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The Contribution of ICT Investment to Economic Growth in Poland 1995-2000

FIRST DRAFT

Abstract

There is large evidence on positive impact of information and communication technologies (ICT) on economic growth and productivity in a number of developed countries in the 1990's. There are however no studies, which would estimate the contribution of ICT to growth and productivity in post-communist, transition economies. Data availability, consistency, and trustworthiness have been so far the main obstacles.

This paper makes a first attempt, based on an extended growth accounting framework, at estimating the contribution of investment in ICT to growth in Poland, the largest post-communist economy in Central and Eastern Europe and a EU member in 2004. The paper discusses the challenges of using available data and its impact on the choice of specific methodologies.

The paper shows that ICT investment contributed on average 0.83 of a percentage point or 16% of GDP growth between 1995-2000. The large impact of ICT capital is due to an extraordinary acceleration in ICT investments between 1993-2001 induced by falling prices of ICT products and services and catching-up in ICT-infrastructure development as local firms were taking advantage of business opportunities created by substantial pent-up demand resulting from years of underinvestment before 1989 and high economic growth in the 1990's.

The size of the ICT capital contribution to output growth places Poland very high in the international comparisons, almost on par with countries like the US, Ireland and Finland, the

paragons of the ‘new economy’. The result should however be taken with caution as various measurement caveats apply.

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1 Introduction

In spite of the worldwide economic gloom, the rapid pace of technological progress has not been arrested. The technological revolution in particularly information and communication technologies (ICT), which has contributed to the extraordinary performance of the US economy in the late 1990's (Jorgenson and Stiroh 2001, Oliner and Sichel 2000, Stiroh 2002), has not slowed down. The computing power of microchips, which underlies the rapid progress in productivity of ICT, has kept on doubling every 18 months, as Moore's Law has rightly predicted since 1967. The resulting rapidly falling prices of ICT products and services, their increasing efficiency and quality and a convergence of information and communication technologies kept on enticing businesses to spend on ICT, although indeed the pace of investment has recently markedly slowed down.

The erstwhile notion of a 'new economy' understood as a superior economic structure displaying sustainable and extraordinary increase in growth and productivity growth fueled by the ICT and coupled with low inflation and unemployment has been discarded. It was replaced with a notion of a 'new economy' understood as a host of new economic phenomena resulting from the two concurrent processes: on the one hand globalization, that is on-going deregulation, integration of the global markets for capital, goods, labor, and increased competition, and on the other hand, technological revolution based mostly on general-purpose ICT, which -- while impacting all sectors of the economy -- accelerate productivity and economic growth[1].

This paper will utilize a more narrow definition, where the 'new economy' is defined as an economy characterized by high growth rates in output and productivity fueled by production and use of ICT products and services.

Aside from the USA, the use and/or production of ICT have contributed to an increase in the rate of productivity and economic growth in a number of developed and developing countries in the late 1990's. Among the former, Australia, Sweden, Finland, and Ireland seem to have tapped the 'new economy' to the largest extent (OECD 2001a, Jalava and Pohjola

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[1] For similar definitions see Stiroh (2002b), Pohjola (2001) and De Masi (2001).

2002, Daveri 2002). Among the developing countries, Malaysia, Philippines, Thailand, South Korea, and Taiwan benefited from the production of ICT (IMF 2001).

Yet, there is no evidence that other countries, both developed and developing, were able to take advantage of ICT in order to accelerate their rates of growth and productivity. The lack of macroeconomic impact of the use of ICT on developing countries was confirmed by the results of a comprehensive cross-country empirical study on the returns of IT investment in developed and developing countries (Dewan and Kraemer 2000). The study showed that returns on IT investment are 'positive and significant for developed countries, but not statistically significant for developing countries' (as quoted in Kraemer and Dedrick 2001, p. 262). The estimate of IT output elasticity is 0.057 (positive and significant) for developed countries, but statistically indistinguishable from 0 for developing countries. Pohjola (2001) shows that the relative contribution of IT to GDP growth in developing countries, was less than 2 per cent (China, India, Argentina, Chile, Brazil, Thailand, Venezuela) compared to more than 10 per cent in the US, Finland, Canada, Sweden, and UK. No other studies have found any sizeable contribution of ICT to growth in developing countries.

There are no studies that would estimate the impact of the ICT revolution on output growth and productivity in post-communist, transition economies i.e. transforming from a command economy to a market economy.

Hence, this paper makes a first attempt at estimating the contribution of ICT investment to growth in Poland, the largest post-communist economy in Central and Eastern Europe and soon a member of the EU, for the period of 1995-2000. The paper uses the extended growth accounting methodology. Data for ICT spending is obtained from WITSA (2002) for the years 1993-2001, which in turn is provided by International Data Corporation (IDC). The data on aggregate capital stock, GDP, share of wages in total income is from the national statistical agency.

The structure of the paper is as follows: Section 2 discusses the methodology of the extended growth accounting for the contribution of ICT investment to output growth. Section 3 discusses the application of the methodology for Poland and transition economies and challenges posed by the availability of data. Section 3 presents results of the estimations and compares them with results for developed countries. Section 4 concludes the paper.

2 Accounting for the economic impact of ICT

The methodology of measuring the contribution of ICT to growth and productivity is based on original work by Solow (1957) and Jorgenson and Griliches (1968) and later extended by inter alia Oliner and Sichel (2000) and Jorgenson and Stiroh (2000). Since ICT products and services are both outputs from the ICT industries and inputs into ICT-using industries, ICT can impact economic growth through four major channels[2]:

(i) production of ICT goods and services, which directly contributes to the aggregate value added generated in an economy;

(ii)increase in productivity of production in ICT sector, which contributes to overall productivity in an economy (TFP);

(iii) use of ICT as in input in the production of other goods and services;

(iv) contribution to economy-wide TFP from increase in productivity in non-ICT producing sectors induced by the use of ICT (spillover effects);

To measure the overall impact of ICT on growth, it is best to express the aggregate production function in the following form:

$$Y_t = Y(Y_t^{ICT}, Y_t^0) = A_t F(C_t, K_t, L_t) \qquad (1)$$

where, at any given time t, aggregate value added Y is assumed to consist of ICT goods and services ICT – $Y^{ICT}_{t,}$ as well as of other production Y^0_t. These outputs are produced from aggregate inputs consisting of ICT capital $C_{t,}$, other (i.e. non-ICT) physical capital $K_{t,}$, and labor L_t. TFP (total factor productivity) is here represented in the Hicks neutral or output augmenting form by parameter A.

Assuming that constant returns to scale prevail in production and that all production factors are paid their marginal products, equation (1) can be expressed in the following form:

$$\hat{Y} = w_{ICT}\hat{Y}^{ICT} + w_0\hat{Y}^0 = v_{ICT}\hat{C}_t + v_0\hat{K}_0 + v_L\hat{L} + \hat{A} \qquad (2)$$

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[2] This section is largely based on Jalava and Pohjola (2002).

where symbol ^ indicates the rate of change and the time index t has been suppressed for the simplicity of exposition. The weights w_{ICT} and w_0 denote the nominal output shares of ICT and non-ICT production, respectively. The weights sum to one similarly as the weights v_{ICT}, v_0, and v_L, which represent the nominal shares of ICT capital, non-ICT capital, and labor, respectively.

Due to limited scope of the paper, the author will focus on only one channel through which ICT impacts growth that is through the contribution of ICT capital to output growth (iii). Nonetheless, in a forthcoming paper by the same author it is argued that due to poor availability of data it is quite challenging to estimate the impact of ICT on growth through the remaining three other channels - direct contribution of ICT production to GDP (i), an increase in productivity of production in ICT (ii) and spillover effects of the ICT use (iv).[3]

2.1. Accounting for contribution of ICT investment to output growth

As on the right hand-side of the equation (2) the contribution of ICT investment to output growth can be defined as a sum of contributions from ICT capital ($\hat{C}_t$), non-ICT capital ($\hat{K}_0$) and labor ($\hat{L}$), where weights weights v_{ICT}, v_0, and v_L represent the nominal shares of ICT capital, non-ICT capital, and labor, respectively, and sum to one. Total factor productivity (TFP) is represented in the Hicks neutral or output-augmenting form by parameter A. Symbol ^ indicates the rate of change.

$$\hat{Y} = v_{ICT}\,\hat{C}_t + v_0\hat{K}_0 + v_L\hat{L} + \hat{A} \qquad (3)$$

So far the efforts to calculate the impact of ICT investment on growth in transition economies have failed due to the lack of data on

(i) ICT capital stock and

(ii)income share of ICT in total income.

[3] At this point, it is only possible to make a rough estimate of the contribution of ICT production to output growth in three countries - Czech Republic, Hungary and Slovak Republic – for which the relevant data exist from the OECD (2002) for the period of 1995-2000.

Yet these shortcomings in data can be overcome. The following two subsections present the specific data problems together with methodologies and assumptions, which were used to arrive at final estimates of ICT capital contribution to growth in Poland between 1995 and 2000.

Accounting for ICT capital stock

National statistical offices in postsocialist countries do not provide information about ICT investment. Nor are they providing quality-adjusted price indices for ICT stock or depreciation rates on ICT products. Moreover, only in a few countries national statistics provide estimates of total capital stock in the economy, not to mention more sophisticated data on human capital.

Nonetheless, the lack of data from national statistics can be mitigated by a use of alternative sources of data and a utilization of a number of assumptions.

In the first step to obtain data on ICT investment the author resorted to private data sources on ICT expenditure provided by International Data Corporation (IDC), published in WITSA (2002)[4]. WITSA provides consistent information on total spending on hardware, software and communication equipment between 1993 and 2001 in 51 countries representing 98% of the total global spending. The series include data on eight transition economies: Bulgaria, Czech Republic, Hungary, Poland, Romania, Russia, Slovak Republic, and Slovenia.

ICT spending as a share of GDP in Poland and seven other transition countries based on WITSA (2002) between 1993-2001 is displayed in Table 1.

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[4] ICT spending by IDC includes computer hardware, software, internal services, other office products, and telecommunications equipment and services. No data is provided on embedded ICT in non-ICT products and on ICT expenditure of non-incorporated entreprises. In addition, WITSA (2002) data definitions of ICT do not exactly conform to those of either OECD or national accounting. WITSA (2002) data is also subject to a few measurement biases, yet their combined effects are hard to measure (for more detailed discussion see Daveri 2002).

Table 1. ICT spending in eight transition countries 1993-2001 as a per cent of GDP

Country	1993	1994	1995	1996	1997	1998	1999	2000	2001	Avg.
Bulgaria	2,23%	2,88%	2,32%	2,71%	2,97%	3,11%	3,60%	4,12%	4,17%	3,12%
Czech Republic	5,56%	5,34%	5,95%	5,80%	6,44%	6,56%	7,85%	9,10%	8,73%	6,81%
Hungary	4,17%	4,32%	3,88%	4,28%	4,46%	7,50%	8,23%	8,93%	10,02%	6,20%
Poland	**2,06%**	**2,08%**	**2,16%**	**2,28%**	**2,57%**	**4,59%**	**5,43%**	**6,06%**	**5,95%**	**3,69%**
Romania	1,07%	1,09%	0,93%	1,03%	1,28%	1,39%	2,09%	2,32%	2,41%	1,51%
Russia	4,01%	3,18%	1,83%	1,71%	1,97%	2,66%	4,11%	3,52%	3,20%	2,91%
Slovak Republic	4,23%	4,18%	4,04%	4,02%	3,89%	5,55%	6,78%	8,12%	8,78%	5,51%
Slovenia	3,02%	3,03%	2,92%	3,08%	3,39%	3,72%	4,42%	5,26%	4,72%	3,73%
Average*	4,45%	4,45%	4,46%	4,69%	4,98%	5,64%	6,22%	6,81%	7,27%	5,44%

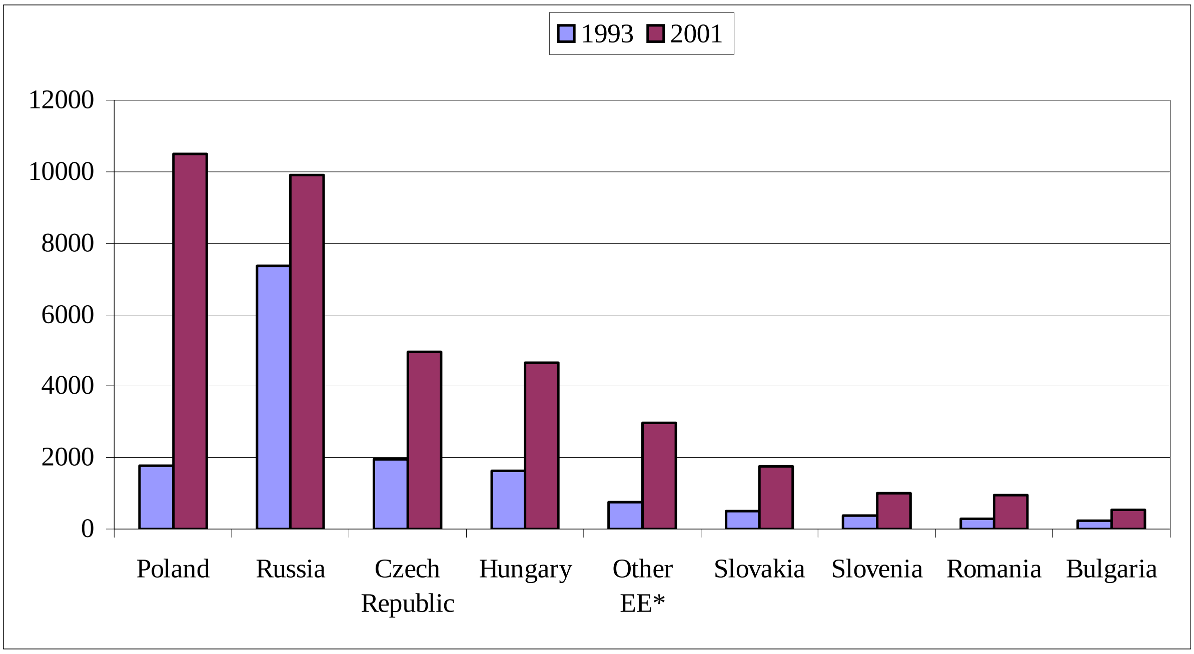
* Average for all 51 countries surveyed.

Source: WITSA (2002)

The ICT spending in relation to GDP in Poland has been steadily increasing since 1993 from 2.06% to 5.95% in 2001. In 2001 more was spent on ICT – in relative terms – in the Czech Republic, Hungary and the Slovak Republic. In the whole sample of 51 countries, which is biased towards developed countries, Poland's average spending on ICT in the period was almost two percentage points lower than the overall average. Nonetheless, the gap has been on a decrease throughtout the period: in 2001 the gap in spending narrowed to 1.3 of a percentage point.

In nominal terms, Poland experienced a phenomenal six-fold increase in annual ICT spending from 1,772 million USD in 1993 to 10,489 in 2001. This result puts Poland in the undisputed forefront of ICT spending among the transition economies (see Figure 1).

Figure 1. Total ICT spending in transition economies in 1993 and 2001 (USD million)

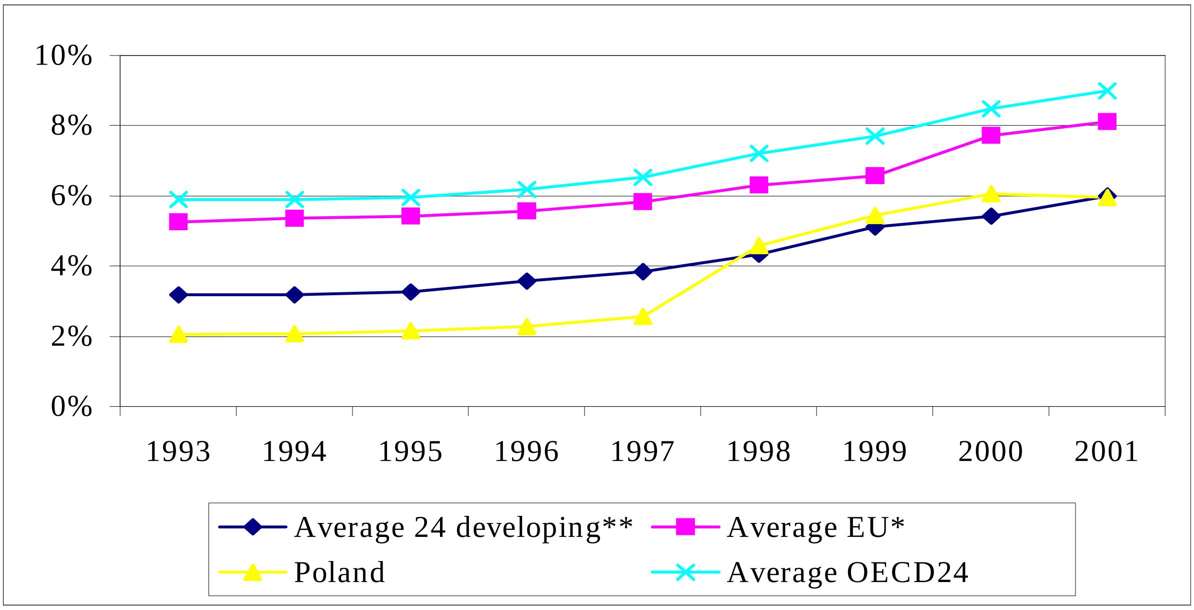


* Other EE – other Eastern European countries.

Source: WITSA (2002)

Trends in ICT spending in Poland should also be displayed against the background of ICT investments in the EU, OECD, and developing countries (Figure 2).

Figure 2: ICT spending to GDP in the EU, OECD, developing countries and Poland (per cent)



* excludes Luxembourg; ** Argentina, Brazil, Chile, China, Colombia, Egypt, Hong Kong, India, Indonesia, Malaysia, Mexico, Philippines, Saudi Arabia, South Africa, Taiwan, Thailand, Turkey, Venezuela, Vietnam. Note: non-weighted arithmetic averages.

Source: WITSA (2002)

Between 1993 and 2001 Poland's relative position in ICT spending has been improving compared to all groups of countries. In 2001 the share of ICT spending in GDP caught up with the average ICT spending in the group of 24 middle and lower income developing countries. The possible explanation for this fast catch-up is the substantial pent-up demand for ICT products and services resulting from substantial underinvestment in ICT infrastructure before 1989[5]. This, together with high rates of economic growth, created opportunities for higher-than-normal returns on ICT investment.

Data from WITSA (2002) on ICT spending does not delineate the expenditure shares of a business sector, households and government. Since household purchases of ICT can not be treated as investment, their share in total spending has to be estimated and deducted from the total.

Schreyer (2000) and Jalava and Pohjola (2002) estimate, based on a comparison between an actual investment data from the US Bureau of Economic Analysis (BEA) and WITSA data on the ICT spending in the US, that the share of telecommunication investment expenditure equals 30% of the total investment (the rest accruing to households). Contrary to this approach, although based on the same BEA - WITSA comparison, Daveri (2002) breaks up the whole IDC data into investment shares and household expenditure, applying 59% share of investment in hardware expenditure, 33% for telecommunications spending and 205% for software (Daveri's investment shares are for business sector only – he excludes government spending).

For Poland, taking into account the magnitude of investments in telecommunication hardware conditioned by a legacy of underinvestment, the share of telecommunication investment in total spending in Poland can be plausibly assumed to be much larger than in developed countries and amount to 50 per cent of total reported spending on telecommunications. The share of investment in IT hardware in total IT spending in the 1993-2001 period is assumed to amount to 86.1% based on actual data from IDC for Poland for

5 Poland's fixed line penetration increased from 12 lines per 100 inhabitants in 1990 to roughly 30 in 2002. Likewise, mobile phone penetration increased from zero in 1990 to approx. 33 lines as of the end of 2002.

2002 (IDC 2002). The value of software spending as reported by IDC is multiplied by 2.0 under an assumption that the data on software does not take into account internally developed, custom made software, what BEA calls ‘own account software’ (Daveri 2002). The data on “other office equipment” is aggregated with IT hardware under the assumption that the former fits into the definition of ICT.

To arrive at ICT spending in local currency, the data in US dollars is multiplied by an annual average exchange rate based on EBRD (2002).

Since a dollar today buys much more computing power than in the previous years, the resulting data on ICT spending needs to be deflated to arrive at constant-quality prices. Current price expenditures are then divided by appropriate price indices based on chain-type quality-adjusted ICT prices. Since no quality-adjusted deflators are available from national statistics in transition countries[6], the paper uses chain-type quality-adjusted ICT prices from the US Bureau of Economic Analysis (BEA 2002)[7]. It is assumed that prices of ICT in transition countries follow those in the US (similarly as done by Daveri 2002 for the EU countries), which seems to be a plausible assumption given high tradability of ICT products.

6 Only US, France, Denmark, Sweden and Canada report quality-adjusted, so-called hedonic prices for ICT equipment. National statistics offices in postsocialist countries do not report ICT separately, as it most often lumped together under “high-technology” products and services. Domestic hedonic price indexes have not been developed yet, either. For discussion of methodology of hedonic pricing, see OECD (2000) and Mulligen (2002).

7 IT hardware spending is deflated by BEA’s index for “computers and peripheral equipment”; software by “software”, and telecommunication spending by price index for “communication equipment”. Base year 1996 has been changed to 1995 to be consistent with the data on GDP and fixed capital stock obtained from the national statistical office (see Appendix Table 5 for indices used in this paper and BEA 2002 for original numbers).

To finally arrive at a measure of ICT stock, the ICT investment data is depreciated using perpetual inventory method, according to the following equation:

$$K_{i,T} = \sum_{t=0}^{\infty} [K_{i,T-t} - (K_{i,T-t} \partial_i)] + (I_{i,T-t} \partial_i) \qquad (4)$$

where $K_{i,T}$ denotes capital stock for a particular stock of assets i at time T, ∂_i stands for depreciation factor for a capital good i, and $I_{i,T-t}$ the investments in period T-t[8]. Geometric depreciation pattern is applied[9].

For the lack of data on ICT spending before 1993 and in order to arrive at a long series of ICT stock, the investment series were extrapolated back to 1985 applying a geometric average of growth rates in ICT spending 1993-2001 as reported by WITSA (2002). ICT stock in 1985 was assumed to equal zero[10]. While this is surely an improbable assumption, given high depreciation rates for ICT, most of the ICT investment series 1985-1993 depreciate to almost zero by 1995[11]. Nonetheless, to limit the impact of this assumption, the contribution of ICT investment to growth will cover the period starting from 1995 only.

Alternative method of obtaining sufficiently long series of ICT investment as reported by Ark et al. (2002) is to derive the ICT investment for the period 1985-93 from a share of ICT investment in aggregate investment in a period for which the relevant data exists. Yet, this approach can be quite misleading since there is no compelling reason to believe that share of

8 As remarked by Ark et al. (2002), various equations of that kind make an implicit assumption that services of assets of various vintages are perfect substitutes for each other.

9 Geometric depreciation pattern was also applied by Jorgenson et al. 1987. Ark et al. (2002) uses this pattern to construct estimates of the non-residential capital stock and capital services in a number of EU countries. As opposed to a straight-line depreciation pattern, which assumes equal depreciation over the life of the asset, empirical evidence from the US showed that geometric pattern is the best approximate of depreciation for most types of assets (Fraumeni 1997). Geometric pattern results in much faster depreciation since it assumes higher depreciation rates in the early years of an asset’s service life than later on. US Bureau of Economic Analysis now uses geometric pattern methodology by default for most types of assets. Alternative methodology of hyperbolic age-efficiency depreciation was used by Jalava and Pohjola (2002), Schreyer (2000) and is being used by the US Bureau of Labour Statistics.

10 Alternatively, one can assume the value of ICT capital stock to equal zero in 1993. Yet, since some ICT stock surely existed in 1993, it seems methodologically more appropriate to extrapolate the data back to 1985 as the starting point of ICT stock accumulation.

11 Except for telecommunications equipment, which depreciates to zero in roughly 6,5 years. Nonetheless, the share of its value in 1995 derived from before 1994 amounts to less than 10% of total stock in 1995 and can thus be disregarded as negligible.

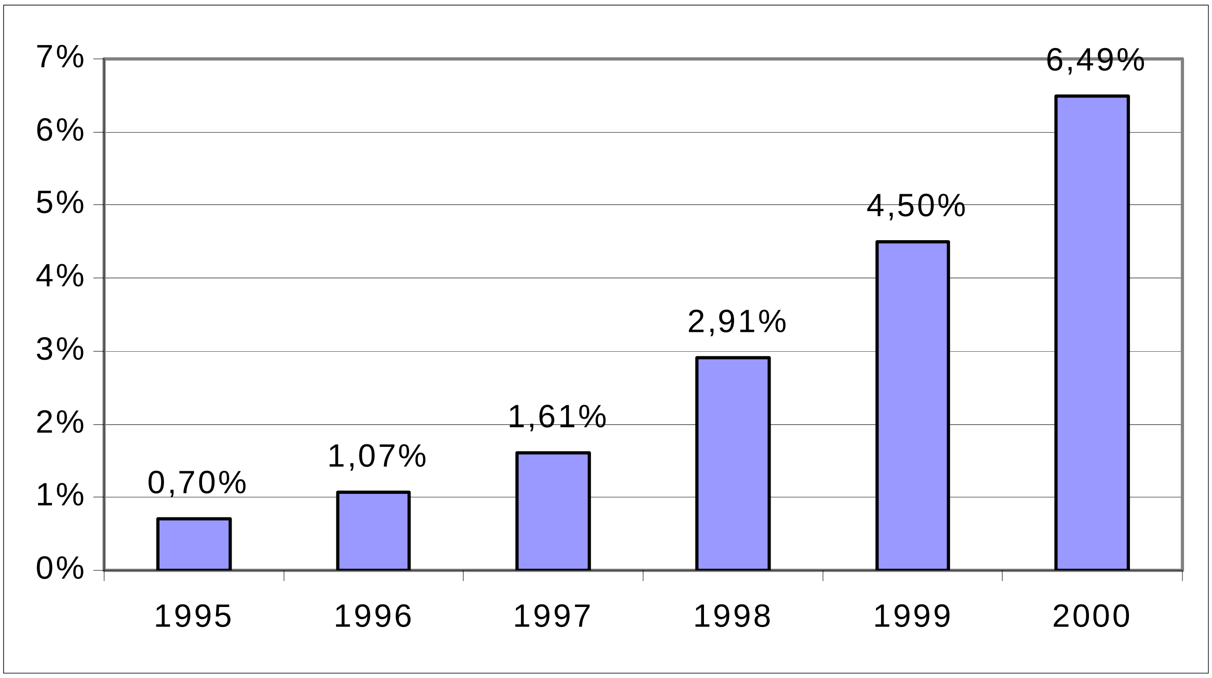
ICT investment in mid-1990's was comparable to that in 1985. It is particularly true in transition economies, which in 1985 were operating under totally different economic system of a command, communist economy.

Ark et al. (2002) in their study apply a commodity flow method to arrive at long series of ICT investment, yet given the lack of detailed data on input-output tables from national statistical offices, its use in measuring ICT investment in postsocialist countries is not possible.

Depreciation rate for IT hardware of 0.312 is based on the US data taken from Fraumeni (1997). Depreciation rates for telecommunications equipment and software based on Jorgenson and Stiroh (2000) and Oulton (2001) were set at 0.115 and 0.315, respectively.

In the end the author arrived at a measure of a year-end ICT capital stock 1985-2001. However, for the reasons enumerated above, the study will focus on the 1995-2000 period. In that period, the share of ICT capital in aggregate gross fixed capital stock in Poland substantially increased from 0.7% in 1995 to 6.5% in 2000 on the back of rapidly growing ICT investments (Figure 3).

Figure 3: ICT capital as a percentage of a gross total capital stock in Poland, 1995-2000 (in fixed prices 1995, PLN million)



Accounting for ICT share in nominal income

In order to obtain an estimate of the contribution of ICT stock to growth, the share of ICT in total nominal income v_{ICT} needs to be assessed through multiplying the nominal ICT capital stock (C_t) by the gross rate of return on investment in ICT (R_{ICT}), and dividing by nominal total income (I)[12]:

$$w_{ICT} = \frac{(R_{ICT} C_t)}{I} \tag{5}$$

Both the value of ICT capital stock, which has been already calculated in step one, and total income is available. R_{ICT} is a sum of a competitive net rate of return on total investments (Rc) and a depreciation rate, separate for IT hardware, software, and telecommunication equipment:

$$R_{ICT} = Rc + d \tag{6}$$

Oliner and Sichel (2000) came up with estimates for competitive net rate of return on non-residential equipment and structures (Rc) in the USA using data from Bureau of Labor Statistics. The estimated Rc for 1970-92 averaged 12 per cent. The study by Ark et al. (2002) found average internal rate of return on total non-residential capital between 1995 and 2000 to be equal to 15% in the USA and 11% in the European Union.

For the lack of data from the national statistical office in Poland, ex-post analysis of net rate of return on investment is not possible. Consequently, one has to make estimates of competitive net rate of return on total investments (Rc) to arrive at the rate of return on ICT investment.

[12] Alternative methodology for measuring capital services from ICT assets can not be used for the lack of data on internal rate of return needed to arrive at rental prices for ICT assets. For methodology of measuring capital services from various assets refer to Jorgenson et al. (1987) and Ark et al. (2002).

The methodologically sound solution can be based on a standard version of a capital asset pricing model (CAPM):

$$Rc = R_f + \beta(E_r - R_p) \quad (7)$$

where the net return on total investments is a sum of a risk free rate (*Rf*) and a risk premium $\beta(E_r - R_p)$, where β is a beta of a particular market share portfolio and E_r denotes expected return on a specific portfolio. However, since no estimates exist for stockmarket beta in Poland and an expected return on a share portfolio[13], one has to assume that a competitive rate of return is a product of a risk free rate (*Rf*) and an estimate of a risk premium (*Rp*):

$$Rc = R_f + R_p \quad (8)$$

Risk free rate in real terms in Poland, based on a yield on long-term government bonds, amounts to roughly 5.0% per annum[14]. As for the risk premium, according to international investment banks based in Poland, the risk premium applied in valuation of Polish companies is assumed to amount to on average 2.0% above the corresponding risk premiums for companies in the EU. Setting the risk premium for developed countries as a constant 5.5% as described in Godfrey and Espinosa (1996), the risk premium for Poland can be assumed to amount to 7.5%. Adding it up to a real risk free rate of 5.0% produces a final estimate of the net return on total investments in the Polish economy of 12.5%.

This result is comparable with actual numbers produced for the OECD countries by Ark et al. (2002). The average internal rate of return on non-residential assets for the EU countries amounted to 11%. The rate for Portugal, a country – next to Greece – with the lowest GDP per capita in the EU and thus the closest in the level of development to Poland and transition economies, was one percentage point higher at 12%. One could argue that -- as the conditional convergence hypothesis would maintain -- the rate of return on assets in lower-

14 Warsaw Stock Exchange, similarly to stock exchanges in other transition economies, was only established in April 1991. Short series of data, significant market volatility and a relatively low liquidity do not allow for measuring the market expected returns on portfolio nor betas for particular portfolios.

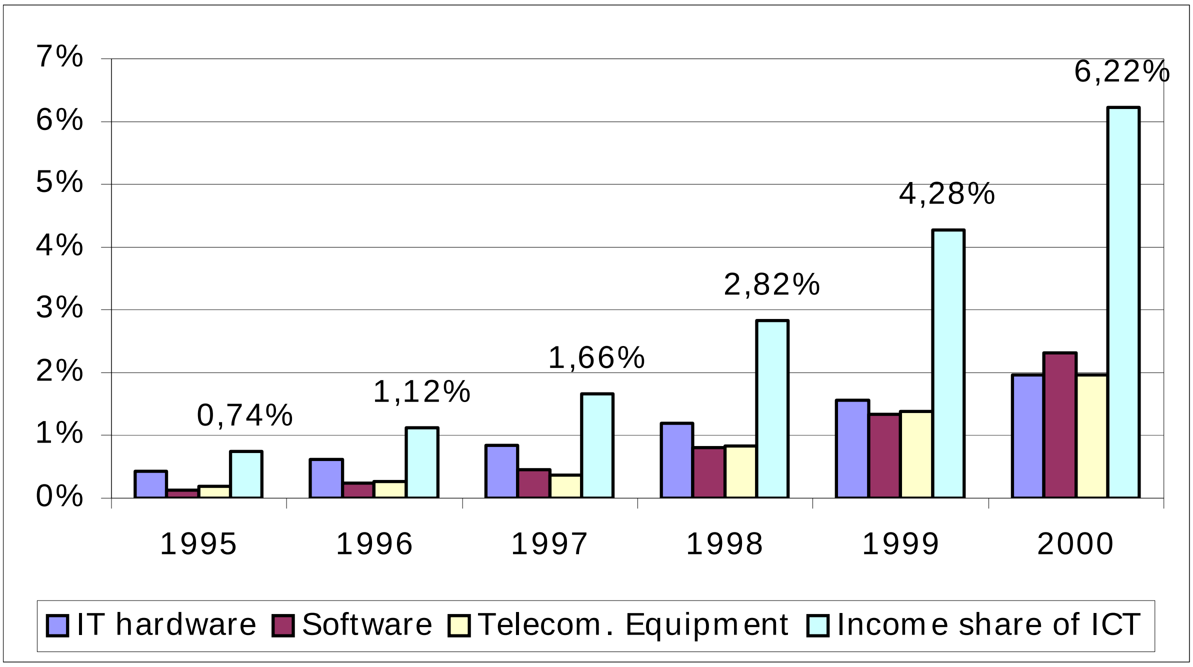
14 On February 19, 2003, the nominal yield on the 10-year government bonds amounted to 5.42%. Inflation February-to February measured by CPI was 0.4%.

income countries should be higher than in developed countries. However, lack of complementary assets and infrastructure should put a limit on the rates of return, particularly as regards ICT (as posited by Kraemer and Dedrick 2001 and Pohjola 2002). In the end, it seems then plausible to assume a 12.5% competitive net rate of return on total investments for Poland.

To check for the robustness of results, a sensitivity analysis on the rates of return has been performed. It transpired that the impact of the rate of return on final estimates of ICT capital contribution to growth is relatively small: for every percentage point change in the rate of return, the contribution of ICT investment to output growth changes by 0.025 percentage points.

Gross rates of return on ICT multiplied by nominal ICT capital stock yield an estimate of an income share of ICT capital in total nominal income (Figure 4)

Figure 4: Income share of ICT in total nominal income of Poland 1995-2000 (in per cent)



Having arrived at the estimates of ICT capital stock and income share of ICT, in order to measure the contribution of ICT investment to GDP growth the author used data from

Poland's Central Statistical Office (GUS 2002) on real growth rates of GDP, aggregate fixed capital stock, labor force measured by employment and a share of wages in total income.[15]

3. The contribution of ICT investment to output growth in Poland

Research findings based on the the methodology presented in Section 2 showed that the average contribution of ICT capital to economic growth in Poland between 1995-2000 amounted to 0.83 percentage points or 16% of average output growth of 5.16% in that period. Table 2 presents the detailed results.

Table 2. Contributions of ICT capital to real output growth in Poland 1995-2000 (in percentage points)

ICT capital	IT hardware	0.31
	Software	0.28
	Telecommunications equipment	0.25
Total ICT capital		0.83
Non-ICT capital		1.03
Labor (employment)		0.26
TFP		2.30
Total		4.42
Actual output growth		5.17
Measurement error due to rounding		0.75

The above results can be compared with estimates for the contribution of ICT capital to growth in the OECD countries in the same period obtained presented by Ark et al. (2002) and Daveri (2002) (Table 3)

15 While data on GDP growth in transition countries is readily available from a number of sources, this is not the case with the remaining items. National statistical offices usually provide data on labor in the form of a number of employed rather than hours worked and a share of wages. Alas, there is often lack of data on the aggregate fixed capital stock. For instance, this kind of data apparently does not exist for Hungary (only investment series available). Slovenia has only one measure of the current value of total fixed capital stock in 2000

Table 3. Percentage point contribution of ICT capital to real output growth in the EU countries and Poland, 1995-2000

	Ark et al. 2002	Daveri (2002)
Ireland	0.76	0.96
USA	0.70	1.45
Netherlands	0.57	0.72
UK	0.54	1.17
Denmark	0.44	0.65
Sweden	0.34	0.85
Italy	0.33	0.35
Finland	0.32	0.74
Austria	0.27	0.43
France	0.27	0.49
Portugal	0.27	0.44
Germany	0.26	0.45
Spain	0.23	0.34
Poland	**0.83**	**0.83**

Source: Ark et al. (2002), Daveri (2002) and author's own for Poland

In the same study by Ark et al. (2002) the average ICT capital contribution to output growth in the EU countries and in the US between 1995 and 2000 amounted to 0.40 or 16% and 0.70 or 17% of GDP growth, respectively. Colecchia and Schreyer (2001) find that during the second half of 1990's, the contribution of ICT investment ranged from 0.3 to 0.9 percentage points of growth in nine OECD countries, with US exhibiting the largest contribution of 0.87, followed by Australia with 0.68. Italy and Japan were at the bottom of the table with a 0.36 and 0.38 percentage point contribution, respectively.

Against this background, contribution of ICT capital to growth in Poland seems to be very large since it is much higher than an average for the EU and the OECD countries. This rather surprising fact can be explained by two main factors:

a) Extraordinary rates of growth in ICT investment which resulted in increases in ICT capital stock by roughly 50% annually between 1995-2000 and corresponding substantial rise in income shares;

b) Slow growth in non-ICT capital of roughly 2% annually resulting in decrease in income share of non-ICT capital in total nominal income (for details on both the capital stock and income share see Table 6 and 7 in Appendix).

The above factors show that profit maximizing firms in response to rapidly falling prices of ICT have massively substituted investment in non-ICT capital for ICT capital. The additional incentive for large ICT investments seems to have been the opportunity to substantially improve underinvested computer and telecommunications infrastructure, which exhibited huge shortcomings in the beginning of the 1990's resulting from of a legacy of underinvestment and technological retardation under the communist system.

This estimate of a very high contribution of ICT to growth in Poland has to be interpreted with caution. The estimates of the ICT capital contribution could be lower due to the following:

a) GDP deflator instead of an investment deflator was used to convert ICT capital stock in fixed prices to current prices. The use of a more appropriate investment deflator, for which however full series were not available, would lower the ICT share in income and consequently decrease the ICT contribution to growth by some 0.10 of a percentage point to 0.72 from 0.83.

b) Rates of return on ICT capital were calculated as a sum of a competitive net rate of return on total capital stock in an economy plus depreciation. This is a very rough estimate of the rate of return. More elaborate methods could yield different results.

c) Constant-quality price indices were used to deflate data ICT data only. The use of similar indices for non-ICT equipment would have lowered the ICT contribution.

d) WITSA data on ICT spending may be on a high side, particularly for software. Ark et al. (2002) remarks that Daveri's (2002) results for the EU countries based on the same WITSA data are much higher than results of his study based on data from national statistical agencies (see Table 3).

e) Use of geometric average on a relatively short ICT series, where the contribution of ICT to output growth is quickly increasing, results in a measurement error of some 15%. The actual ICT contribution on a year-to-year basis would most likely be higher.

The combined effect of the above factors would slightly lower the contribution of ICT capital to growth. Hence, the reported result should be treated as a ceiling for the impact on growth of ICT capital.

Relative contribution (in per cent) of IT hardware, telecommunications equipment and software to output growth in Poland between 1995-2000 was also quite high at 16.1%. It was roughly the same as the EU average, but lower than in Italy, UK and the US (Table 4). The same caveats apply as to the results in absolute terms.

Table 4. Percentage contribution of IT hardware, software and telecommunication investment to real GDP growth in Poland and the OECD countries, 1995-2000

	IT hardware*	Telecomm. equipment	Software	Total ICT
Austria	4,8	3,1	2,7	10,6
Denmark	2,4	0,5	8,7	11,6
Finland	2	1,4	2,8	6,2
France	4,8	2,1	3,6	10,5
Germany	9,2	2,2	4,1	15,5
Ireland	5,1	2,2	0,6	7,9
Italy	6,6	6,6	3,3	16,5

Netherlands	8,3	2,2	4,7	15,2
Portugal	2,9	2,3	1,8	7
Spain	3,4	1,4	1,3	6,1
Sweden	3,1	1,5	6,9	11,5
UK	11	2,4	5,1	18,5
EU	8,1	2,9	4,5	15,5
USA	8	2,9	5,8	16,7
Poland	**6,0**	**5,35**	**4,7**	**16,1**

* in Ark et al. (2002) "Office and computer equipment"

Source: Ark et al. (2002) and author's own for Poland.

3 Conclusions

This paper makes a first estimate of a contribution of ICT capital to output growth in Poland for the period 1995-2000 based on an extended growth accounting framework and private-source data from IDC published in WITSA (2002). Quite surprisingly, the paper shows that the contribution of investment in IT hardware, software and telecommunication equipment was quite substantial and represented some 16% of an average GDP growth or 0.83 of a percentage point out of 5.13% output growth in that period. This result places Poland very high in the international comparisons, almost on par with countries like the US, Ireland and Finland, the paragons of the 'new economy'.

The large contribution of ICT capital is based on an extraordinary acceleration in ICT investments, which were growing between 1993-2001 at an average cumulative rate of 24.9% a year. Consequently, by 2001 Poland has caught up with other middle and lower income countries in terms of ICT spending per GDP. Among transition economies, Poland is fourth in relative terms, but number one in nominal terms of total spending on ICT.

Large investments in ICT seem to have been induced by falling prices of ICT products and services, which enticed companies to substitute non-ICT for ICT capital. Polish companies substantially increased outlays on ICT also in response to business opportunites created by poor ICT infrastructure, a legacy of decapitalization and technological gap existing before 1989, and high rates of economic growth, which accelerated from 3.8% in 1993 to 6.8% in 1997 and more than 4% in 2000-01.

One can plausibly assume that given a small size of ICT-producing sector in Poland, its impact of GDP growth would not be significant. As for the spillover effects of ICT use and production, it is too early to estimate them, yet given still low penetration of ICT networks, any potential effects are not likely to be significant. Hence, the overall impact of ICT on output growth seems to be predominantly dependent on ICT capital, whose contribution to GDP growth is presented in this paper.

Future research should focus on measuring the contribution of ICT capital to labor productivity and providing estimates on the impact of ICT production and contribution of ICT-producing sectors to an economy-wide TFP growth for Poland and other post-communist countries for which relevant data is available.

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Appendix

Table 5. Price indices for ICT stock

(based on the US Bureau of Economic Analysis Table 7.8. Chain-Type Quantity and Prices Indexes for Private Fixed Investment in Equipment and Software by Type. Base year changed from 1996 to 1995)

	1993	1994	1995	1996	1997	1998	1999	2000
Computers and peripheral equipment	108,66	104,80	100	92,67	86,16	78,45	73,38	71,00
Software	135,86	119,80	100	76,17	58,94	43,41	33,21	28,84
Communication equipment	101,99	99,73	100	98,15	96,03	93,45	94,18	95,48

Table 6. Labor and capital income shares in Poland, 1995-2000

	Labor	Total capital	Non-ICT	ICT Total	IT hardware	Software	Telecom equipment
1995	0,50	0,49	0,49	0,007	0,004	0,001	0,002
1996	0,56	0,42	0,41	0,011	0,006	0,002	0,003
1997	0,60	0,38	0,37	0,017	0,008	0,005	0,004
1998	0,50	0,47	0,44	0,028	0,012	0,008	0,008
1999	0,55	0,41	0,37	0,043	0,016	0,013	0,014
2000	0,53	0,41	0,35	0,062	0,020	0,023	0,020

Table 7. Changes in labor and stocks in Poland, 1995-2000

	Labor	Total capital	Non-ICT	ICT Total	IT hardware	Software	Telecom equipment
1995	0,98	2,08	1,78	57,63	53,05	58,25	63,44
1996	4,98	4,69	4,31	47,22	41,99	72,36	43,06
1997	-0,32	3,44	2,89	44,24	39,20	68,14	36,80
1998	2,32	3,83	2,50	62,88	39,19	62,15	87,01
1999	-2,74	3,83	2,18	47,37	31,13	55,14	54,68
2000	-2,34	4,11	2,01	40,78	26,18	58,82	38,81