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An Updated View of the Productivity Paradox in the Early 21st Century

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Abstract

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Information Technologies (ITs) are an inseparable part of modern life and one of the key drivers of economic activity. However, rapidly growing investments in IT, since the 1970s, coincided with poor productivity gains. This problem of the 'productivity paradox' has attracted much academic attention. Using statistical data from 21 developed countries, this paper analyses the trends of productivity paradox from 1995 to 2005 employing three-level methodological approach to assess the productivity. The first level analysis examines macroeconomic indicators (GDP per capita and IT investment growth), the second level considers the internal structure of IT investments, and the third level analyses labour and multi-factor productivity. The findings of the study suggest there is a high positive correlation of IT investments with GDP growth. At the same time labour and multi-factor productivity do not significantly correlate with technology investments.

1 INTRODUCTION

Information and communication technology (ICT) is considered by some as the key factor driving economic growth in present-day industrial societies (Pohjola 2003). Investing in information technology (IT), is therefore regarded as having potential for reducing costs, enhancing productivity, and improving living standards (Murakami 1997). However, there is a body of evidence that IT has not consistently produced positive business results. Since the 1970s productivity growth in almost all of the world economies has slowed, while expenditures on ICT have risen (Rei, 2004). This phenomenon became a key management concern not only for businesses but also for economies as a whole and further became known as the 'productivity paradox'.

During the last two decades, the topic of productivity paradox has been revisited periodically by many researchers (Baily 1986; David 1990; Brynjolfsson and Hitt 1993; Kraemer and Dedrick 1994; Berndt and Malone 1995; Jorgenson and Stiroh 1995; Dewan and Kraemer 1998; Oliner and Sichel 2000). Extensive multi-dimensional (firm-level, industry-level, country-level and cross country) analysis found little evidence that IT significantly increased productivity in the 1970s and 1980s. This could have emerged due mainly to inaccurate productivity measurement, time lags related to technology diffusion, mismanagement issues, and insufficient use of technologies. However, some recent studies of Brynjolfsson and Hitt (1996), Dedrick and Kraemer (2001) and Pilat (2004) present strong evidence that ICT has consistently produced positive results implying that there was no paradox in productivity.

Over the past thirty years the practice of ICT implementation has helped to build a relatively sound empirical base for study. Modern statistical methods have enabled more accurate data. New data processing and collection approaches are able to quantify previously immeasurable impacts of ICT, revealing new opportunities for research.

The most up-to-date productivity paradox research covers the trends only up to 2000 and there are no papers examining the period following the 'Dot-Com boom'. The modern business environment is innovative, rapidly changing (Hammer 1990) and turbulent (Chakravarthy 1997) and variables (IT, labour force, companies, legislation etc.) involved in the 'paradox' have undergone certain transformations (Brynjolfsson and Hitt 2000). Moreover, other structural and technological changes in the world economy, such as the removal of trade barriers, and the growth of the Internet, have given rise to a revolution in global business (Nataraj and Lee 2002) reflected in the productivity of ICT investments.

This paper contributes new findings to the research into the productivity paradox by being the first paper covering 21 developed economies for the period from 1995 to 2005 with the application of three-level methodological approach to assess productivity. The longitudinal nature of the research has updated the existing knowledge and presented new evidence of the paradox after the 'Dot-Com boom'. Findings have added additional value to the understanding of the trends of ICT investments and productivity in modern economy. This paper, while accepting the validity of conventional approaches (quantitative methods) suggests examination and inclusion of qualitative (social) benefits of ICT to assess real productivity gains.

The lack of correlation between labour and multi-factor productivity and ICT investments which was discovered in previous papers is not novel, however, the current research hypothesized that economic, political and technological changes during the last decade could have affected the productivity of ICT, therefore this relationship was re-examined to understand modern trends of the paradox.

The data set was broader and deeper than in previous research, while being consistent with previous papers for the comparability of findings. It is broader due to implementation of three-level methodological approach which has combined different indicators in one study which were used separately or individually in a number of previous papers.

Thus, this research set the goal of ***testing the existence of, and analysing the trends of, the 'productivity paradox' in the first years of 21st century*** and aimed to answer the following research questions:

- What is the effect of IT investments on national productivity at the present time, and is there an 'IT productivity paradox' in modern economies?
- How have ICT and productivity tendencies and the structure of ICT investments changed over time?

2 LITERATURE REVIEW

Since the emergence of the modern computer era in 1945 (Denning 1980), rapid industrial adoption of subsequent technologies in 1960s-80s, popularisation of personal computing and the Internet from 1990s (Oz 2002), IT has become an inseparable part of modern life. Today, the strategic advantages provided by IT seem to be clear and obvious.

However, empirical research of the US economy conducted by (Baily 1986) showed persistent decline in productivity growth in almost all of the major sectors of the economy, while a substantial portion of total industry investments accounted for IT investments. According to (Brynjolfsson and Yang 1996) by 1979, 68% of total investments in US service sectors and 32% in non-service sectors were attributable to IT spending. The same trend was observed in other developed economies. Significant divergence of IT capital expenditures and output growth rates in Japan, UK, Germany and France in 1980s suggested international dimensions (Dewan and Kraemer 1998). Further studies conducted from 1980s to the present days are summarised in Table 1.

Study	Country	Period
Baily (1986)	USA	1955-1979
Oliner and Sichel (1994)	USA	1970-1992
Kraemer and Dedrick (1994)	12 Asia-Pacific countries	1984-1990
Dewan and Kraemer (1998)	17 developed countries	1985-1992
Gera et al. (1999)	USA and Canada	1970s-1990s
Schreyer (2000)	G7 countries	1980-1996
Dewan and Kraemer (2000)	36 developed and developing countries	1985-1993
Oliner and Sichel (2000)	USA	1991-1999
Pohjola (2000)	39 countries	1980-1995
Colecchia and Schreyer (2002)	9 OECD countries	1980-2000
Gust and Marquez (2002)	13 industrial countries	1992-1999
Daveri (2002)	USA and EU	1992-2001
Ark et al.(2002)	EU	1980-2000
Lee and Khatri (2003)	9 South-eastern Asia countries	1992-1999
Vijselaar and Albers (2004)	EU	1990-2001
Becchetti and Adriani (2005)	65–92 Developed and developing countries	1985-1997

Table 1. The summary of country-level studies. Adapted from Wilson (1995), Brynjolfsson and Yang (1996), Dedrick and Kraemer (2001) Papaioannou and Dimelis (2007).

Irrespective of the level of analysis, studies have resulted in ambiguous findings. Initial findings clearly depicted the situation: growing share of service sector accounting for 55% of the economy in 1970s (which reached 75% by 1990) created lots of jobs and spawned tremendous inefficiencies (Roach 1991). At the same time, productivity statistics did not deteriorate for manufacturing as much as for services, where output measurements are notoriously difficult (Griliches 1994). Significant productivity slowdown starting from 1974 has occurred in the United States and in other OECD countries (Griliches 1994; Gera, Gu et al. 1999), most dramatically in Japan, where growth of output per worker exceeding 8% in 1970 fell to about 2.5% by 1985 (Dewan and Kraemer 1998).

Between 1970 and 1990, constant investment in office and computing equipment grew at an annual rate of 18.1% (Yorukoglu 1998). In 1982, US service sector invested $6,000 in IT per white-collar employee (Roach 1991). The share of IT in total producer investment in durable equipment, in current prices, has more than doubled, from about 17% in 1960 to 36% in 1992 (Griliches 1994). However, according to Morrison and Berndt (1990) every dollar spent on computers in the United States at that time, delivered the return of around $0.80, indicating a general overinvestment in IT.

Massive investments in technology during the 1980s simply did not improve productivity. Increased spending on ICT, being a fixed asset, has shifted firms from variable cost to a fixed cost regime without concomitant productivity benefits (Roach 1991). Thus, economists, researching different countries, industries, time spans, indicators and applying various statistical tools and methods could not provide a clear answer to the problem. Most of the results acquired before 1990s, strongly supported the productivity paradox.

The productivity resurgence of the late 1990s initiated new studies attempting to measure the relative importance of IT in productivity gains. Most of these studies came to optimistic results. Economists such as Jorgenson and Bresnahan, and even previous sceptics such as Baily and Sichel, came to the conclusion that the gains from IT were real and probably sustainable (Dedrick and Kraemer 2001). During the period from the mid-1990s to 2000, the macroeconomic performance of the United States was remarkable (Vijselaar and Albers 2004). Oliner and Sichel (2000) explain the rapid growth of GDP in the USA to be driven by a rebound in the growth of labour productivity. They estimate the total contribution from IT doubled, reaching 1.1% and denotes the increased importance of IT in the economy. Moreover, the authors indicate that IT contributed nearly 50% to boost labour productivity from 1.5% to 2.6% at the end of 1990s. Gordon (2000) described this change in the US economy a fundamental transformation, one which is wiping out the 1972-1995 productivity slowdown, along with inflation, the budget deficit, and the business cycle.

The United States has not been alone in benefiting from the positive effects of ICT investments. Colecchia and Schreyer (2002) in their study of nine developed countries indicate the acceleration of positive effects of ICT on economic growth. During the second half of the 1990s, average contribution to economic growth rose from 0.3 to 0.9% per year. By the end of the 1990s the disparities in IT expenditures have simply disappeared. Daveri (2003) indicates the beginning of new millennium, when cross-country differences in IT spending have levelled off to a large extent among six of the G-7 countries, excluding Italy. The American economy is no longer a comparatively bigger IT investor than other countries in the G-7 group (Daveri 2003).

The continuous increase in ICT investments reached its peak by 2000. Anderson et al. (2003) assert that increased investments in ICT were mainly connected with the Year 2000 problem (Y2K) spending and increasing demand and popularity of Enterprise Resource Planning (ERP) and Supply Chain Management (SCM) applications. However, Gordon (2000) argued that the burst in economic performance of the late 1990s was cyclical. He agrees that the aggregate productivity numbers are impressive, but emphasises that the productivity upturn occurred primarily within the IT sector itself which produced a massive productivity spillover affecting aggregate figures.

By the end of 2000, the United States experienced the collapse of the stock market. Technology-led NASDAQ index which peaked 5,132 on March 10, 2000 closed at 1,185 on September 23, 2002. The 18-month decline of stock prices resulted in $4.4 trillion of market value loss, including $1 trillion in Silicon Valley's 150 largest companies (Goldfarb, Kirsch et al. 2006). It was the largest stock market collapse in the history of industrial capitalism (Cassidy 2002), resulting in a sharp decline in technology stocks and the slump in the ICT equipment industry, directly affecting the trend of ICT investments. This brought out pessimists who stated that the 'New Economy' was little more than a brief bubble (Dedrick and Kraemer 2001).

ICT investments resumed their growth from the start of 2002. As economic growth, underpinned by strong performance in the United States, China and Korea started to improve, recovery in the ICT sector spread to Japan and Europe. Labour productivity rose rapidly, mirroring output growth (OECD 2004).

Researchers during these decades also examined a more crucial problem widely discussed in parallel, the reasons underlying the inefficient performance of IT. Economic literature on the issue identified several distinct causes of paradox including cyclical factors (explanation of slowdown in productivity due to the negative stage of business cycle) (Gordon 2000), insufficient or improper use of computer technologies (Oliner and Sichel 1994), sectoral shifts in the economy - the shifts from manufacturing and agriculture to services (Spithoven 2003), energy crises etc. Thus there is divergence of opinion about the causes of the productivity paradox. However, various explanations have been proposed and grouped into four categories by Erik Brynjolfsson (1993):

- ***Measurement Errors or Mismeasurement***. Researchers such as Santos (1991), Griliches (1994), Brynjolfsson and Hitt (1995), Berndt and Malone (1995), Jorgenson and Stiroh (1995), Wyckoff (1995), Lehr and Lichtenberg (1999) pinpointed the mismeasurement problem as one of the core reasons why we can not see the productivity of ICT investments. Measurement errors were related to difficulties of assessing service sector productivity, and inability of national statistics to take into account qualitative contribution of IT. In addition, this was related not only to errors in measuring the output, but also drawbacks in quantifying inputs (Spithoven 2003).
- ***Time lags or Diffusion lags***. First proposed by David (1990) who argued that productivity gains from ICT investments materialise only after certain time and depend significantly on changes in the complementary infrastructure. He also emphasized that there is a critical mass of diffusion and experience after which ICT would produce measurable impact on productivity (Rei 2004).
- ***Mismanagement***. The argument that management were not prepared to take full advantage of disposable technological resources making ineffective decisions which led to great IT project failures directly affecting the productivity of IT investments.

- ***Income Distribution***. IT brings competitive advantage and productivity to certain companies utilising it, while other rivals fail to perform effectively, canceling out improved productivity in aggregate data. That is why the productivity in the scale of the whole economy could not be observed. This reason is partially interconnected with measurement errors in the sense that aggregation of statistics on country level disperses the true value of IT productivity. This has initiated increased interest in firm-level studies. As a result, empirical studies have found positive and excess returns to investments in information technologies (Gurbaxani, Melville et al. 1998).

In the next section of this paper the research method and approach is discussed in detail. The three level methodological approach is presented, and the data source and study period is defined.

3 RESEARCH METHODS

The approach employed for this research combines the techniques used in several previous studies: Spithoven (2003), Dedrick et al. (2003), Saito (2001), Dewan and Kraemer (1998), Brynjolfsson and Hitt (1996), Kraemer and Dedrick (1994) and Baily (1986). A three-level structured framework was adopted for the research (Figure 1). On the first level, the country-level macroeconomic indicators are analysed and compared to ICT investment dynamics. The second level analysis deals with internal structure and trends of ICT investments. The last level analyses productivity-specific indicators: MFP (multi-factor productivity) and labour productivity. The given approach was consistent and aligned with previous studies while overcoming shortfalls of narrow firm-level studies.

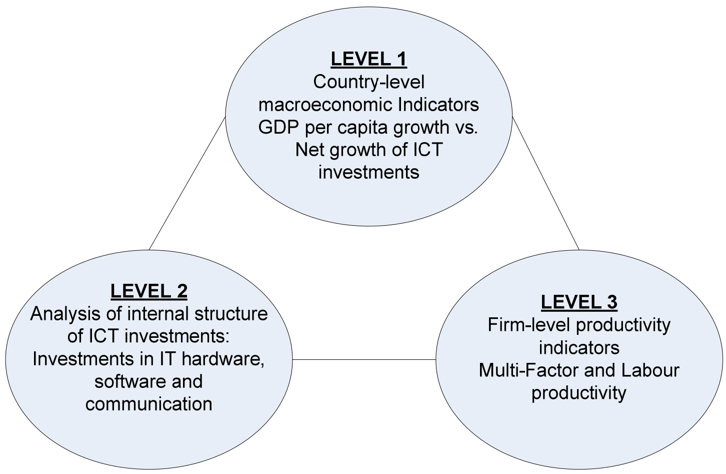

Figure 1. Three-level methodological approach to assess productivity.

The research focuses attention on analysis of statistical data from a selected set of developed countries – 21 leading countries – members of OECD. The choice of leading world economies is not coincidental and based on previous research (Dewan and Kraemer 1998; Daveri 2003; Spithoven 2003). Western economies have pioneered IT alongside an educational system preparing a qualified labour force to use IT systems, which supports the rationale of investigating the group of advanced economies. This minimises the affect of 'time lags' associated with the gap between investments in IT and the time when technologies actually yield productivity gains. The last supporting aspect is the availability of relatively comprehensive and reliable statistical data covering the timescale of the current research.

As the scope of the study embraces twenty leading countries of the world, the data for the research is acquired using secondary sources. Particularly, the fundamental measures of country-level productivity such as Gross Domestic Product (GDP), its dynamics, per capita growth, ICT investments, their share in gross capital formation, employment and labour force productivity statistics

– all acquired from OECD online database and from specialised publications of this organisation. The use of single data source was crucial for accuracy since unmatched input and output statistics could lead to the distortion of final results. This study examines the period from 1995 – 2005.

For the purpose of correct estimates of productivity indicators the real GDP per capita and its growth are used for analysis, being adjusted to inflation and therefore providing more accurate measure of output. For comparability of data among twenty different countries all indicators are presented in US dollars or percentage change in relation to the previous year. In order to give a historical outlook and compare longer-term dynamics, some of the observable data include the periods starting from 1985.

Further analysis includes the study of the internal structure of investments in IT. ICT investments are reviewed in three dimensions: investments in hardware, software and communications equipment, as it is adopted by the OECD.

At the last stage, the research examines more specific indicators such as labour productivity and multi-factor productivity (MFP). Labour productivity is a useful measure: it relates to the single most important factor of production (OECD 2001) and is relatively easy to measure. Also, labour productivity is a key determinant of living standards, measured as per capita income and reflects how efficiently labour is combined with other factors of production (OECD 2001). However, it only partially reflects the productivity in terms of the personal capacities of workers or the intensity of their efforts. For this reason further analysis includes multi-factor productivity which conceptually is a better tool to measure technical change, available in modern statistics. It shows how productively combined inputs (labour and capital) are used to generate gross output[1].

4 FINDINGS

The analysis of 21 developed countries showed that the total amount of investments in ICT has reached nearly 1 trillion US dollars, or approximately 2.6% of cumulative GDP of the given set of countries. The positive growth dynamics of investments, averaging 12.7% per year from 1995 onwards, remained up to the year 2000, when the economies consumed more than 950 billion US dollars in IT investments, exceeding annual growth rate of 14.8% (Figure 2).

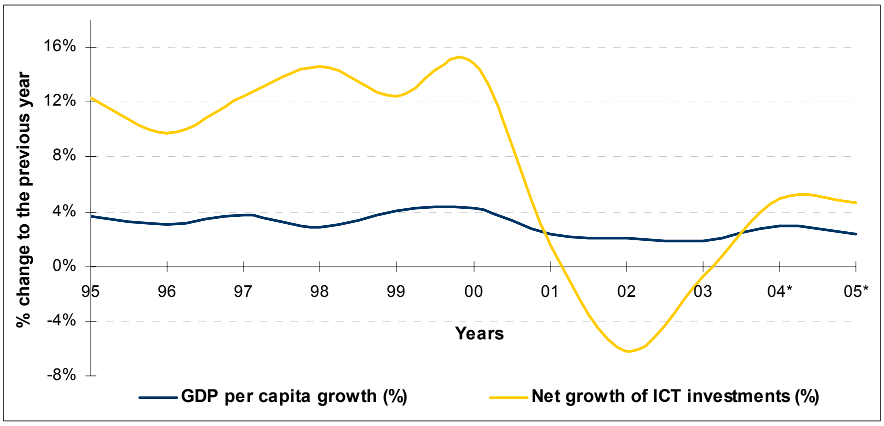

Figure 2. GDP per capita and net ICT investments growth (1995-2005), 21 OECD countries. Source: OECD Online Database 2007, calculations of authors. Note: * - actual or the latest available data.*

Almost half of the total IT spending for countries in the dataset (48%) was attributable to the United States. Among the remaining countries, Korea is the only country where the average share of IT

[1] Since the research used secondary data sources, final calculated MFP values were acquired for the analysis. Detailed calculation methodology is available from OECD Online Productivity Database.

investments for the last 12 years exceeded 4% of gross domestic product. The Scandinavian countries (Sweden, Finland and Denmark), the USA and Australia all invest heavily in ICT.

The economic slowdown experienced by the US at the end of 2001, and later reflected in the global trends, affected the intensity of investment activity, including ICT investments. As a result, ICT investment growth in the following two years, for the first time since the productivity paradox phenomenon was recognised, was negative: -6.2% and -0.7% respectively. In the two years following that, the global economy started to recover. However the growth dynamics of investments remained sluggish, far from the record values of the Dot-Com boom.

Analysis of GDP per capita and net ICT investments growth over the period from 1995 to 2005 reveals very high correlation between these two indicators. The Pearson correlation coefficient (r) measuring the degree to which the variation in one variable is related to the variation in another variable (Malhotra and Birks 2003) equalled 0.846 (significance level = 0.01). This means that the net growth of ICT investments is strongly associated with the growth of output per person. Furthermore, the positive sign of r implies a positive relationship; the higher the net growth in investments, the greater the amount of GDP per capita. This finding confirms the previous results of Gust and Marquez (2002) who also identified the positive relationship of IT expenditures and productivity. At this stage it can be inferred that at least there is a positive relationship between investments in IT and real productivity growth.

The results show that today ICT investments occupy a considerable share in gross fixed capital formation. Particularly, countries such as the United States, Finland, Sweden, United Kingdom and Australia are the most intensive users of IT capital. By 2005, ICT investments in these countries had nearly reached one fourth of all capital expenditures. Even though this indicator is much smaller for countries like Ireland, Norway, Italy, Spain, Greece and Portugal, it exceeds the 10% level of all capital expenditures holding considerable share in production of goods and services.

Internal structural analysis of ICT investment shows that in 1985 hardware expenditures grossed 6% of all investments in the economy or almost half (47.7%) of total ICT investments, while the software proportion was relatively small (3.2% and 25.2% respectively). By 2005 the share of investments in software has considerably increased and reached 42.8%, or 7.3% of the gross fixed capital formation. It is interesting to note that the share of investments in communication equipment remained relatively constant, varying only between 27.1% and 25.7% during the twenty-year time span (Figure 3).

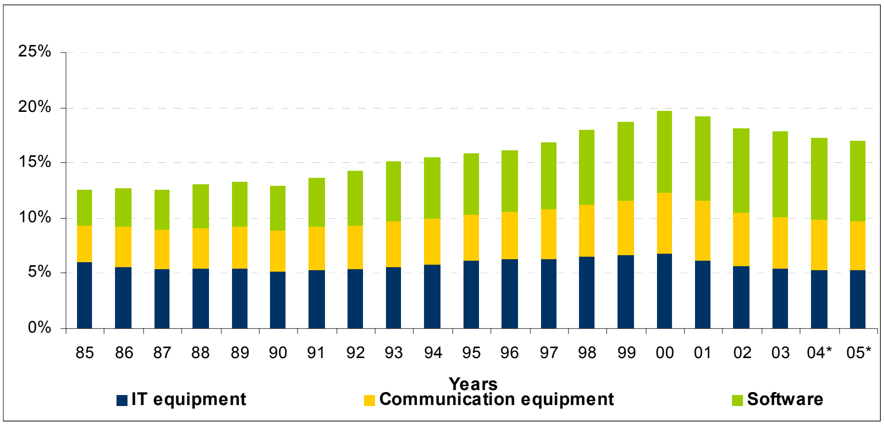

Figure 3. Internal structure of ICT investments (1985-2005), 19 OECD countries. Source: OECD Online Database 2007, calculations of authors. Note: * - actual or the latest available data.*

The higher share of hardware spending in 1980s can partially be explained by the relatively high costs of IT equipment. While the average rate of price change for computer hardware and peripherals was equal to 14.7% a year between 1987-1995, the acceleration in price decline reached 31.2% during 1996-1999 (Gordon 2000). This feature of ever decreasing prices for IT hardware could affect the structure of IT spending. Thus, the distribution of expenditures shifted from a dominating role of hardware to software.

The average labour productivity growth measured as a percentage change from the previous year between 1995 and 2005 constituted 1.6%. The highest rates of growth were demonstrated by Korea and Ireland, where this indicator exceeded 3% a year. Spain exhibited the lowest productivity rates averaging only 0.2% a year. The labour force performance for Italy, New Zealand and the Netherlands was also relatively poor remaining under 1% a year.

Further analysis to test the relationship of average labour productivity growth and average growth rate of ICT investments for 21 countries suggests that there is a certain association between these two variables. The correlation coefficient in this case equalled 0.532[2] suggesting there is a positive relationship. However, the correlation between the labour productivity and ICT investment growth is weaker than in the case of GDP per capita an does not allow us to assert that there is a significant impact of one variable due to the change of the other during the observation period.

The last indicator used for the analysis in this research is the multi-factor productivity (MFP). This is a complex measure of productivity. It is computed as a difference between the rate of change of output (presented as the logarithmic value of annual change of GDP at constant prices for the entire economy) and total production inputs including labour inputs, capital inputs and their cost of shares.

To understand the bigger picture Figure 4 demonstrates average, minimum and maximum values of MFP for 19 developed countries. It can be seen that during the period of study this indicator averaged approximately 1.2%, fluctuating between 0.7 and 2%. The correlation test of MFP and ICT investments growth brought the coefficient equal to 0.565. Even though it is slightly greater than in the case of labour productivity, it does not give sufficient justification to consider high association between two variables.

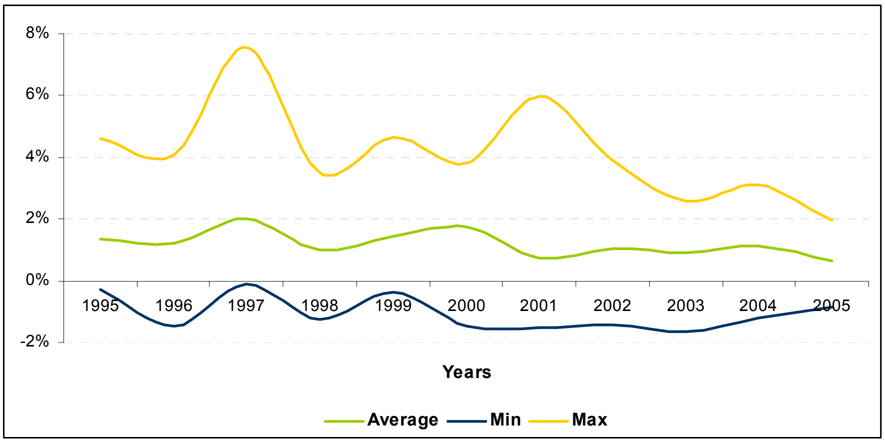

Figure 4. Multi-factor productivity trend (1995-2005). Based on 'harmonised' price indices for ICT capital goods, average of 19 OECD countries in %. Source: OECD Online Database 2007, calculations of authors.

The maximum and minimum values were found to be significantly different implying big differences in MFP between countries. The minimum value always being negative implies that some countries in the dataset were demonstrating decrease in productivity, which can not be noticed in the case of aggregation.

According to the results of the study, three developed countries, Spain, Italy and Denmark, finished the decade starting from 1995 with a nearly zero increase in MFP. Moreover in the case of Spain there was an insignificant negative change in productivity (-0.06%). The top performers are Ireland,

[2] In their study of 13 industrial countries Gust and Marquez (2002) calculated the correlation coefficient between IT expenditures and labour productivity to equal 0.65

Finland, Greece, Sweden and the United States. In general, the countries can be divided into two categories: those which experienced a decline in productivity after the year 2000, and those which were not affected by the global slowdown and continued to improve their returns (MFP) on investments. The later include Japan, the United States, Sweden and Greece.

5 DISCUSSION AND CONCLUSION

The analysis confirms that countries still continue to spend huge amounts of money on IT. The research identified a high correlation between output per capita and ICT investment growth. The average growth of technology investments in developed countries, fluctuating at around 12.6% per year between 1995 and 2000, was reflected in subsequent growth of GDP averaging 3.6%. After the economic decline in 2001-2002, the GDP growth slowed to about 2%. ICT investments account for almost 15% to 25% of the gross fixed capital formation in developed countries, and therefore the contribution of ICT should be rescaled. Rescaled growth varies between 1.9% and 3.2%. In this case the observable total output growth is absolutely in accordance with the growth of ICT spending. Thus, the examination of macroeconomic indicators suggests strong positive correlation between the growth in ICT investments and productivity in national economies. This finding is consistent with the previous results of Kraemer and Dedrick (1994), Dewan and Kraemer (1998) and provides preliminary evidence to challenge the notion of the productivity paradox after 1995.

At the same time this paper suggests there is no significant correlation between investments in IT, labour, and multi-factor productivity. It is important to note that there is a general decreasing trend of average MFP for 19 countries. The trends on national level do not tend to have a certain pattern and look chaotic. The labour productivity indicator also demonstrates highly fluctuating behaviour which is not correlated to ICT investment growth. There were periods (for example 1998) when these two indicators (the growth of investments and labour productivity) were moving in opposite directions. Thus, another inference made from the study is that during the period from 1995 to 2005 the growth in ICT investments was not correlated to the change in labour and multi-factor productivity.

One of the caveats of relatively low rates of MFP growth can be in the assumptions used in its calculation. The MFP, for example, may not take into account the effects of increasing returns to scale and imperfect competition. And if that is the case, the MFP index is subject to measurement errors (Guellec and Potterie 2001).

The findings again lead us to inconclusive results. There is still ambiguity and the answer to the first research question is not clear: GDP per capita rejects the evidence of the paradox while labour productivity and MFP do not. Perhaps, the answer to this 'epic' question most probably cannot be acquired by quantitative research methods and statistical data alone. The measurement problems, including the inability to measure the contribution of ICT, distort the final results of any research. The practice shows that there is a need for a qualitative analysis. The understanding and explanation of the problem may require qualitative study.

Today, new goods and services are produced at a completely new quality level (Guellec and Potterie 2001). Widely used production concepts as TQM (Total Quality Management), JIT (Just-In-Time), CAD (Computer-Aided Design) applications have considerably reduced the cost, design, development and production cycle and at the same time leveraged the quality of products and services to a new unprecedented level. This may include improved customer service, greater precision and performance of equipment with the use of IT. ICT industry has significantly extended the service sector by creating more than seventy new types of services (OECD 2007). The products are more durable, their mean time between failures (MTBF) is longer, and they possess some qualities which were unimaginable in their predecessors (Oz 2005). Further, it is worth considering the contribution of ICT to general knowledge of society. Guellec and Potterie (2001) argue that high investments in technologies, as a part of R&D, enhance the stock of scientific knowledge of the society and its immense indirect results are not integrated in existing measures of GDP. For example, health-related research allows improving length and quality of life, which are not taken into account by any GDP measures.

The research studied 21 developed countries, however some findings are based on the statistics from 19 countries because certain indicators for Norway and Korea are unavailable. Moreover, some indicators such as investments in ICT, their share in grossed fixed capital formation and GDP were not available for some countries for the year 2004 and 2005. In this case, the data for the last available year (mainly 2003 and 2004) was used for calculations. Later research based on actual data may reveal the distortion caused by the extrapolation of indicators for the last two periods considered for the analysis. However, since the study examined aggregate statistics to understand the trends for a large set of countries the deviations are believed to be insignificant to affect the findings of the paper.

Certain limitations were imposed by the research method, particularly the number of productivity indicators. The latest data monitoring methodology of the OECD expanded the number of indicators included in productivity statistics. Higher detail level of statistics may increase the accuracy of findings. However, this data is available for a limited number of countries and covers the period only after 2000. From this perspective, using more input variables is an opportunity for future research.

Finally, we can consider an alternative research design to overcome the shortfalls of previous studies. Most of the research examined the growing presence of IT correlating it with various other indicators to evaluate its impact and productivity. None of this research was able to provide a conclusive answer to the problem of productivity paradox. An alternative approach might be to conduct an analysis of backward effects: assessment of the degree of negative consequences when there is a decrease in ICT utilisation. In this way, the problem is analysed from the perspective of opportunity costs of not acquiring (or investing in) ICT. Practically, it can mean to ask people to do the same tasks which they used to do, but without currently available technological tools (such as computers, printers, mobile phones etc.) and assess their productivity. We can hypothesise that the performance will fall to some degree, implying the crucial role of IT in economy.

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