Kingdom and US with higher average levels in all indicators.

4.3 Discriminant Analysis

The objective of the discriminant analysis is to determine which are the characteristics that distinguish the members of one group from the members of the other. One or more classification functions (multivariable functions) are determined for each cluster, in order to maximise the difference between the groups. After the calculation of the discriminant functions we have to select the ones that are relevant (F value >4 and a p value <5%).

The solution of the discriminant analysis (table 5) showed that variables **Illiteracy rate (D), Life expectancy (F)**, **Software investment as percentage of GDP (O) and Number of patents per 1000 inhabitants (N)** are enough to classify countries as belonging to cluster 1 or to cluster 2.

4.4 Factorial Analysis

To determine which principal components are designed a combination of three conditions should be verified: a) to retain the first order factors until the eigenvalue has a abrupt fall b) to hold the components that explain a significant percentage of the total variance, usually above 70% c) and finally, to exclude the components that have an eigenvalue under one. The rotation of the principal components turns it easier to understand the dimension that each component represents. Four dimensions (components) were identified as table 7 shows.

The analyses of the factor loadings (varimax normalized) showed the following (table 8):

a) the first dimension, explaining 43,98% of the development includes the variables:
   - A) GDP per capita
   - E) Internet users per 1000 inhabitants
   - N) Software investment

b) the second dimension, explaining extra 14,27% of the development includes the variables investment in IT venture capital (H,I).

c) the third dimension, explaining extra 10,18% of the development includes the variables:
   - F) Personal computers per 1000 inhabitants
   - H) Number of patents registed

These variables explain 68,43% of the development of the countries analysed. As we can see, the IST variables are relevant to the development of the countries.

Table 7: Eigenvalues of Principal Components

	Eigenvalue	% Total Variance	Cumulative Eigenvalue	Cumulative %
1	7,0365	43,9782	7,0365	43,9782
2	2,2828	14,2675	9,3193	58,2457
3	1,6289	10,1809	10,9483	**68,4267**
4	1,3282	8,3012	12,2765	76,7279
5	1,0077	6,2981	13,2842	83,0259

Table 8: Factor Loadings (Varimax normalized)

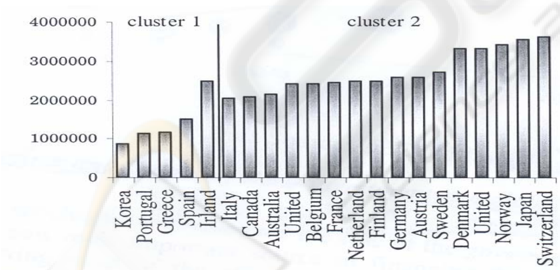
	Principal components (Marked loadings are > 0,700000)			
	Factor 1	Factor 2	Factor 3	Factor 4
A	**0,776441**	0,313813	0,226774	0,217372
B	0,069716	0,365983	0,676391	0,562182
C	-0,06284	0,591424	-0,07712	0,283421
D	-0,08924	-0,18102	-0,44036	-0,63511
E	**0,907184**	-0,06792	0,097383	0,083256
F	0,26646	-0,09935	**0,830615**	0,016621
G	0,420495	0,380441	0,401267	0,644132
H	0,212596	**0,790361**	0,240486	-0,24583
I	0,169086	**0,880694**	-0,05586	0,315324
J	0,118514	0,211158	-0,10157	**0,836123**
K	0,587552	0,387134	0,208871	0,46764
L	0,409986	0,031861	0,286064	**0,776305**
M	0,027451	0,152493	**0,797236**	0,277228
N	**0,808623**	-0,13354	0,022294	0,237529
O	0,277521	0,082643	0,410776	**0,779332**
P	-0,27323	0,614356	0,280418	0,20938
Expl.Var	3,09787	2,79531	2,6494	3,733877
Prp.Totl	0,193617	0,174707	0,165587	0,233367

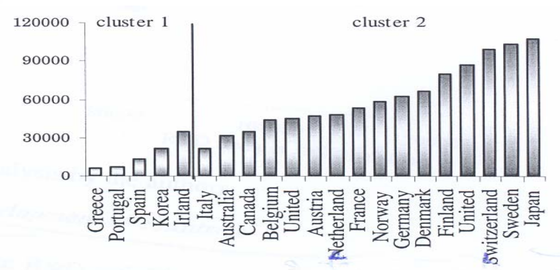
4.5 Regression Analysis

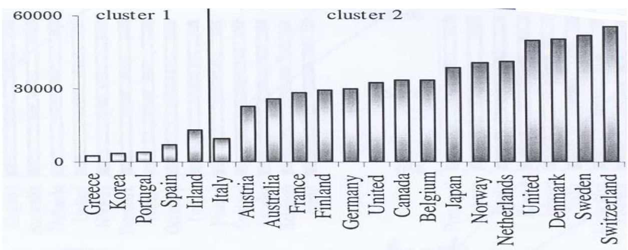
Analysing the GDP per 100 inhabitants, the investment in R&D per 100 inhabitants and the investment in software per 100 inhabitants in 1999, keeping each cluster together, conclusions of the cluster analysis are reinforced.

The GDP per 100 inhabitants is higher among countries of cluster 1 then among countries of cluster 2. The same conclusion follows the analysis of the investment in R&D and in Software per 100 inhabitants.

The correlation between these three variables is high, as displayed in table 9 and shown in figure 6. The Investment in R&D, investment in Software, and the GDP are variables correlated.







Figures 3, 4 and 5 :GDP per 100 inhabitants, Investment in R&D per 100 inhabitants and investment in software per 100 inhabitants in US dollars, indexed to 1995. Data Source: OECD, Analysis by the authors

Table 9: R-squared values

R^2	R&D investment	Software investment
GDP	0,756	0,7742

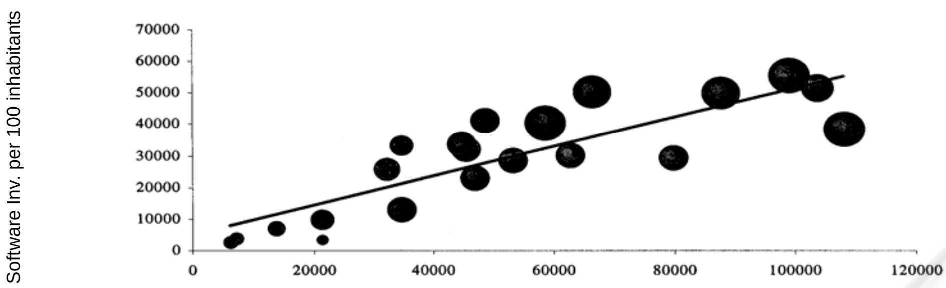


Figure 6: GDP, Investment in software and in R&D per 100 inhabitants in US dollars, 1999, indexed to 1995 (GDP per 100 inhabitants presented in circles)

5 CONCLUSIONS AND FUTURE RESEARCH

The conclusion about the hypothesis formulated is the following:

A stronger effort of investment in IST creates a higher sustained development of a country – is confirmed.

The temporal series analysis shows that there is a causal relationship between investment in R&D and productivity. The cluster analysis (figure2) shows that more developed countries have higher levels of investment in R&D and higher levels of productivity. The discriminant analysis shows that four variables are enough to classify countries according to their maturity of sustained development. From these four variables, one is an indicator of IST (investment in software) and the other a R&D indicator (number of patents).

GDP is positively and strongly correlated with the level of investment in R&D and the level of investment in Software. More developed countries also show better figures of these three variably. Finally, the return, of the financial effort in R&D is not the same for all countries, showing the research the Japan is the country that profits faster its investments (7 years).

However, several developments can improve their work. Future research should increase the time dimension of the analysis. The methodology should be applied to a different set of time periods of seven years, ten and twenty years. The type of variables can also be argued. An important difficulty, already mentioned by previous researchers (Byrd and Marschall, 1997; Gurbaxani and Whang, 1991; Im et all 2001; Devaraj and Kohli, 2003; Pereira, 2004), was to select the significant socio-economic and technological variables. The use of variables describing in a even more robust way the sustainable development of a country, the productivity of a country and the state of the IST and R&D of a country, can complement future analysis.

The contribution of this paper to the field is to confirm the importance of IST investments in the sustainable development of the countries.

To summarise, this research concludes that IST and R&D variables should not be neglected by decision makers to achieve a sustainable development of a country.

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